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Editorial

In recent years, the integration of technology into various aspects of our lives has brought about significant advancements and innovations across multiple fields. In this issue of the Journal of Engineering Research and Sciences, we present five papers that explore diverse applications of technology, ranging from disaster response to digital art, from peer-to-peer networks to healthcare services, and from chemical analysis to environmental sustainability. These papers offer valuable insights into the latest developments and challenges within their respective domains, showcasing the interdisciplinary nature of modern technological research.

Fast and accurate observation of an area in disaster scenarios such as earthquake, flood and avalanche is crucial for first aid teams." This paper delves into the utilization of Unmanned Aerial Vehicles (UAVs) equipped with digital surface models, orthomosaics, and object detection algorithms for real-time mapping and object identification in disaster-stricken areas. The study presents a monocular SLAM based system coupled with deep learning techniques to enhance efficiency and accuracy in emergency response scenarios [1].

The constant advancement in the area of machine learning has unified some areas that until then did not converge, such as computing with the arts in general." Focusing on the intersection of machine learning and digital art, this paper explores the evolution of neural networks in generating expressive and complex digital works of art. It raises intriguing questions about authenticity and authorship in the context of computer-generated art, while also presenting applied research on neural network techniques for artistic creation [2].

Centralized file-sharing networks have low reliability, scalability issues, and possess a single point of failure, thus making peer-to-peer (P2P) networks an attractive alternative." This paper conducts a comprehensive literature survey on emerging research areas of P2P networks, addressing issues such as security, privacy, trust management, and hybrid network models. It emphasizes the need for further research to tackle challenges in sensitive applications like healthcare services and vehicular communication networks [3].

Telemedicine is using telecommunications and IT tools to widen healthcare services to remote rural areas." Focusing on the utilization of ICT and satellite technology in telemedicine, this paper examines the challenges posed by long end-to-end latency in GEO satellite networks. It highlights the importance of optimizing TCP performance and minimizing latency to ensure effective real-time communication for remote healthcare services [4].

The work considered comparative analysis of CRI and TLI as green indicators versus some synthetic indicators in acid – base titration." This paper presents a comparative analysis of natural and synthetic indicators in acid-base titration, advocating for the use of green indicators like Curcuma longa rhizome extract and Tectona grandis leaves extract due to their effectiveness and environmental friendliness. It suggests future research directions for determining the properties and stability of these natural indicators [5].

Collectively, the papers featured in this issue offer valuable contributions to the advancement of technology across various domains. From disaster response and digital art to peer-to-peer networks, healthcare services, and chemical analysis, these studies showcase the diverse applications and challenges within the realm of advanced technologies and innovations. We hope that the insights presented in these papers will inspire further research and innovation in these fields, driving progress and societal impact.

References:

[1] O. Eker, H. Cevikalp, H. Saribas, “Visual Slam-Based Mapping and Localization for Aerial Images,” *Journal of Engineering Research and Sciences*, vol. 1, no. 1, pp. 1–9, 2022, doi:10.55708/js0101001.

[2] R.A.V. Costa, F.L. Schiavoni, “Neural Networks and Digital Arts: Some Reflections,” *Journal of Engineering Research and Sciences*, vol. 1, no. 1, pp. 10–18, 2022, doi:10.55708/js0101002.

[3] F.O. Ehiagwina, N.A. Iromini, I.S. Olatinwo, K. Raheem, K. Mustapha, “A State-of-the-Art Survey of Peer-to-Peer Networks: Research Directions, Applications and Challenges,” *Journal of Engineering Research and Sciences*, vol. 1, no. 1, pp. 19–38, 2022, doi:10.55708/js0101003.

[4] O.S.A. Omuya, A.O. Tayo, “Analytical Framework to Minimize the Latency in Tele-herbal Healthcare Service,” *Journal of Engineering Research and Sciences*, vol. 1, no. 1, pp. 39–50, 2022, doi:10.55708/js0101004.

[5] K. Asemave, A.S. Shiebee, “Comparative Analysis of Curcuma longa Rhizome and Tectona grandis Leaves Extracts as Green Indicators versus some Synthetic Indictors in Acid-Base Titration,” *Journal of Engineering Research and Sciences*, vol. 1, no. 1, pp. 51–55, 2022, doi:10.55708/js0101005.

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Visual Slam-Based Mapping and Localization for Aerial Images

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ABSTRACT: Fast and accurate observation of an area in disaster scenarios such as earthquake, flood and avalanche is crucial for first aid teams. Digital surface models, orthomosaics and object detection algorithms can play an important role for rapid decision making and response in such scenarios. In recent years, Unmanned Aerial Vehicles (UAVs) have become increasingly popular because of their ability to perform different tasks at lower costs. A real-time orthomosaic generated by using UAVs can be helpful for various tasks where both speed and efficiency are required. An orthomosaic provides an overview of the area to be observed, and helps the operator to find the regions of interest. Then, object detection algorithms help to identify the desired objects in those regions. In this study, a monocular SLAM based system, which combines the camera and GPS data of the UAV, has been developed for mapping the observed environment in real-time. A deep learning based state-of-the-art object detection method is adapted to the system in order to detect objects in real time and acquire their global positions. The performance of the developed method is evaluated in both single and multiple UAVs scenarios.

KEYWORDS SLAM (Simultaneous Localization and Mapping), Mapping, Orthomosaic, Object detection, Aerial imaging

1. Introduction

Classical 2D image stitching methods that perform real-time mapping from monocular camera in aerial images are built based on feature extraction and matching in consecutive frames [1]. These methods are mainly based on the calculation of homography, which defines the motion between two image planes. Since the calculations are limited to a planar surface in these methods, the 3D structure of the observed environment cannot be obtained. To solve this problem, authors in [2] used the Kanade-Lucas-Tomasi feature tracker, and fused the UAV's IMU (Inertial Measurement Unit) and GPS (Global Positioning System) sensor data. Dense point cloud and digital surface model were generated with the 3D camera position obtained by sensor fusion techniques.

Structure from Motion methods can also be used in orthomosaic generation. There are several algorithms that use Structure from Motion methods, such as OpenMVG [3], PhotoScan [4]. These methods generally follow feature extraction and matching, image alignment and bundle adjustment algorithm, sparse point cloud generation, dense point cloud and mesh generation, orthomosaic stages. In order to generate the final orthomosaic image with Structure from Motion methods, all images to be used in the mapping process must be prepared in advance and the mapping process takes a long time. Therefore, Structure from Motion based methods are not suitable for real-time and incremental usage.

Aside from Structure from Motion algorithms, SLAM (Simultaneous Localization and Mapping) methods are used for real-time 3D mapping and localization. Monocular camera based SLAM applications have recently become one of the most studied topics in robotics and computer vision. SLAM is considered a key technique for navigation and mapping in unknown environments. Monocular SLAM algorithms are basically categorized as feature-based and direct methods. Feature-based SLAM algorithms detect features in frames and track them in consecutive frames. Then, they use the resulting features to estimate the camera pose and generate the point cloud map [5, 6, 7]. On the other hand, direct methods directly use pixel intensities of the images instead of extracting features from the images. Therefore, direct methods tend to create a much more detailed map of the observed environment since they use more information coming from images [8, 9]. However, in case of illumination changes and sudden camera movements, feature-based methods are more robust and can estimate camera pose with higher accuracy compared to direct methods. There are also semi-direct approaches such as SVO [10] that compute strong gradient pixels and achieve high speed. In [11], the authors proposed a dense monocular reconstruction method that integrates SVO as camera pose estimation module. In [12], authors use a feature-based SLAM method and the GPS data of the UAV to generate 2D orthomosaic

maps from aerial images. In this study, to generate 2D and 3D orthomosaics, ORB-SLAM [6] which is a very fast and robust feature-based monocular SLAM method is used for camera pose estimation and spare point cloud generation. In [13], author propose a monocular SLAM-based method to generate 2D and 3D orthomosaic images. Similar to our study, the method uses ORB-SLAM as the monocular SLAM method. In addition, in their paper, values of the cells on the overlapping regions were determined by using a probabilistic approach at the orthomosaic stage. As opposed to this method, the values of the cells are determined according to the minimum elevation angle similar to [2] in our proposed method. Moreover, in our method, a deep learning based object detection method which is trained on a novel dataset was integrated to the mapping pipeline to detect objects on the rectified images. By marking these detections on 2D and 3D maps, the real world positions of the detected objects can be calculated, and these positions can be used to create a better map. Another method which is similar to ours is GPS-SLAM [14]. GPS-SLAM is expected to perform well on scarce datasets where FPS (frames per second) is 1 or below. The method augments ORB-SLAM's pose estimation by fusing GPS and inertial data. In addition to this, the authors increase the number of features that are extracted by ORB-SLAM, which highly affects and reduces the computation speed. The method works robust and more accurately compared to the ORB-SLAM on scarce datasets where FPS is 1 or less. A drawback is that as FPS increases (above 1 FPS) GPS-SLAM fails to track and estimate the camera pose which prevents the usage of the method in the pose estimation stage of an end-to-end mapping and localization pipeline. Unlike GPS-SLAM, we can achieve more robust camera pose estimation compared to ORB-SLAM at higher FPS as demonstrated in our experiments.

Object detection is the process of estimating the position and scale of an object instance in an image. Recently, deep learning based methods have achieved the highest accuracies in object detection. With the increasing processing capabilities of GPUs, deep learning based detection methods can now operate in real time. YOLOv3 [15], RetinaNet [16], SSD [17], Faster R-CNN [18] are the most important object detectors that can work in real time with high accuracies. Recently, anchor-free methods are proposed for object detection task [19, 20]. In this study, YOLOv3, which is a very fast and highly accurate object detection network, is used in the proposed mapping pipeline.

Our Contributions: In this study, we propose a novel real-time mapping and localization pipeline for aerial images built on top of a highly accurate monocular feature-based SLAM method. We fuse GPS and SLAM data for better localization of the UAV and to be able to map the observed environment in multiple UAVs scenario. Although there are methods using SLAM as backbone in mapping methods, we use a fast interpolation method to densify the sparse depth map of feature-based SLAM in order to generate dense 3D maps. While this approach generates semantically strong maps, its main advantage is fast operating time which is crucial for multiple UAVs scenario. In addition, we integrate a state-of-the-art object detection method to the pipeline that allows to acquire real-world positions of the desired objects in the observed environment. Detection of certain objects will be extremely useful for certain applications such as locating lost persons in wilderness or locating some military targets (e.g., vehicles or radar systems) in military operations. Moreover, successful object detection systems return positions of these objects more accurately, therefore these positions can be used as fiducial marker points to align different frames and improve the accuracy of the created 2D/3D maps. To this end, the positions of stationary objects such as buildings, bridges, or military targets such as airports, radomes, and heliports will be extremely useful. An overview of the proposed mapping pipeline is given in Figure 1.

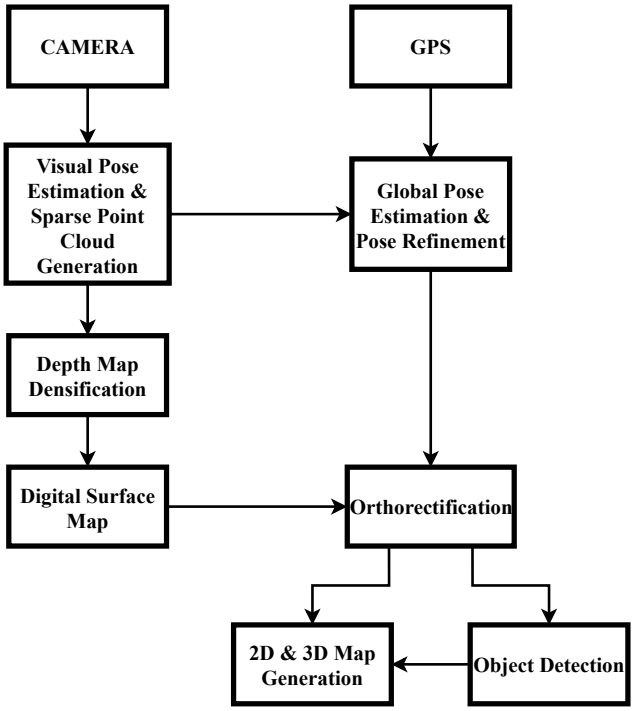

Figure 1: Overview of the proposed 2D/3D mapping pipeline.

2. Method

In this study, a real-time 2D/3D mapping and object detection pipeline has been developed for both single and multiple UAVs scenarios. The main steps applied for this purpose are analyzed under the following sections: global pose estimation, dense point cloud generation, digital surface map, orthorectification, object detection and orthomosaic.

2.1. Camera Pose Estimation, Sparse Point Cloud Generation and Global Pose Estimation

Digital surface model and orthorectification steps are required to create an orthomosaic with images acquired from a ground-facing monocular camera attached to a UAV. For this purpose, the camera pose estimation and sparse point cloud generation steps are computed by using a feature-based SLAM method in the proposed method. The chosen monocular SLAM method in our work, ORB-SLAM, is a very fast and robust algorithm that can perform in large scale environments. It can compute camera pose accurately

due to its robust ORB-based feature tracking, pose graph optimization and loop detection features. However, in monocular SLAM systems, the real world scale cannot be estimated, and the camera pose is given in a local coordinate system. The transformation of the camera pose estimated by the ORB-SLAM to the global coordinate system can be achieved by fusing the GPS data of the UAV and the computed camera pose. In order to calculate the real world scale, the first 20 frames were used for scale estimation at the initialization stage. To this end, the visual and geographic distances between frames are calculated first. Then, the average scale is computed by averaging the scales of the distances between frames which is calculated as,

$$m_{gps} m_{slam}, \tag{1}$$

where m_{gps} is the distance between the GPS positions of the two frames, and m_{slam} is the distance between the visual camera pose of the two frames. Once the scale is computed and initialization is done, the camera pose transformation is calculated for the next frames. In order to find the camera pose transformation, a transformation function must be calculated between the two 3D point models of the global positions in UTM (Universal Transverse Mercator) coordinates and the visual poses obtained by ORB-SLAM. Least-squares estimation of transformation parameters between two point patterns [21] is used to calculate the transformation parameters between two 3D point models. After calculating the scale and similarity transformation matrix, the camera pose matrix can be denoted in the global coordinate system as,

$$\begin{pmatrix} r_{11} & r_{12} & r_{13} & t_E \\ r_{21} & r_{22} & r_{23} & t_N \\ r_{31} & r_{32} & r_{33} & t_A \end{pmatrix} \tag{2}$$

where $\mathbf{r}$ $\left[r_{ij}\right]$ represents the rotation matrix and $\mathbf{t}$ represents the position in UTM coordinate system.

2.2. Dense Point Cloud Generation

Sparse cloud interpolation is used to densify the sparse point cloud of the images after computing global camera pose. First, the depth values of the 3D points calculated by ORB-SLAM are written to the pixel positions in the image plane according to,

$$d \begin{pmatrix} r_{31} & r_{32} & r_{33} & t_z \end{pmatrix} \cdot \begin{pmatrix} x & y & z & 1 \end{pmatrix}^T, \tag{3}$$

where $\mathbf{r_3}$ $\left[r_{3j}\right]$ is the last row of the rotation matrix, x, y, z, 1 is the point in the world frame, and z is the height. After re-projecting depth values to the image plane, inpainting is applied to fill the spaces between sampling points. Navier-Stokes based Inpainting [22] method is used for inpainting process which is inspired from fluid dynamics. This method travels along the edges of the known regions to the unknown regions as the edges are intended to be continuous. It continues isophotes (lines joining points with the same intensity) and matches gradient vectors at the border of inpainting regions continuously. Empty pixels are filled in a way to reduce the minimum variance in the region. Although the method cannot produce the details of the structures in the observed regions, the output depth maps usually have low noise and homogeneous appearance, and the method works very fast. Sparse point cloud computed by ORB-SLAM must be highly accurate for the method to produce accurate dense depth maps.

2.3. Digital Surface Map

A grid-based method as used in [2] is adapted to create a digital surface map using the generated dense point cloud in the previous stage. GridMap library [23] is used to efficiently handle RGB, elevation, point cloud data with multi-layer grid maps. The library provides rapid manipulation of the image data represented in global coordinates and speeds up the global orthomosaic operation with multi-layer approach. In order to represent the observed surface with a 2.5D grid map containing elevation data, the x and y coordinates of the dense point cloud are structured as a 2-dimensional binary kd-tree [24]. Within a pre-defined interpolation radius (20 pixels radius), the nearest neighbors of the points are calculated. Then, inverse distance weighting is applied to interpolate the map points. Inverse distance weighting intuitively determines the height of the cell using a linear weighted combination of the nearest neighbors. Thus, by giving higher weight to the points closer to the center of the cell, interpolation provides smooth transition and noiseless elevations in the elevation map.

2.4. Orthorectification

After digital surface map generation stage, we have all the data that is required to create the final orthomosaic image. However, the visual distortion caused by the viewing angle and surface structure of the images should be corrected. Rectification of the images is done by using the camera pose and the digital surface model. Incremental grid-based orthomosaic method [2] is used in orthorectification step. With the corresponding camera pose and the intrinsic matrix of the camera, it is checked whether each cell is in the visible camera cone. The grid map containing the elevation layer of the image is re-sized to the desired ground sampling distance. A 3D point X x_i, y_i, z_i) is created for each cell of the grid. These 3D points are reprojected to the camera image as,

$$x \quad KR|tX, \tag{4}$$

where K is the intrinsic matrix, $R|t$ is the global camera pose matrix. Due to the noisy and erroneous pose estimations on the elevation map, some of the projected points can fall outside of the image boundaries. These points are specified as invalid points and were not back-projected to the image plane.

2.5. Object Detection

The aim of object detection is to classify and localize objects with their labels and bounding boxes in an image. The architectures of generic object detectors can mainly be categorized into two types as regression-based and region proposal based. Region proposal based frameworks first

propose regions and then apply regression and classification on these proposals. The other regression-based frameworks skip the region proposal stage and directly predict class probabilities and their bounding boxes using an end-to-end learnable one stream network. In this study, once the rectification stage is completed, object detection can be performed on the RGB data stored in the multi-layer grid map. We use YOLOv3 for object detection in the proposed method. YOLOv3 is an extremely fast regression-based object detection algorithm. YOLOv3 divides images into $S \times S$ grids and each grid predicts a fixed number of bounding boxes. YOLOv3 predicts offsets tx, ty, tw, th to the anchor boxes and box confidence score that represents the class probabilities. Instead of directly computing the bounding box coordinates, computing the offsets to the ground-truth box results in a more robust training procedure. YOLOv3 architecture uses a more robust and deeper network called Darknet-53 instead of Darknet-19 [25]. There are residual connections between convolutional layers similar to ResNet [26] structure. YOLOv3 makes predictions at three different scales to improve the performance of detecting small objects in the images which is crucial for aerial images captured in high altitudes. We also used YOLOv3-Tiny architecture which is a faster version of YOLOv3. The local and global coordinates of the detected object can be obtained on rectified images. Then, these positions can be used as fiducial marker points to align consecutive frames and improve the quality of the resulting maps.

2.6. Orthomosaic

All of the data computed in previous stages can be combined to form high resolution 2D and 3D maps. First image taken from the orthorectification stage initializes the global map. After the initialization, the 2D and 3D maps are continuously updated with dense point clouds and orthorectified images using the multi-layer grid map. There are two conditions in the map updating stage. Observed area in the image can be a completely unknown region or the image can overlap with the global map. In the first case, new image data is directly added to the global map and the map is updated. In the second case, the color and elevation values of the intersecting pixels have to be determined in regions where the global map and the image overlap. The color and elevation values of the cells in the overlapping regions are determined by comparing elevation angles between the global map and the image. Cell values in the global map are updated if the elevation angle of the cell is smaller in the new frame. Otherwise, cell values are not updated. The non-maximum suppression is applied to the global bounding box coordinates of the detected objects in consecutive frames to prevent the representation of the same object with more than one bounding box on the global map.

3. Experiments

The performance of the developed mapping and object detection pipeline is evaluated in both single and multiple UAVs scenarios on two different datasets. In addition, we also collected a new dataset to train the utilized car detection algorithm. Here, we will first explain our car detector below and then evaluate the performance of the proposed mapping and localization system on two datasets.

Figure 2: Some collected positive car class samples.

Car Detection: Here, we focus on cars in the mapping area, and train YOLOv3 and YOLOv3-Tiny for car detection in aerial images. To this end, we created our own data set consisting of colored digital images obtained in different weather conditions and scales by using DJI Matrice 600 Pro and DJI Inspire 1 unmanned aerial vehicles. The data set consists of approximately 10.000 colored digital images, and it contains approximately 30.000 aerial view car images. We annotated the cars by using the bounding boxes and created the data belonging to the positive class. Figure 2 shows examples from the data set that contains positive images. We used 80% of the data (approximately 24 K positive samples) for training the YOLOv3 and YOLOv3-Tiny detectors and the remaining 20% of the data is used for testing. NVIDIA Quadro P5000 GPU was used to train the YOLOv3 and YOLOv3-Tiny car models.

To evaluate the performance of the trained detectors, we used PASCAL VOC criterion which is the most commonly used metric for object detection. According to this metric, the position of the object is classified as true or false in accordance with the overlapping ratio of the detected coordinates and the ground truth positions. This overlapping was calculated by using $\frac{\text{area}|Q \cap R|}{\text{area}|Q \cup R|}$ formula. In this formula, Q shows the ground-truth location of object and R shows the location returned by the algorithm. If this ratio is over 50%, the detected position is considered as true positive – TP, otherwise, it is considered as false positive – FP. Then the mean average precision-mAP was determined by using precision-recall curves. Table 1 gives the mAP scores and speeds of the car detectors on the created dataset. The trained YOLOv3 and YOLOv3-Tiny detectors achieved accuracies of 83.4% and 80.2%, respectively in terms of mAP score. In terms of the speed, YOLOv3 and YOLOv3-Tiny methods operate at 22 FPS and 55 FPS respectively, on a laptop with i7 7700HQ processor and NVIDIA GTX1050TI

GPU.

Table 1: The mAP scores and speeds of the YOLOv3 and YOLOv3-Tiny detectors on the created dataset.

Method	mAP(%)	Speed (FPS)
YOLOv3	83.4	22
YOLOv3-Tiny	80.2	55

Figure 3: Generated orthomosaic in single UAV scenario.

Orthomosaic Generation: For this purpose, aerial images captured with a ground-facing camera attached to a UAV at an altitude of approximately 100 meters were used. Images are captured at 10 FPS with a GoPro Hero3+ camera. The dataset consists of 1500 frames with a size of 1280×720 and the GPS data of each frame is kept in Exif format. Fig. 3 shows the generated orthomosaic and the detected objects in the single UAV scenario. Centers of the detected objects on the map are indicated with red boxes. The orthomosaic given in the figure is generated by using the incremental grid-based orthomosaic approach, selecting the cell values of the image which has the smallest elevation angle in the intersection regions. A good orthomosaic should have high resolution, homogeneous appearance and low geometric distortion. The observed area should be represented as much detailed as possible and aligned correctly in global scale. In the figure, incorrect alignments and seams at the alignment points can be observed due to the incorrect estimation of the global positions computed by fusing the SLAM and GPS data. However, in the high resolution orthomosaic, structures and the roads can be observed well and cars are localized correctly. The observed environment is reconstructed in a global coordinate system using UTM coordinates. Thus, distances can be measured on a real-world scale, and real-world positions of desired objects can be obtained.

The real world scaling accuracy of the method can be observed better in multiple UAVs scenario. In order to simulate the multiple UAVs scenario, the dataset is divided into two sets and these sets are arranged to have a small intersection between them. The method successfully maps the observed regions to the same plane as shown in Fig. 4 by using the data incoming from different sources.

Figure 4: Generated orthomosaic in multi UAVs scenario.

The generated 3D map by using sparse cloud interpolation is given in Fig. 5. Sparse cloud interpolation fails to recover information in sharp elevation transitions. This stems from the fact that the utilized interpolation approach is based on the sparse point cloud computation of ORB SLAM, which uses highly discriminative features for 3D mapping. Consequently, the low resolution of the sparse cloud leads to uncertain elevations, which distorts visual appearance. However, the generated 3D map is homogeneous with low noise and contains sufficient information about the structure of the observed area.

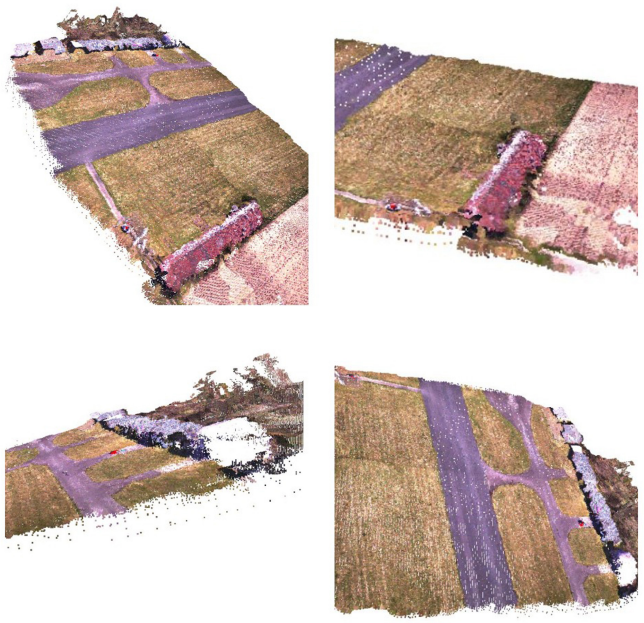

Figure 5: Appearance of 3D map from different angles.

Since there is no ground-truth data to evaluate the performance of the proposed method, ground-truth data is generated with PhotoScan [4] which is a highly accurate offline photogrammetry software. PhotoScan is an advanced computer vision algorithm that robustly estimates camera positions and creates high quality 2D-3D maps. Although it does not perform well in oblique images, it works better than other methods such as Bundler and Photosynth in moving, still, sequential and unordered images. The algorithm consists of three steps. The first step is alignment of the images, estimating camera parameters and positions. Second step consists of generating dense point clouds and building the geometric scene details on these aligned images. Final step is the texturing of the map with the images. Map and camera positions generated by using Photoscan are considered as ground-truth data.

Table 2: RPE scores of the proposed method, orb-slam and gps on first dataset.

	max	mean	median	min	rmse	sse	std
ORB-SLAM	1.12	0.27	0.25	0.02	0.35	47.32	0.22
GPS	2.34	0.60	0.54	0.06	0.69	194.32	0.34
OURS	0.96	0.22	0.17	0.01	0.29	35.08	0.19

Table 3: APE scores of the proposed method, orb-slam and gps on first dataset.

	max	mean	median	min	rmse	sse	std
ORB-SLAM	2.01	0.69	0.62	0.03	0.88	222.54	0.38
GPS	2.78	1.12	1.11	0.08	1.21	595.42	0.46
OURS	1.75	0.52	0.46	0.01	0.63	161.15	0.35

The relative pose error (RPE) and absolute pose error (APE) metrics were used to evaluate the performance of the camera pose estimation [27]. APE, is also called the absolute trajectory error, makes a direct comparison between predictions and reference camera locations. APE tests the global consistency of the trajectory. RPE compares camera movements, motions and calculates translational and rotational drift per meter. We generated trajectories of the proposed method, ORB-SLAM and GPS on the dataset. RPE and APE values of the generated trajectories are compared to the ground-truth data generated by Photoscan in Table 2 and Table 3. The low standard deviation (std) values in the table (below 1 meters for both RPE and APE) indicate that camera pose estimation has low error. In addition, proposed method obtains lower error values than ORB-SLAM and GPS. Which shows that proposed method increases the robustness of ORB-SLAM's pose estimation.

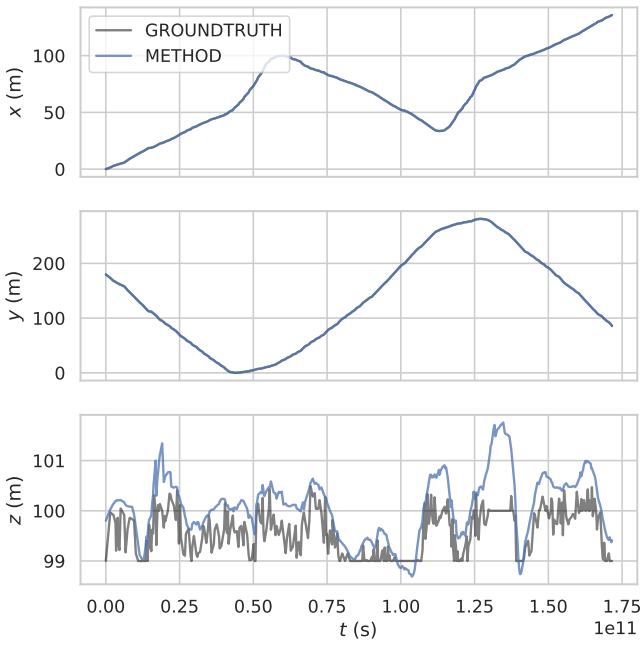

Figure 6: Trajectory graphs of method and ground-truth.

Fig. 6 shows the trajectory graphs according to the plane x, y, z for orthomosaic generated in single UAV scenario. In the x and y planes, the method has not suffered from any shifts or errors. However, when the elevation increases, an instant shift and error occurs in the z plane. The main reason for this situation is ORB-SLAM's erroneous depth estimation in regions with insufficient features to detect and track. Generated trajectory of the UAV is given in Fig. 7. Robustness and success of the method can also be observed from the figure since trajectory generated with the method is almost equal to ground-truth trajectory. Operation time for the dataset is approximately 4 FPS.

The performance the method is also evaluated in single UAV scenario on phantom3-village dataset introduced in Map2DFusion [12]. Video sequence is recorded at an altitude of approximately 160 meters using DJI Phantom3 equipped with a ground-facing GoPro Hero3+ camera. The dataset consists of 200 frames. Fig. 8 shows the generated orthomosaic and the detected objects on phantom3-village dataset in single UAV case. Generated map achieves satisfactory results on plain regions and areas containing buildings and trees. The method fails to recover information on water regions since generation of the map is highly dependent

to the feature-based SLAM approach. This results in some mis-alignments on the generated orthomosaic. Since the altitude is very high, YOLOv3 model failed to detect some of the vehicles.

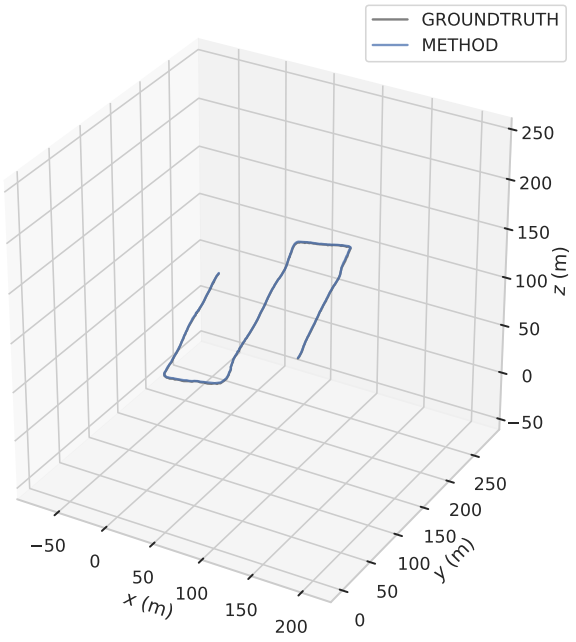

Figure 7: Generated and ground-truth trajectory of the UAV in single UAV scenario.

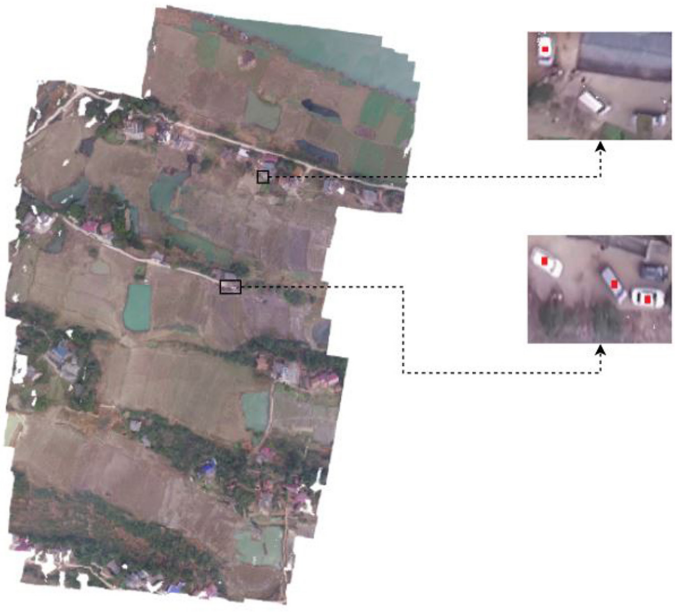

Figure 8: Generated orthomosaic in single UAV scenario on Phantom3-village dataset.

The 3D map generated by using sparse cloud interpolation is given in Fig. 9. Phantom3-village dataset is captured at 1 FPS. Low frame rate severely reduces the ORB-SLAM's depth map generation performance and this highly affects the depth map interpolation. Pipeline cannot generate 3D surfaces properly on featureless regions due to nature of the feature-based SLAM. Sparse cloud interpolation has difficulties in sharp elevation transitions as in the previous experiment. As seen in the generated 2D map, the method also fails to generate map points for water regions because of the featureless surface of the water.

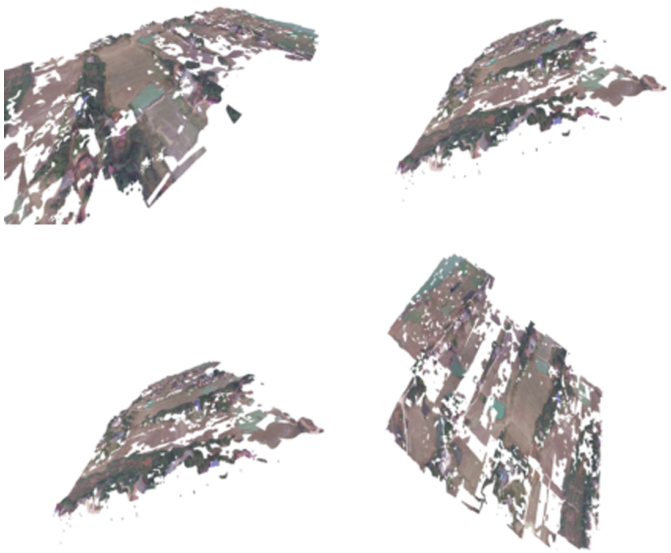

Figure 9: 3D map of Phantom3-village dataset from different angles.

Since there is no ground-truth data for the dataset, ground-truth data is generated with Photoscan as before. We generated trajectories of the proposed method, ORB-SLAM and GPS on the dataset. RPE and APE values of the methods are compared to the ground-truth data in Table 4 and Table 5. Similar to first dataset, proposed method achieves lowest error for both APE and RPE. The large standard deviation (std) values indicate erroneous camera pose estimations. In the dataset, images captured in high altitudes. This highly affects ORB-SLAM's pose estimation performance. Fig. 10 shows the trajectory graphs according to the x, y, z plane for orthomosaic generated in single UAV scenario on phantom3-village dataset.

Table 4: RPE scores of the proposed method, orb-slam and gps on phantom3-village dataset.

	max	mean	median	min	rmse	sse	std
ORB-SLAM	16.23	6.23	5.92	0.82	7.02	591.33	4.01
GPS	25.95	11.23	10.68	1.32	9.42	1042.58	6.23
OURS	14.68	5.63	4.81	0.73	6.49	486.70	3.21

Table 5: APE scores of the proposed method, orb-slam and gps on phantom3-village dataset.

	max	mean	median	min	rmse	sse	std
ORB-SLAM	28.12	14.02	14.75	1.28	16.12	2304.39	8.01
GPS	38.17	22.19	21.34	2.26	23.12	2884.42	9.54
OURS	26.11	12.69	13.63	1.07	14.34	2165.06	6.68

Similar to Fig. 6, the method has not suffered from any shifts or errors in the x and y planes. However, instant shifts

and errors can be observed in the z plane. These errors are due to the erroneous depth estimations in featureless regions such as water regions and due to the capturing images at very high altitudes. Generated trajectory of the UAV is given in Fig. 11. Operation time for the dataset is approximately 4.5 FPS.

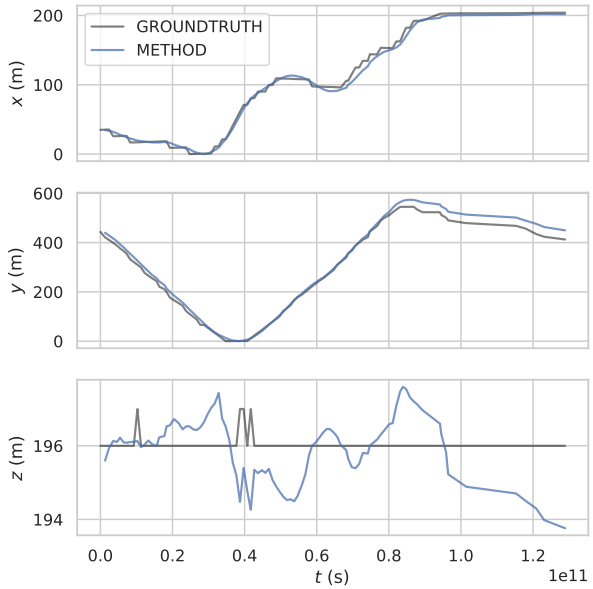

Figure 10: Phantom3-village dataset trajectory graphs of method and ground-truth.

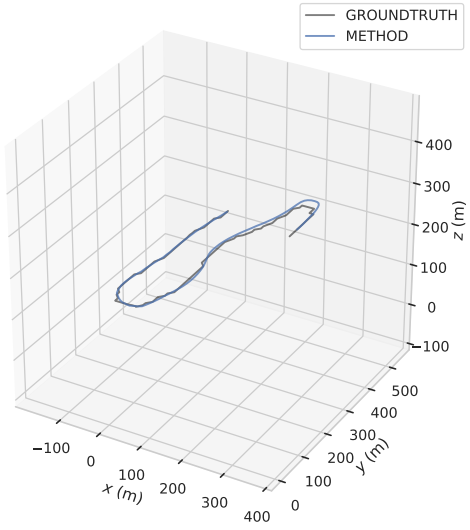

Figure 11: Generated and ground-truth trajectory of the UAV in single UAV scenario on Phantom3-village dataset.

4. Conclusion

In this study, a real-time 2D and 3D mapping pipeline with object detection ability is developed by combining the camera and GPS data of UAVs. The method uses a robust monocular SLAM method, ORB-SLAM, and point cloud interpolation algorithm, which operates at a very high speed to generate the dense point cloud efficiently. The proposed method creates semantically strong, high-resolution maps and detects objects in real-time using incremental grid-based mosaic and YOLOv3 object detection methods. The proposed method also reconstructs the map in a global coordinate system and obtains the real-world positions of the detected objects. The developed method performs global scaling, object detection, alignment operations efficiently and accurately in both single and multiple UAVs scenarios. The experimental results on two tested datasets show that the mapping pipeline generates a 3D map in real world scale, operates in real time, and the resulting generated map contains semantically strong information about structure of the observed region.

Conflict of Interest The authors declare no conflict of interest.

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References

[1] M. Brown, D. G. Lowe, "Automatic panoramic image stitching using invariant features", *International Journal of Computer Vision*, vol. 74, no. 1, pp. 59–73, 2007.

[2] T. Hinzmann, J. L. Schönberger, M. Pollefeys, R. Siegwart, "Mapping on the fly: Real-time 3d dense reconstruction, digital surface map and incremental orthomosaic generation for unmanned aerial vehicles", "Field and Service Robotics", pp. 383–396, Springer, 2018.

[3] P. Moulon, P. Monasse, R. Perrot, R. Marlet, "Openmvg: Open multiple view geometry", "International Workshop on Reproducible Research in Pattern Recognition", pp. 60–74, Springer, 2016.

[4] G. Verhoeven, "Taking computer vision aloft–archaeological three-dimensional reconstructions from aerial photographs with photoscan", *Archaeological prospection*, vol. 18, no. 1, pp. 67–73, 2011.

[5] G. Klein, D. Murray, "Parallel tracking and mapping for small ar workspaces", "Proceedings of the 2007 6th IEEE and ACM International Symposium on Mixed and Augmented Reality", pp. 1–10, IEEE Computer Society, 2007.

[6] R. Mur-Artal, J. M. M. Montiel, J. D. Tardos, "Orb-slam: a versatile and accurate monocular slam system", *IEEE Transactions on Robotics*, vol. 31, no. 5, pp. 1147–1163, 2015.

[7] C. Campos, R. Elvira, J. J. G. Rodríguez, J. M. Montiel, J. D. Tardós, "Orb-slam3: An accurate open-source library for visual, visual–inertial, and multimap slam", *IEEE Transactions on Robotics*, 2021.

[8] J. Engel, T. Schöps, D. Cremers, "Lsd-slam: Large-scale direct monocular slam", "European Conference on Computer Vision", pp. 834–849, Springer, 2014.

[9] G. Pascoe, W. Maddern, M. Tanner, P. Piniés, P. Newman, "Nid-slam: Robust monocular slam using normalised information distance", "Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition", pp. 1435–1444, 2017.

[10] C. Forster, M. Pizzoli, D. Scaramuzza, "Svo: Fast semi-direct monocular visual odometry", "2014 IEEE International Conference on Robotics and Automation (ICRA)", pp. 15–22, IEEE, 2014.

[11] M. Pizzoli, C. Forster, D. Scaramuzza, "Remode: Probabilistic, monocular dense reconstruction in real time", "2014 IEEE International Conference on Robotics and Automation (ICRA)", pp. 2609–2616, IEEE, 2014.

[12] S. Bu, Y. Zhao, G. Wan, Z. Liu, "Map2dfusion: real-time incremental uav image mosaicing based on monocular slam", "2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)", pp. 4564–4571, IEEE, 2016.

[13] A. Kern, M. Bobbe, Y. Khedar, U. Bestmann, "Openrealm: Real-time mapping for unmanned aerial vehicles", "2020 International Conference on Unmanned Aircraft Systems (ICUAS)", pp. 902–911, IEEE, 2020.

[14] D. Kiss-Illés, C. Barrado, E. Salamí, "Gps-slam: an augmentation of the orb-slam algorithm", *Sensors*, vol. 19, no. 22, p. 4973, 2019.

[15] J. Redmon, A. Farhadi, "Yolov3: An incremental improvement", *arXiv preprint arXiv:1804.02767*, 2018.

[16] T.-Y. Lin, P. Goyal, R. Girshick, K. He, P. Dollár, "Focal loss for dense object detection", "Proceedings of the IEEE International Conference on Computer Vision", pp. 2980–2988, 2017.

[17] W. Liu, D. Anguelov, D. Erhan, C. Szegedy, S. Reed, C.-Y. Fu, A. C. Berg, "Ssd: Single shot multibox detector", "European conference on computer vision", pp. 21–37, Springer, 2016.

[18] S. Ren, K. He, R. Girshick, J. Sun, "Faster r-cnn: Towards real-time object detection with region proposal networks", "Advances in Neural Information Processing Systems", pp. 91–99, 2015.

[19] Z. Tian, C. Shen, H. Chen, T. He, "Fcos: A simple and strong anchor-free object detector", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 2020.

[20] C. Zhu, F. Chen, Z. Shen, M. Savvides, "Soft anchor-point object detection", "Computer Vision–ECCV 2020: 16th European Conference, Glasgow, UK, August 23–28, 2020, Proceedings, Part IX 16", pp. 91–107, Springer, 2020.

[21] S. Umeyama, "Least-squares estimation of transformation parameters between two point patterns", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, , no. 4, pp. 376–380, 1991.

[22] M. Bertalmio, A. L. Bertozzi, G. Sapiro, "Navier-stokes, fluid dynamics, and image and video inpainting", "IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR)", vol. 1, pp. I–I, IEEE, 2001.

[23] P. Fankhauser, M. Hutter, "A universal grid map library: Implementation and use case for rough terrain navigation", "Robot Operating System (ROS)", pp. 99–120, Springer, 2016.

[24] J. L. Bentley, "Multidimensional binary search trees used for associative searching", *Communications of the ACM*, vol. 18, no. 9, pp. 509–517, 1975.

[25] J. Redmon, A. Farhadi, "Yolo9000: better, faster, stronger", "IEEE Society Conference on Computer Vision and Pattern Recognition", pp. 7263–7271, 2017.

[26] K. He, X. Zhang, S. Ren, J. Sun, "Deep residual learning for image recognition", "IEEE Society Conference on Computer Vision and Pattern Recognition", pp. 770–778, 2016.

[27] R. Kümmerle, B. Steder, C. Dornhege, M. Ruhnke, G. Grisetti, C. Stachniss, A. Kleiner, "On measuring the accuracy of slam algorithms", *Autonomous Robots*, vol. 27, no. 4, p. 387, 2009.

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Neural Networks and Digital Arts: Some Reflections

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ABSTRACT: The constant advancement in the area of machine learning has unified some areas that until then did not communicate, such as the area of computing with the arts in general. With the emergence of digital art, people have become increasingly interested in the development of expressive techniques and algorithms for creating works of art, whether in the form of music, image, aesthetic artifacts, or even combinations of these forms, usually being applied in an interactive technology installation. Due to their high diversity of creation and complexity during processing, neural networks have been used to create these digital works, which present results that are difficult to reproduce by human hand and are usually presented in museums, conferences, or even at auctions, being sold at high prices. The fact that these works are gaining more and more recognition in the art scene, ended up raising some questions about authenticity and art. In this way, this work aims to address the historical context regarding the advancement of the area of machine learning, addressing the evolution of neural networks in this field, about what art would be and who would be the artist responsible for digital work, given that despite After performing a good part of the creation process, the computer does not perform the entire process, becoming dependent on the programmer, who in turn is responsible for defining parameters, techniques and, above all, concepts that will attribute all the aesthetic value to the work. From this point of view and the growing interest in the generation of art via computers, the present work presents applied research around neural network techniques and how they can be applied in artistic practice, either generating visual elements or generating sound elements. Finally, some perspectives for the future are presented and how this area can evolve even further.

KEYWORDS Computer music, Generational art, Neural networks

1. Introduction

Natural language processing uses processes from artificial intelligence, linguistics, and statistics to naturally analyze and represent the occurrence of texts or other levels of human language in computers. Although it was used in encryption and code translation systems during World War II, it was only in 1957 that the idea of generative grammar began to gain strength, thanks to the studies of Noah Chomsky. Today, this relationship between AI and linguistics can be seen in speech recognition, in the retrieval of transcribed information, summarizing and machine translation [1].

The application of artificial intelligence to text, image, and audio files, started to gain strength in the second half of the 20th century. The relationship between computers and art arose from the need to represent a piece of art digitally. Several initiatives helped in this process, among them, the AI, which allowed the manipulation and representation of this data. However, the first personal computers were unable to process this data as WAVE and BMP directly, using some other strategies, such as the symbolic representation of music and images. In Section 2, the research methodologies are presented, highlighting its literary review, understanding of the context and analysis of neural network techniques. Section 3 shows the beginning of the relationship between art and artificial intelligence.

The evolution of Computers and the possibility to add neural networks could be combined to add more sensibility to computers. Cameras became digital eyes and microphones became digital ears. Computer vision, in turn, became the area of signal processing computing that seeks to build systems capable of obtaining information through images. Focusing on machine listening, Computer music is an area of interdisciplinary study that also involves signal processing computing, encompassing concepts from computer science, electrical engineering, and of course, music. These fields of study investigate methods, techniques, and algorithms for processing and generating sound and images. Since its inception, computer music and computer vision have been strongly related to artificial intelligence, as presented in Section 4.

With the increase of computational power, some special Neural Networks were created to signal processing. Some of these NN, like CNN, made it simple to process signals, like image and/or sound, because they need fewer preprocessing stages and can process signals directly. Section 5

present some of these models.

However, since computers could directly process signals and generate signals, how can we think about artwork authorship? Looking forward to this discussion, Section 6 presents some inconclusive topics on this subject. In the end, Section 7 presents final remarks and future works.

1.1. Literature Survey

Research on the relationship between technology and art (whether visual or sound) was based on the works A (very) brief history of artificial intelligence [2], Artificial intelligence and the arts: Toward computational creativity [3], Machine learning for artists [4] and History of LISP [5].

The concepts about Neural Networks were guided by works Learning features from music audio with deep belief networks [6] and Extracting knowledge from artificial neural networks [7], while those about Convolutional Neural Network were based on Gradient-based learning applied to document recognition [8], Early Diabetes Discovery From Tongue Images [9], Intelligent Diabetes Detection System Based On Tongue Datasets [10] and A study on convolutional neural networks and their application in pedestrian detection [11].

The concepts of Generative adversarial Network go through Introduction to degenerative adversarial networks (GANs– Generative Adversarial Networks) [12], An introduction to generative adversarial networks [13] and Enhanced super-resolution generative adversarial networks [14], while Autoencoder and Variational Autoencoder are guided by works Transforming auto-encoders [15], Introduction to Autoencoders [16], An Introduction to variational Autoencoders [17] and Collaborative variational autoencoder for recommender systems [18].

2. Methodology

The central question of the work involves an approximation between neural network techniques and artistic creation. As it involves several theories, methods, and techniques of computer science, it is applied research. In addition, such research has a cyclical character, based on the following steps:

- **Understanding the Context and Rationale of the Problem**

  Systematic Analysis of Literature: the investigation of techniques, state-of-the-art, and justifications for this work go through selective bibliographic research in materials published in books, journals, and proceedings of international congresses that deal with the main theme (Convolutional Neural Network, Generative Adversarial Network, Autoencoder, and Variational Autoencoder;

  Historic evolution: from the literature review, a timeline is exposed demonstrating the historical evolution of artistic creation mediated by technology;

- **Analysis of Neural Network Techniques:** stage where techniques such as brainstorming and brainwriting are used to expand the repertoire of alternatives for artistic creation mediated by artificial intelligence. This makes the research present an exploratory character and seeks to understand the behavior, particularities, and motivations of these processes;

- **Research Rating:** with the entire functional system, tests will be carried out with users, whether experts or laymen, to validate the experimentation environment. There will also be analyzes of the answers to the questionnaires to identify problems and possible improvements.

3. The Early days - Generational Art and Symbolic data

In its history, artificial intelligence has always permeated other fields of study, such as philosophy, engineering, and even literature. Since Homer wrote about automated "tripods", even a mechanical trumpet created by Ludwig van Beethoven and the works of Jules Verne and Isaac Asimov, AI and computer systems have also become important in the design of art [2].

Concerning the use of computer systems for the creation of plastic arts, the first works date from 1950, when Franke and Laposky, without knowing about the other's experiment, used oscilloscopes to generate photographs. However, the rise of this mode of art production was in the 1980s, when personal computers and video game consoles began to improve graphics software [19]. Among the works worth mentioning are AARON [3], a pioneering robotic system capable of painting an image of reference drawings and Painting Fool [20], a software created by Simon Colton, capable of giving its artistic interpretation of the images found on the Web.

The machine learning area has also been used to create art. Between the years 1970 and 1990, Myron Krueger carried out several studies in the area of augmented reality, creating several interactive installations, which used computational techniques for artistic creation, reinforcing the relationship between the computer and art [4]. Such applications ended up inspiring a whole generation of artists/scientists who started to see the computer as a very promising tool for creating art.

Some tools played a fundamental role in this process, namely: Lisp and Prolog. Lisp is a programming language that allows you to use mathematical functions as a structure for elementary data. One of its main advantages is the ability to treat software as data, thus enabling it to serve as an input in another application. It is present in document processing, hypermedia, graphics and animation, and natural language processing [5].

An example of how LISP can be used in the Art field with symbolic music representation is the software OpenMusic [21]. This software is a visual programming environment, dedicated to computer-assisted composition and music analysis. Its main feature is the easy programming of visual modules, consisting of the connection of boxes with information that presents some logical relationship, from

a musical point of view. Thus, it allows artistic projects to be built on the computer through the expressive power of a programming language [22].

Initially, OpenMusic's visual programming tools were used to generate or process musical objects, such as scores or other symbolic data. Recent developments have extended this approach, allowing the creation of scores containing their own functional or algorithmic structure, in the form of constructed visual programs and also the processing of real-time audio.

Lisp also assists in programming languages that are used to create plugins that increase the functionality of software geared to art. Some languages to be highlighted are Nyquist and Scheme. The first one is focused on the synthesis and sound analysis and serves as a basis for plugins present in Audacity. The second supports functional and procedural programming and builds plugins for Gimp, a tool used to create and edit vector and raster images.

Prolog focuses more on describing facts and their occurrences, rather than describing a sequence of steps to be followed by the computer to solve a problem, just like in traditional programming languages. Thus, this technique provides better communication between human-computer interfaces [23].

These classic techniques are good to process discrete data, like numbers and strings but were not used at that time to process streams of data, like WAV files and bitmap images. At this time it was not easy to think about signal processing and creation using large data, like audio and images. For this reason, in the early days, it was used to combine artificial intelligence with symbolic data representation in music and visual art, such as the MIDI[1] and the SVG[2] format.

4. Neural Networks reaching Arts and Sound Processing

With the advancement of the computer, in addition to the processing of symbolic data, several audios, images or videos have also been processed, expanding the possibilities for artistic creations. These surveys gave rise to several data pre-processing techniques, such as convolution, feature extractors, filters, and audio descriptors, providing support for the rise of the multidisciplinary area called Music Information Retrieval (MIR) that involves areas as Machine Learning and Musical Computing.

Audio is stored in the time domain, which ends up bringing little or no information about its content beyond its respective amplitude (in the time domain) and envelope. One of the ways to get information from audio files is extracting characteristics from an audio in the frequency domain, using for it the audio descriptors. These descriptors can act between two domains, being the time domain, also called basic descriptors, involving the processing of the sampled audio signals, or the frequency domain, using spectral descriptors, such as the Mel Frequency Cepstral Coefficients [6].

As they are implemented with convolutions, in the form of mathematical equations such as the Discrete Fourier Transform (DFT) and the Fast Fourier Transform (FFT), the audio descriptors end up being part of the data pre-processing step, followed by the application of some machine learning algorithm. In this way, it is possible to use non-convolutional neural networks in conjunction with audio descriptors.

From these descriptors, the audio is reduced to a simplified structure, without loss of information, which can be defined according to the descriptor used. Currently, there is a lot of research in relation to the development of technological tools for the extraction of audio descriptors, both in the form of programming libraries and graphic software or extensions to existing tools aimed at extracting and visualizing the characteristics of audio.

Among the existing tools, we have the Aubio [26] and LibXtract [27] libraries, frameworks like MARSYAS [28], jAudio [29], CLAM Music Annotator [30], jMIR [31] and Sonic Visualiser [32], and the toolbox for MatLab MIRtoolBox [33].

Consequently, more complex databases started to emerge, including, for example, historical images, scientific articles, recordings of artistic performances, among other types of data. In this way, the data started to be stored in different formats such as MP3, AIFF, and WAV for audio and JPEG, RAW and BMP for images.

Currently, regarding audio as data to be processed, there are several databases for different purposes, such as dataset's dedicated to voice recognition tasks such as AudioSet [34] and Common Voice [35]; musical dataset's like Million Song Dataset [36] and BallRoom [37]; or even more specific datasets for classifying instrument tones [38].

On one hand, we had the emergence of artistic datasets and on the other hand, the possibility to process this data with neural networks. However, in addition to the complexity of the data, the entry of neural networks was still unidimensional, which led to several studies on efficient ways to reduce the space of data representation without loss of information.

With neural networks, which use different weights and connections under one architecture, processing has become more complex and the types of data to be processed have been expanded, enabling the creation of several artistic applications. It is worth mentioning that, until then, only symbolic data were used under Production Rules or Decision Trees algorithms, such as CN2 and C4.5, mentioned in [7]. These techniques had the advantage that all the knowledge processed and generated is something understandable for the human being, however, the data used must be symbolic.

In machine learning, several statistical and data mining algorithms are used, focused on extracting characteristics and information from a given database. That is, from a

[1]The MIDI protocol was created in 1983 by a consortium of electronic instrument manufacturers, with the aim of standardizing communication between them and also allowing connection to computers. It is important to note that this protocol does not transmit sound, but music information, such as the pitch of a specific note, the time of a song, its pitch, etc. In general terms, it is the equivalent of a score for computers [24].

[2]SVG, is an open file format, which represents drawings and graphics in a vector way. Its main feature is the fact that it maintains the quality of the file when it is enlarged and is present in the representation of vector geometric shapes, raster, and bitmap images and text. Although it did not cause a major revolution on the Web after its introduction, this type of format is present in the most diverse publishing software, both proprietary and free software [25].

certain amount of data, it became possible to train the computer to classify something or even generate new data automatically. In this way, increasingly larger databases have emerged and are being made available to the whole community, such as MIDI libraries containing various artistic performances performed around the world.

5. Special NN models to signal processing

Another way to process digital signals, especially audio, is through the use of convolutional neural networks. As the name implies, this type of network performs convolution and data processing within its structure, causing information to be extracted without the use of descriptors. Thus, these networks can directly receive the file and use less computational resources to learn what kind of processing can be used to extract data from the input value.

5.1. CNN - Convolutional Neural Network

Around 1988, inspired by biological processes [39], Yann LeCun and collaborators [8] created the so-called Convolutional Neural Networks. Initially, the proposal was for these networks to be focused on the processing of one-dimensional or two-dimensional data structures, making CNN's very promising for the processing of images and sounds. It is worth mentioning that the images are composed of pixels that form a 2D structure, but the audio can be treated either as a one-dimensional structure if we analyze the variations of sound waves over time, or two-dimensional if we analyze their respective spectrogram, in which case, he would be treated as an image.

A CNN is a variation of the Multilayer Perceptron Network, but focused on a type of processing quite similar to those of computer vision, enabling the application of filters under the data to be processed, maintaining the relationship between their respective pixels [11]. As the name implies, CNN's operate mainly under a mathematical operation called convolution, which is described as:

$$st \quad x * wt \quad _a \; xawt - a \tag{1}$$

Convolution is a linear operator that is based on the calculation of two functions: the kernel function, also called a filter, described as w; and the sum of the products generated by the function x, referring to the processed data. Regarding the architecture of a CNN, they can be classified as a combination of several layers, which can be classified as Convolutional layers; Pooling layers; and the fully connected layers [40].

The convolutional layers are composed of several neurons, which are connected, according to a certain weight, to a set of pixels provided by the previous layer. These neurons are responsible for applying filters under the captured pixels, through kernel functions, and the result of this processing is then propagated to the next layer.

In this step, the kernel is convoluted together with the input provided, sliding the window, which in this case will move twice, generating two outputs. The variable stride concerns how many pixels will be skipped since the window will not always move from pixel to pixel, generating a size 2 entry for the next layer, as shown in Figure 1. In addition, it is not always possible for windows to convolve to the end. To do this, exist a technique called *zero-padding* where zeros are added at the edges allowing convolution under all pixels. And after convolution, it is common to apply a nonlinear activation function, like those used in common neural networks.

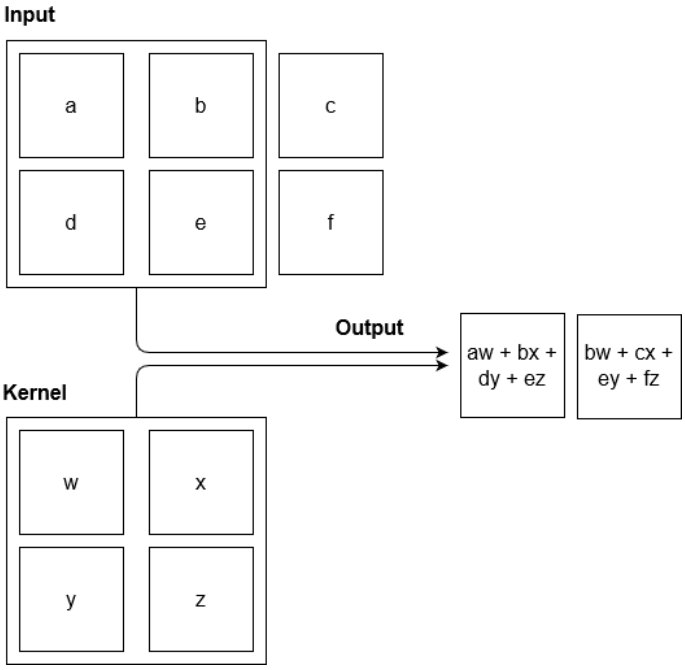

Figure 1: Kernel function example.

An interesting aspect about CNN is the possibility of using more sophisticated filters when compared to the classics used for image processing, which are generally two-dimensional. That is, it is possible to apply a filter that has height, width, and even depth, optimizing the extraction of information provided by the training data.

After the convolution with the activation function, we have the *pooling* layer, responsible for reducing the size of the data. For example, given an entry with 2x2 windows, a value is selected to represent it through a function, which is usually the function called *maxpooling* which selects the maximum value within a rectangular neighborhood.

Currently, there are other more sophisticated architectures such as LeNet-5 [8] which has two convolution layers followed by *pooling* and one more convolution layer or GoogLeNet [41] which has five convolution layers in a row of *pooling* [11].

Finally, after the *pooling* layer, for classification problems, usually one more layer is used, fully connected. This layer is then responsible for making the decisions that the network will take, given the outputs received by the previous layers. In this layer, machine learning algorithms or regressions are generally applied, generating an output called *score*, which will define the classification result.

5.2. GAN - Generative Adversarial Network

First of all, it is important to understand the discriminative and generative algorithms. A discriminative model tries to classify the data from the entry of its label or category, being concerned only with this relationship. The generative model is the opposite of this process. Instead of predicting a label from input data, it tries to predict the resource that led to that label. In mathematical terms, the discriminative algorithm is concerned with the relationship between x and y inputs, while GAN investigates how x value is obtained from an input y [12].

From a competition between these two models, the Generative Adversarial Network emerges. The generative network is responsible for receiving noise as input and generating data samples. The discriminating network receives samples from the generator and the training data and must be able to distinguish what is noise and what is real data. These networks play against each other continuously, where the generative model is learning to produce increasingly realistic samples, and the discriminator is learning to improve more and more in the distinction of data. The purpose of all this is to make the generated samples indistinguishable from the actual data [13].

Training involves presenting samples of the training dataset until acceptable accuracy is achieved. The generator trains based on its ability to "trick" the discriminator. Typically, the generator is seeded with random input that is sampled from a predefined latent space (for example, a multivariate normal distribution). Subsequently, the candidates synthesized by the generator are evaluated by the discriminator. Backpropagation is applied to both networks, so that the generator produces better images, while the discriminator becomes more adept at signaling synthetic images. The generator is typically a deconvolutional neural network and the discriminator is a convolutional neural network [12].

Although originally proposed as a form of a generative model for unsupervised learning, GANs have also proved useful for semi-supervised learning, fully supervised learning and reinforcement learning [14].

Consequently, the potential of GANs allows it to mimic any data distribution, creating images from scratch, using all possible combinations of pixels in a figure, in addition to songs, poetry, etc. This type of network can be found in fashion and advertising, simulating models, makeup and products [42]; in science, helping to improve astronomical images [43]; and digital art, contributing to the modeling of characters and scenarios [14].

5.3. AE - Autoencoder

Autoencoder is a type of unsupervised neural network that uses backpropagation to copy the input and display it as an output, to learn a new representation of the input data. In mathematical terms, he learns an approximation of the identity function, generating a function $f(x')$ similar to $f(x)$ [15].

This type of network is divided into two parts: the encoder, responsible for encoding the input data, represented by the function $f(x)$, and the decoder, a function $g(x)$ that reconstructs that data [15].

Because it generates a copy of the input data, the autoencoder must be able to generate useful properties. This can be achieved through the so-called incomplete autoencoder, which creates restrictions on the copy task and forces the network to learn the most important features of a given data [16].

A characteristic that differentiates this method from the others is its ability to offer several outputs that enhance the model. One is to add a sparse condition to the weights, which reduces the size of the latent vector. Another way of improvement is to allow the encoder and decoder to be deep neural networks. So, instead of trying to find linear transformations, the network will be concerned with finding nonlinear information [16].

Currently its common application in noise removal systems, dimensionality reduction in data visualization and in the acquisition of semantic meaning in words. In music, it is widely used for compression and reconstruction of musical information, in addition to being able to be used as a denoising filter, common in music production.

5.4. VAE - Variational Autoencoder

Variational Autoencoder, as the name suggests, has some relationship with Autoencoder, such as the architecture composed of an encoder and a decoder, trained to minimize the reconstruction error between the initial data. In a nutshell, VAE is an Autoencoder whose encodings are regulated during training, ensuring that the latent space has good properties for generating new data. The term "variational", in turn, comes from the relationship between regularization and the methods of variational inference in statics [17, 18].

However, there are also significant differences, the main one being the fact that Autoencoders are deterministic discriminative models, while VAEs are generative models. This happens because of the different mathematical formulations addressed by both. Variational Autoencoder is directed probabilistic graphical models (DPGM), approximated by a neural network, that tries to simulate how the data is generated, and from that, understand the underlying causal relationships. Therefore, instead of creating an encoder that generates a single value to describe each latent state attribute, an encoder is formulated to describe a probability distribution for each attribute.

In contrast to the most common uses of neural networks as regression or classification, VAEs are powerful generating models. This is because it is allowed to generate a new random output, similar to the training data, in addition to changing or exploring variations in the data more frequently, following a specific and desired direction. This is where VAEs work better than any other method currently available.

The framework of variational autoencoders (VAEs) provides a principled method for jointly learning deep latent-variable models and corresponding inference models using stochastic gradient descent. The framework has a wide array of applications from generative modeling, semi-supervised learning to representation learning and inference models.

Among the applications for this tool are the generation of fake human faces; recognition of manuscripts; interstellar photographs; and the production of purely synthetic music.

When dealing with music specifically, MusicVAE [44] emerges, where its main characteristic is to be hierarchical in the learning of latent spaces for musical scores. The tool uses a combination of recurrent neural networks (RNN) and VAE that encodes a musical sequence into a latent vector, which can later be decoded into a musical sequence. As latent vectors are regularized to be similar to a standard normal distribution, it is also possible to sample from the sequence distribution, generating realistic music based on a random combination of qualities [45, 46].

This is possible through the interpolation of the music, that is, through the mixing of different musical sequences, or through the vector arithmetic of attributes, which adds certain features to the music. As a creative tool, the goal is to provide an intuitive palette with which a creator can explore and manipulate the elements of an artistic work [47].

6. Looking forward: Some perspectives and inconclusive topics

From a technical point of view, the use of artificial intelligence has helped in various ways the production of art. In music, examples range from the classification of the musical genre through the combination of information contexts [48] or through the classification by relational algorithms [49], to the creation of hierarchical systems for recommending music [50] and intelligent systems that propose audio plugins to assist in musical production [51].

In addition to also occupying space in the artistic area and making several transformations in this field, it also covered the use of different technologies to create a (no more) new type of art, called digital art. With the emergence of several discussions between researchers and artists about this artistic mode, digital art is increasingly present in several places, such as museums (Uncanny Mirror, Museum of Modern Art and Barbican Center), auction houses (Christie's and Sotheby's), or even at certain scientific events.

A very successful work that unites artificial intelligence with the artistic world is "ToTa Machina", developed by Katia Wille. This work is an installation that captures the emotions of the audience using facial recognition techniques and, through robotics, has visual projections that move according to the audience. Through facial stimuli, the relationship between the human being and the machine ends up becoming even shorter, reinforcing engagement and appreciation under the work [52]. An interesting fact that reinforces even more the promise of technological installations, is that during the presentations of the work, the public stayed a long time in the installation, where the children were curious to know more about the structure of the installation and the adults interacted creating different affections for obtaining different results.

Another more current example of neural networks aimed at artistic production is the work "Edmond de Belamy", created in 2018 by the Obvious group, formed by three researchers from the University of Montreal who used a GAN neural network, explained in subsection 5.2, to elaborate this art work [53]. The work consists of a set of 11 portraits generated by the neural network, portraying members of the fictional Belamy family. This work was very successful, being auctioned for US$432.500,00, reinforcing the idea that the computer is capable of being a tool for artistic productions [54].

The inclusion of this work caused several discussions involving both artists and researchers in the field of AI who wondered about the possibility of algorithms by themselves, being artists. Mark Riedl, associate professor of machine learning and AI at the Georgia Institute of Technology, classifies the algorithms as "very complicated brushes with many mathematical parameters, which make it possible to create an effect that would be difficult to obtain otherwise".

It is worth mentioning that GAN's are networks that need a large amount of data to obtain a good result and all the knowledge acquired is then used to generate new results. That is, the final product is directly linked to a long process of data selection, mathematical parameters, and selection of the results obtained. In this way, we cannot say that the machine is fully responsible for the work generated since the researcher himself became an artist because he was responsible for all the elaboration of the parameters and the architecture used during the creative process. Then the question arises as to who the real artist would be, the algorithm for being trained for months to generate a certain work or the researcher carrying out various tests and adjustments to obtain a certain result?

Under this question, like any work of art, we must analyze the entire creation process and not just the final product. Thus, it is worth mentioning the thinking of three contemporary artists: Anna Ridler, a British artist who used a GAN relating the volatility of the cryptocurrency market with Tulip Fever, who understands AI as a tool, as it allows specific creations, and also as process, since the artist needs to label objects and model the data to be used; Gauthier Vernier, french artist who participates in the Obvious group, mentioned above, who has a less human thinking in the sense of who is responsible for art, providing credit to the machine and signing the work with the algorithm's own formula, because according to the author, it was him even who created the work; and Mario Klingemann, a German artist pioneering the use of artificial intelligence, says that what the machine does to create a work of art is basically imitating human aspects, and under current technology, it ends up failing to try to interpret subconscious and emotional aspects that many sometimes difficult to quantify [55].

Some discussions precede the question about who the artist would be in a work developed by AI, such as the definition of whether the result obtained is an artistic work or not. There are people with more futuristic thinking like the gallery owner Luisa Strina who defends the idea that to have quality, art must not follow trends. She further states "Used with conceptual and aesthetic coherence, new technologies open a door for research that has not yet been done in art" [52]. Neural networks are new techniques if analyzed in the artistic field, and because they are not fully automated, since the programmer needs to adjust it for certain results, they end up opening space for the insertion of

aesthetic and conceptual concepts during the creation stage, making sure that the final result can be directly related to the artist/programmer's intention. Consequently, neural networks end up having a great potential for the creation of several quality artworks, bringing us one more question raised by several artists. But concerning art creation, will machine replace artists in the future?

Heretofore, It is worth mentioning three thoughts: Anna Ridler states that people pay a large amount of money for simple and minimalist work, but if we analyze works in which there is a lot of repetition, perhaps the AI will optimize these processes, facilitating the creation and perhaps making the work cheapest; Gauthier Vernier states that the machine will not replace man, given that the human takes care of much of the creative process and it is he who provides purpose for what was created, that is, the machine is not capable of creating a work of art by itself, human/machine collaboration is necessary; finally, Mario Klingemann addresses the idea that for artists who perform repetitive works, AI has great potential to replace them in the future [55].

Finally, in this section were presented thoughts on the definition of what would be art, in addition to the presentation of some works that involve the use of neural networks for artistic creations. However, the fact is that, defining or not, digital art has evolved more and more, in addition to generating both financial and academic results. In this way, it is interesting to think not only about new ways or techniques for creating innovative artistic works but also about what type of art people are seeing, what tool is used or even what type of music is created due to the concept of what it is popular.

7. Final Remarks

Maybe, the digital arts are as old as the computer, and until then, several artistic works have been created, in the form of interactive web pages, pictures painted by machines, installations that capture the interaction of the public to synthesize images and sounds, among others. The discussion about what is art is quite old and pertinent, however, willingly or not, artists are creating digital artworks and also a public that admires this type of work.

This market has grown considerably in recent years, which makes the creation of digital works very promising, in addition to increasingly engaging researchers to develop techniques that provide to the programmer, more autonomy under a neural network, bringing benefits and innovations not only under the arts but also machine learning in general.

Taking into account the point of view that work, to be artistic, must have an entire aesthetic concept, which involves both the creative process and the final result, the artistic definition under work is exclusively up to its creator. As previously mentioned, when using a neural network, the programmer needs to define the entire network structure, referring to the number and type of layers, parameters to be used, and even what would be the type of input.

In this way, we can affirm that the programmer is essential for the creative process and that perhaps the work itself is not art, but rather the entire creation process involving the choices and decisions that the programmer had to carry out for the development of the work. It may be possible that in the future, digital artists will start to be recognized not for their works, but for all the creative processes created for the creation of art, causing auction houses, for example, to sell algorithms and not just concrete works.

The choice of algorithms and techniques throughout this text is due to the fact that they are widely disseminated in the academic community, in addition to highlighting that even the oldest technologies can be used in the relationship between art and AI.

Having exposed this long-standing relationship and contribution of Artificial Intelligence in art, future strategies should be considered. The technological advance of the latest techniques has provided the emergence of new algorithms and software that support the artistic practice mediated by computers, in addition to making this process cheaper and popular. In addition, fields such as STEAM (Science, Technology, Engineering, Arts and Mathematics) began to gain more space, being an excellent tool to explore both areas.

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References

[1] E. D. Liddy, "Natural language processing", *Encyclopedia of Library and Information Science*, 2001.

[2] B. Buchanan, "A (very) brief history of artificial intelligence.", *AI Magazine*, vol. 26, pp. 53–60, 2005.

[3] R. L. de Mántaras, "Artificial intelligence and the arts: Toward computational creativity", https://www.bbvaopenmind.com/en/articles/artificial-intelligence-and-the-arts-toward-computational-creativity/, 2020-05-17.

[4] G. Kogan, "Machine learning for artists", https://medium.com/@genekogan/machine-learning-for-artists-e93d20fdb097#.xc9qk7ca7, 2020-05-17.

[5] J. Mccarthy, "History of lisp", *ACM SIGPLAN Notices*, vol. 13, 1996, doi:10.1145/960118.808387.

[6] P. Hamel, D. Eck, "Learning features from music audio with deep belief networks.", "ISMIR", vol. 10, pp. 339–344, Utrecht, The Netherlands, 2010.

[7] E. Martineli, "Extração de conhecimento de redes neurais artificiais.", Ph.D. thesis, Universidade de São Paulo, 1999.

[8] Y. LeCun, L. Bottou, Y. Bengio, P. Haffner, "Gradient-based learning applied to document recognition", *Proceedings of the IEEE*, vol. 86, no. 11, pp. 2278–2324, 1998.

[9] S. Naveed, G. G, L. S, "Early Diabetes Discovery From Tongue Images", *The Computer Journal*, 2020, doi:10.1093/comjnl/bxaa022, bxaa022.

[10] S. Naveed, G. Mohan, "Intelligent diabetes detection system based on tongue datasets", *Current Medical Imaging Reviews*, vol. 14, 2018, doi:10.2174/1573405614666181009133414.

[11] A. C. G. Vargas, A. Paes, C. N. Vasconcelos, "Um estudo sobre redes neurais convolucionais e sua aplicação em detecção de pedestres", "Proceedings of the XXIX Conference on Graphics, Patterns and Images", vol. 1, 2016.

[12] D. S. Academy, "Introdução às redes adversárias generativas (gans – generative adversarial networks)", http://deeplearningbook.com.br/introducao-as-redes-adversarias-generativas-gans-generative-adversarial-networks/, 2018, 2020-05-18.

[13] J. Glover, "An introduction to generative adversarial networks", https://blog.aylien.com/introduction-generative-adversarial-networks-code-tensorflow/, 2018, 2020-05-18.

[14] X. Wang, K. Yu, S. Wu, J. Gu, Y. Liu, C. Dong, C. C. Loy, Y. Qiao, X. Tang, "Esrgan: Enhanced super-resolution generative adversarial networks", "Proceedings of the European Conference on Computer Vision (ECCV)", pp. 0–0, 2018.

[15] G. Hinton, A. Krizhevsky, S. Wang, "Transforming auto-encoders", "21st International Conference on Artificial Neural Networks", vol. 6791, pp. 44–51, 2011.

[16] J. Jordan, "Introduction to autoencoders", https://www.jeremyjordan.me/autoencoders/, 2018, 2020-05-18.

[17] D. Kingma, M. Welling, "An introduction to variational autoencoders", *Foundations and Trends® in Machine Learning*, vol. 12, pp. 307–392, 2019, doi:10.1561/2200000056.

[18] X. Li, J. She, "Collaborative variational autoencoder for recommender systems", "23rd ACM SIGKDD International Conference", pp. 305–314, 2017, doi:10.1145/3097983.3098077.

[19] M. Kauw-A-Tjoe, "Generation of abstract geometric art based on exact aesthetics, gestalt theory and graphic design principles.", *Journal of Computational and Applied Mathematics - J COMPUT APPL MATH*, 2005.

[20] A. Organization, "Timeline of ai art", https://aiartists.org/ai-timeline-art, 2020-05-17.

[21] G. Assayag, C. Rueda, M. Laurson, C. Agon, O. Delerue, "Computer-assisted composition at ircam: From patchwork to openmusic", *Computer Music Journal*, vol. 23, no. 3, pp. 59–72, 1999.

[22] J. Bresson, C. Agon, "Visual programming and music score generation with openmusic", "2011 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)", pp. 247–248, IEEE, 2011, doi:10.1109/VLHCC.2011.6070415.

[23] A. Colmerauer, P. Roussel, "The birth of prolog", "History of programming languages—II", pp. 331–367, 1996, doi:10.1145/234286.1057820.

[24] E. M. Miletto, L. L. Costalonga, L. V. Flores, E. F. Fritsch, M. S. Pimenta, R. M. Vicari, "Introdução à computação musical", "IV Congresso Brasileiro de Computação", sn, 2004.

[25] J. D. Eisenberg, *Svg Essentials*, O'Reilly Media, 2014.

[26] P. M. Brossier, "Automatic annotation of musical audio for interactive applications", Ph.D. thesis, University of London, 2006.

[27] J. Bullock, U. Conservatoire, "Libxtract: a lightweight library for audio feature extraction.", "ICMC", 2007.

[28] G. Tzanetakis, P. Cook, "Marsyas: A framework for audio analysis", *Organised sound*, vol. 4, no. 3, pp. 169–175, 2000.

[29] C. McKay, R. Fiebrink, D. McEnnis, B. Li, I. Fujinaga, "Ace: A framework for optimizing music classification.", "ISMIR", pp. 42–49, 2005.

[30] X. Amatriain, J. Massaguer, D. Garcia, I. Mosquera, "The clam annotator: A cross-platform audio descriptors editing tool.", "ISMIR", pp. 426–429, 2005.

[31] C. McKay, I. Fujinaga, "jmir: Tools for automatic music classification.", "ICMC", 2009.

[32] C. Cannam, C. Landone, M. Sandler, "Sonic visualiser: An open source application for viewing, analysing, and annotating music audio files", "Proceedings of the 18th ACM international conference on Multimedia", pp. 1467–1468, ACM, 2010.

[33] O. Lartillot, P. Toiviainen, T. Eerola, "A matlab toolbox for music information retrieval", "Data analysis, machine learning and applications", pp. 261–268, Springer, 2008.

[34] J. F. Gemmeke, "Audioset", .

[35] M. Team, "Common voice", .

[36] L. Rosa, "Million song dataset", .

[37] F. Gouyon, "Ball room", .

[38] N. Team, "Nsynth dataset", .

[39] M. Matsugu, K. Mori, Y. Mitari, Y. Kaneda, "Subject independent facial expression recognition with robust face detection using a convolutional neural network", *Neural Networks*, vol. 16, no. 5-6, pp. 555–559, 2003.

[40] H. R. Guimarães, "Recuperação de informações musicais: Uma abordagem utilizando deep learning", 2018.

[41] C. Szegedy, W. Liu, Y. Jia, P. Sermanet, S. Reed, D. Anguelov, D. Erhan, V. Vanhoucke, A. Rabinovich, "Going deeper with convolutions", "Proceedings of the IEEE conference on computer vision and pattern recognition", pp. 1–9, 2015.

[42] C. Wong, "The rise of ai supermodels", https://www.cdotrends.com/story/14300/rise-ai-supermodels, 2020-05-18.

[43] K. Schawinski, C. Zhang, H. Zhang, L. Fowler, G. K. Santhanam, "Generative adversarial networks recover features in astrophysical images of galaxies beyond the deconvolution limit", *Monthly Notices of the Royal Astronomical Society: Letters*, vol. 467, p. slx008, 2017, doi:10.1093/mnrasl/slx008.

[44] A. Roberts, J. Engel, C. Raffel, I. Simon, C. Hawthorne, "Musicvae: Creating a palette for musical scores with machine learning", https://magenta.tensorflow.org/music-vae, 2020-04-21.

[45] W. Sharber, "Musicvae: A tool for creating music with neural networks", https://medium.com/@wvsharber/musicvae-a-tool-for-creating-music-with-neural-networks-db0f4b84a698, 2020-04-20.

[46] M. Dinculescu, J. Engel, A. Roberts, eds., *MidiMe: Personalizing a MusicVAE model with user data*, 2019.

[47] A. Roberts, J. Engel, C. Raffel, C. Hawthorne, D. Eck, "A hierarchical latent vector model for learning long-term structure in music", *International Conference on Machine Learning*, 2018.

[48] M. Domingues, S. Rezende, "The impact of context-aware recommender systems on music in the long tail", "Brazilian Conference on Intelligent Systems, BRACIS 2013", pp. 119–124, 2013, doi:10.1109/BRACIS.2013.28.

[49] J. Valverde-Rebaza, A. Soriano Vargas, L. Berton, M. C. Oliveira, A. Lopes, "Music genre classification using traditional and relational approaches", "Brazilian Conference on Intelligent Systems, BRACIS 2013", 2014, doi:10.1109/BRACIS.2014.54.

[50] I. Nunes, G. Leite, D. Figueiredo, "A contextual hierarchical graph model for generating random sequences of objects with application to music playlists", "Brazilian Conference on Intelligent Systems, BRACIS 2013", 2019.

[51] P. Moura da Silva, C. Mattos, A. Júnior, "Audio plugin recommendation systems for music production", "Brazilian Conference on Intelligent Systems, BRACIS 2013", 2019, doi:10.1109/BRACIS.2019.00152.

[52] B. Calais, "A inteligência artificial invade o mundo da arte", https://forbes.com.br/forbeslife/2020/01/a-inteligencia-artificial-invade-o-mundo-da-arte/, 2020, 2020-05-25.

[53] D. Kaufman, "Dá pra fazer arte com inteligência artificial?", https://epocanegocios.globo.com/colunas/IAgora/noticia/2019/08/da-pra-fazer-arte-com-inteligencia-artificial.html, 2020, 2020-05-25.

[54] J. Pearson, "Uma obra de arte gerada por ia foi vendida num leilão por us$ 432 mil", https://www.vice.com/pt_br/article/43ez3b/uma-obra-de-arte-gerada-por-ia-foi-vendida-num-leilao-por-usdollar-432-mil, 2020, 2020-05-25.

[55] F. Gonzaga, M. Fernandes, "Inteligência artificial é o próximo passo na evolução da arte?", https://arte.estadao.com.br/focas/estadaoqr/materia/inteligencia-artificial-e-o-proximo-passo-na-evolucao-da-arte, 2020, 2020-05-25.

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A State-of-the-Art Survey of Peer-to-Peer Networks: Research Directions, Applications and Challenges

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ABSTRACT: Centralized file-sharing networks have low reliability, scalability issues, and possess a single point of failure, thus making peer-to-peer (P2P) networks an attractive alternative since they are mostly anonymous, autonomous, cooperative, and decentralized. Although, there are review articles on P2P overlay networks and technologies, however, other aspects such as hybrid P2P networks, modelling of P2P, trust and reputation management issues, coexistence with other existing networks, and so on have not been comprehensively reviewed. In addition, existing reviews were limited to articles published in or before 2012. This paper performs a state-of-the-art literature survey on the emerging research areas of P2P networks, applications and ensuing challenges along with proposed solutions by scholars. The literature search for this survey was limited to the top-rated publisher of scholarly articles. This research shows that issues with security, privacy, the confidentiality of information and trust management will need greater attention, especially in sensitive applications like health services and vehicle to vehicle communication ad hoc networks. In addition, more work is needed in developing solutions to effectively investigate and curb deviant behaviours among some P2P networks.

KEYWORDS: Bitcoin, file-sharing, hybrid P2P, overlay network, peer-to-peer network, privacy, security

1. Introduction

There have been increasing attention given to peer-to-peer (P2P) file-sharing network, due to the fact that centralized file-sharing system suffers from poor reliability and scalability, and single point of failure [1]. Most are scalable, anonymous and decentralized [2], and according to [3], P2P networks are flexible, autonomous, and cooperative. However, peer-to-peer networks have unpredictable network topology and complex management owing to their decentralized structure.

So efforts are on to overcome emerging issues such as searching of participating peers and high rate of site failures, which may be due to loss of power or wireless network link. Other issues with P2P system have to do with balancing the load in the peer-to-peer based systems [4], [5]; management of the trust, provision of incentive mechanisms to encourage peers participation, forensic investigation, and so on.

In [6], [7], a survey of P2P overlay networks was done. In [8] indexing in P2P networks was examined. In [9], the author did a "state-of-the-art survey on P2P overlay networks in pervasive computing environments", where Literature publish on P2P overlay network up to 2012 were reviewed. In addition, ref. [10] discussed peer-to-peer technology in 2008. This paper performs a state-of-the-art literature survey on the emerging research areas of P2P networks, applications and ensuing challenges along with proposed solutions by scholars. To the best of our knowledge, there have not comprehensive survey of the P2P network and related research areas. In addition, to reviewing articles before 2012, more attention will be given to literature published between 2012 and 2017.

The rest of this article is arranged as follows: Section II presents research in the different areas of interest in P2P networks such as hybrid P2P systems, security issues, multimedia file sharing, P2P modelling and coexistence with other networks, and so on. Relevant P2P applications

are also highlighted. In section III research on forensic investigation and management of P2P network are presented. Section IV highlights emerging challenges and future trends of peer-to-peer networks, and finally, the conclusions reached are presented in section V.

2. Peer-to-Peer Research Areas

The author in [11] highlighted P2P network research areas, which have been put in a tabular form as shown in Table 1.

Table 1: P2P research areas, an extension of [11]

P2P Research areas	Hybrid P2P system [12]–[15]
	P2P overlay network [16]–[20]
	Knowledge-based application and management [14], [19-22]
	Security issues in P2P [19-33]
	Multicasting and multimedia file sharing [34]–[45]
	P2P architecture and protocols [13], [26], [36], [41], [46]–[49], [50-53]
	Data and index structure [54-55]
	Semantic routing and search [56–62]
	P2P based wireless and mobile networks [21], [37], [41], [63–64]
	Coexistence and converge of P2P and other networks [44], [65-68]
	Modelling of P2P systems [22], [38], [69-77]
	System analysis, design and development [78-82]

The following discussion presents a survey of relevant literature on P2P research.

2.1. P2P Overlay Network

By conception, an overlay network is networking riding on another network, and in this case, nodes are connected by virtual links. The P2P overlay network is built on top of the previously existing internet. Peer-to-peer overlay networks are grouped into structured network (Chord [15], [83]–[85], Tapestry, Pastry, Viceroy, and Kademlia [26-27], [86]); and unstructured network (Freenet [28-31], Gnutella [50-51], KazaA [31], BitTorrent [78-79],[87-88], and eDonkey [89]). Research discussing the structure and applications of the P2P overlay network is reported in [16]–[20]. FastTrack and eDonkey request for username and password for network access. Hence, they are not anonymous [2].

Meanwhile, in [42], the authors developed an overlay network that functions by connecting smaller structures in an unstructured manner and, peers can be connected to several rings. But, the proposed overlay network is less expensive in comparison with hierarchical structured P2P systems. Furthermore, unstructured peer-to-peer networks are not efficient and scalable, although, they are very resilient. Nodes interconnect randomly in unstructured P2P networks, therefore, the diameter of the network cannot be precisely determined. In contrast, structured peer-to-peer networks are based on DHT. Since its structure is rigid on the overlay network, performance is degraded and potential for attack when nodes are removed [18]. 1n 2019, the author in [90] created a non-DHT-based structured P2P network using residue class (RC). It was a pyramid tree structure based on interests. In this tree, node I represent a group of peers who are interested in a resource of type i. Because there are many paths between most of the nodes in a complete pyramid tree, a P2P architecture was chosen for this project. From the standpoint of creating load-balanced as well as robust communication protocols, such a structural property can be beneficial. Furthermore, the tree diameter limits the search latency for its intergroup data lookup technique, which is independent of the number of distinct resource kinds and the total number of peers in the system. Furthermore, every intra-group data lookup communication just requires a single overlay hop. In a discussion of structured and unstructured P2P networks, [19] pointed out that an exact and exhaustive search can be done on a structured overlay network. They further attempted to address security issues in gossip-based protocols by using a probabilistic approach to determine the best candidate for gossip. Conceptually, gossip-based protocols are designed for unstructured P2P networks, owing to their ability to form dynamic structures with the aid of the view of the node. When it comes to routing of large distributed infrastructure, there are associated security challenges such as trust and reputation management, privacy and anonymity.

Overlay networks depend on Distributed Hashing Table (DHT), however, many hash functions do not consider the interconnections between item sets, thereby making them ineffective for related items. Owing to this realization, the authors in [91] developed a distributed array by adapting a DHT, with a resultant reduction in the number of messages needed to access elements.

Furthermore, to improve the data rate in sharing files, [16] developed a peer-to-peer overlay network over optical fibre, which uses dense wavelength division

multiplexing. With this privacy and the high data rate needed for multimedia communication can be ensured. In [17], the authors sought to enhance multicast communication by developing a generic method, which is used to optimize multicast tree depth in structured and unstructured peer-to-peer systems. The proposed system further helps to manage the latency issue of the overlay network. Features of group communication were incorporated into the system, leading to a multicast system that is based on a distributed algorithm.

2.2. Hybrid P2P System

According to [92], "*a hybrid architecture attempts to strike a balance between the accuracy of the centralized architecture and the lower load of the pure architecture. An example of hybrid P2P structure is super-peer P2P systems*." Figure 1 shows a general architecture of a super-peer P2P network. As indicated by the following literature, there are ongoing efforts to maximize the advantages of P2P and that of other systems, leading to the development of more robust hybrid systems [12]–[14], [70]. The authors in [14] presented the development of a scalable, efficient and fault-tolerant hybrid of P2P network and wikis, an application of web 2.0 for use in content repositories. Also, discussed were the key blocks that enable peer-to-peer data management at the system non-volatile storage layer for repositories. The authors noted that many internet-based repositories do not use user comments to classify and organize their contents. For some that do, they rely on a centralised web server and seek to make a profit from users comments and tagging.

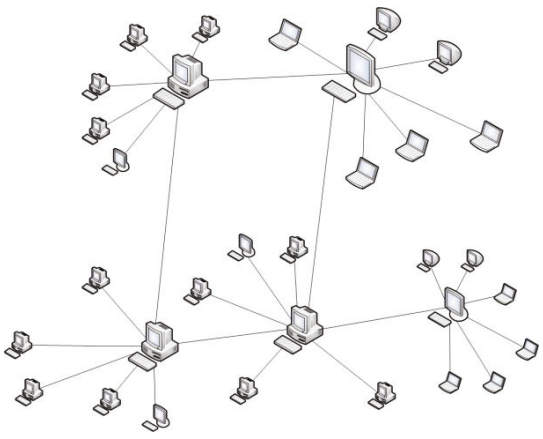

Figure 1: super-peer peer-to-peer network [92]

Video sharing is a critical application of P2P systems. An architecture that integrates the merits of peer-to-peer and Ethernet passive optical network (EPON) architecture was proposed in [93] for addressing the problem of low-cost large-scale video sharing. The proposed architecture included a mechanism that adds downstream bandwidth at the optical live terminal. The researchers in [13] presented a hybrid live peer-to-peer network based on tree and mesh topologies. This was necessitated by the requirement to ensure smooth media playback. The developed hybrid system sought to maximize the merit of either topology, although trading off some data rates. Table 2 shows the merits and demerits of tree and mesh topologies.

Table 2: Comparison of tree and mesh topologies

The Merit of tree topology	**The merit of mesh topology**
Minimized transmission delay	Immunity to node failures
Demerit of tree topology	**Demerit of mesh topology**
Failure of nodes close to the root negatively affects traffic	Prone to unpredictable latencies

2.3. P2P Architecture and Protocols

Examples of literature discussing P2P architecture and protocols are [13], [36], [41], [46]–[49], [52]. In designing efficient P2P protocol and architecture, it is essential to consider churn. Conceptually, churn refers to the dynamics of peers, in terms of how peers join and leaves the network, which may result in network instability. It usually split the network into smaller units, leading to loss of communication or node failure and undesirable consequential data loss.

Monitoring network communication for violations of data security regulations and monitoring data at endpoints to determine whether it was correctly transported from one node to the other might be used to avoid data loss between nodes. For safe inter-node communication, the data might also be encrypted. Incorporating the idea of least privilege is another viable answer. That is, at any abstraction layer of a computer environment, each node must have access to just the information and resources required for its legal function. The authors in [80] modelled churn both as degree-dependent and degree-independent node failures using random graphs. Peer-to-peer protocols were evaluated in [48] while analyzing several factors in connection with churn.

Efficient routing in P2P networks is an issue that has also attracted the attention of researchers such as [47], who noted that existing routing algorithms were based on a random selection of neighbour nodes. Subsequently, a novel routing algorithm based on iterative self-organizing data analysis technique clustering topology for improved routing efficiency. Also, a typical peer-to-peer file-sharing network is not topology-aware. And this constraint leads to its having lower efficiency. With this challenge in view, [41] proposed a P2PMesh that is aware of its topology and

allows for efficient data sharing. It involves the use of three strategies depicted in Figure 2.

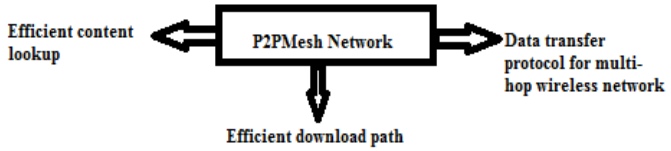

Figure 2: P2PMesh topology-aware strategies proposed by [41]

Distributed denial-of-service attacks (involving exhaustion of connections), server bottlenecks and centralization of the server are examples of problems encountered by internet protocol (IP) voice call technologies. Hence, in [26], the authors presented improved Kademlia protocol to achieve high-level security, rapid addressing and discovery in P2P voice communications. This resulted in a peer locating efficiency increase of up to 20%. Figure 3 depicts a super and normal nodes structure of the proposed I-Kademlia protocol. Also, in a centralized system, servers can break down or operates at a low level of performance, owing to excessive multimedia loading [11].

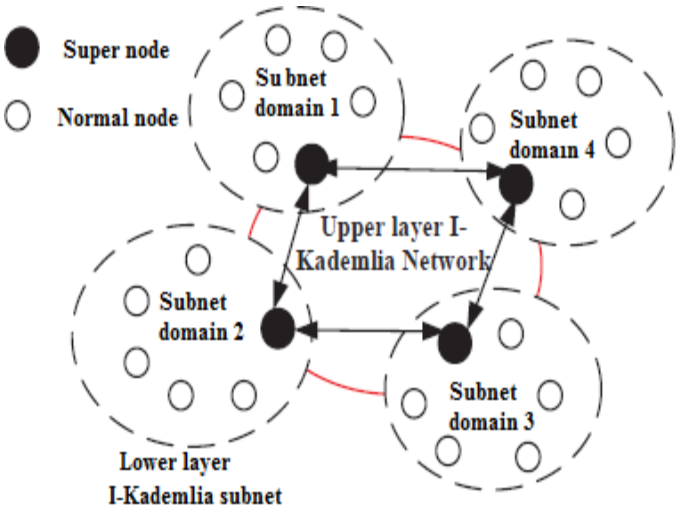

Figure 3: Double layer structure of I-Kademlia protocol consisting of supernodes and normal nodes [26]

In [49], the authors presented a strategy for the detection of P2P botnet traffic. The authors used a more accurate 2-tuple conversation-based methodology that is oblivious of port and protocol, in contrast to 5-tuple based methodology, which is flow-based. The desirable protocol should ensure efficient scheduling of video data dissemination among peers that will reduce the number of hops, delays, and improve the user-perceived quality of video streaming is challenging in P2P video streaming. Owing to this, agent-based scheduling has been proposed such as the belief-desire-intention (BDI) agent architecture in [36], which aid in partner selection, and Net Logo for simulating the modified Gnutella protocol [75].

2.4. Security and Trust Issue in P2P Networks

Since P2P networks are largely anonymous and decentralized, security is a major issue attracting the interest of researchers such as [2], [19]–[25], [52]. The authors in [2] examined the effect of anonymity on P2P users deviant tendencies. Instances of deviant behaviour include peers distributing illegal pornography such as CSA, bestiality, rape and incest, and copyrighted materials. Consequently, queries and query hits were intercepted and analyzed.

Researchers such as [20] noted that effective identity management is key to addressing these issues with P2P overlay networks for large distributed infrastructure routing. One approach for ensuring anonymity, while giving identities via the active operation of two trusted third parties, which internally certify users. Protection against the following can be achieved Sybil attack [27], [32], eclipse attack [20], [92], [94] and whitewasher. Eclipse attack constitutes one of the most disruptive attacks on P2P networks, in which an entity uses "multiple identifiers for the purpose of cutting off traffic to and from a particular node, thereby eclipsing them from the network" [92]. Figure 4 shows a depiction of an eclipse attack on a hybrid P2P system.

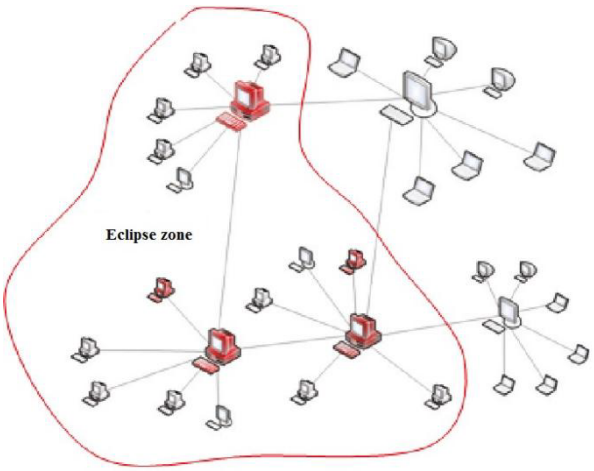

Figure 4: An eclipse attack [92]

More so, in P2P several trust mechanisms can hardly prevent peers with bad behaviour from gaining access to the network and hindering trusted activities in the network. Thus, in [95], the authors presented a meta-reputation system that evaluates peer reputation by examining the behaviour of peers it has invited to join, and not just its behaviour. In so doing, bad peers are not merely marginalized but pushed out. Ref. [96] developed a trust-based admission control model that manages the

manner, in which nodes can join the system and help nodes in demanding services more efficiently because nodes with the highest evaluation may not be available for all service requests and do not necessarily provide the best service.

The authors noted in [79] that owing to BitTorrent traffic volume, it is a potential candidate for hidden data carrier, in a report of StegTorrents. The authors further noted that hiding information in network steganography can be for non-malicious intent such as organizations afraid of corporate espionage. Another use will be to conceal communications between journalists and information sources. Meanwhile, a P2P based network capable of detecting local man-in-the-middle attack targets at secure socket layer (SSL) and transport layer security (TLS) was proposed in [25]. The design neither rely on centralized notary service nor owners of websites, rather, the proposed design authenticate certificate via retrieving them at various points on the network. Owing to the need to realize a decentralized and scalable system coupled with the privacy-aware feature, several strategies were integrated into the design called Laribus as shown in Figure 5.

Figure 5: Strategies of Laribus (adapted from [25])

Peer-to-peer traffic is typically not friendly to other sources of traffic in a network, emphasizing the need to identify them. Effects of P2P traffic on network anomaly detector is still a subject of research, in spite of the work in [61], who attempted to minimize the reduction of accuracy to traffic anomaly detectors owing to the presence of P2P traffic by identifying the properties of malicious traffic that do not overlap with peer-to-peer traffic, which is then used to design a traffic preprocessor used by the detector to improve its accuracy.

Furthermore, in order to check for the integrity of files during sharing, many networks depend on several quantities of hash values. Thus, the authors in [88] examined how these hash values can be used to identify unknown data remnants and file fragments. The proposed methods, was, however, not tested on hard drives. Figure 6 shows a typical file content in torrent.

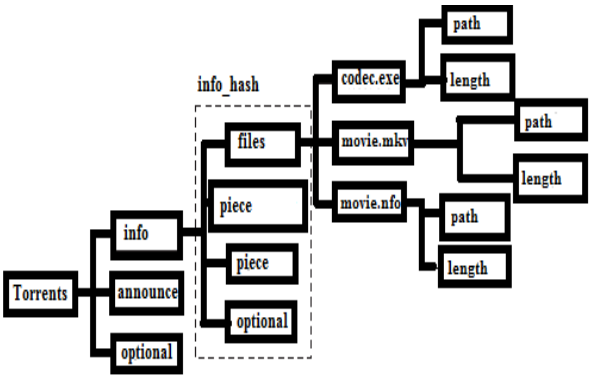

Figure 6: Constituent of torrent file [88]

2.5. Multicasting and Multimedia File Sharing

Multimedia file sharing is a key application of the P2P system. However, the following challenges exist the need to have a pause-free video quality, effective bandwidth utilization, lowering of jump latency, scalable video for heterogeneous platforms, and so on. Some of these challenges depend on the length of the video file. For video with playback time <10 minutes, the challenges encountered are (a) peers can jump to other pages faster or close to the page, and (b) greater overhead is created in establishing an overlay network. Owing to these, the authors in [97] proposed a peer-to-peer based online short video sharing policy that integrates interest-based peers, clustering strategies, short video caching and streaming source peers algorithm, and VoD popularity factor. Other researches on multicasting and multimedia file sharing applications and solutions are presented in [34]–[42], [98-99]. The authors in [100] developed an algorithm for finding frequent itemsets within a P2P network. For QoS constraint services such as live streaming, neighbour peer selection must be done efficiently in terms of reduced playback delay, startup delay, end-to-end delay in the network, distortion and frame loss ratio is decreased. This is in view of the influence of overlay construction and scheduling tactics on the performance of P2P live streaming [101]. Consequently, random peer selection, decentralized mechanism, and specialized protocol where peers regularly exchange information about their status have been proposed. In[101], it was observed that despite the fact that a great number of scheduling techniques have been created, none of them is broad enough to address live streaming concerns. At the receiver end, there is a significant latency and poor visual quality. Therefore, the researchers proposed a new start-up–based selection technique and a slack time–based scheduling strategy. The start-up buffer location for a new peer was defined by the start-up selection procedure, and the scheduling scheme picks both the chunk and the peers. Both push and pull priority-based techniques were used

in the scheduling strategy with a significant improvement in network performance and video quality at the receiver end as the result.

However, the researchers in [102], observing that peers are not equally endowed with resources such as battery life, network connectivity, available bandwidth, and online permanence time, introduced a fitness parameter f_i, defined in equation (1) and the parameters are defined in Table 3. The aforementioned resources are critical when the files to be shared are multimedia.

$$f_i = f(g_i, h_i) = \frac{g_i(\boldsymbol{r_s})}{k_0 + h_i(\boldsymbol{r_m})} \quad k_0 > 0 \quad \boldsymbol{r_s} \in R_s^{m_i} \quad \boldsymbol{r_m} \in R_p^{n_i} \quad (1)$$

where $g: R_s^m \to R \quad m \in N$

$g: R_p^n \to R \quad n \in N$

In [40], a system that delivers live multimedia streaming using a P2P network was proposed. Components of the multimedia system are shown in Figure 7.

Table 3: Fitness parameters notations

Notations	Definitions
R_c	Secondary resource set
R_p	Principal resource set
	Domain of resources
	Principal resource of peer
	Secondary resource of peer
	Constant of proportionality

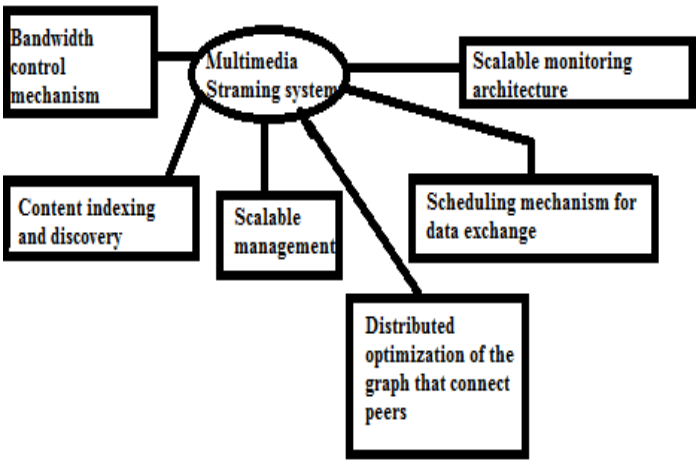

Figure 7: Components of the live multimedia streaming proposed by [40]

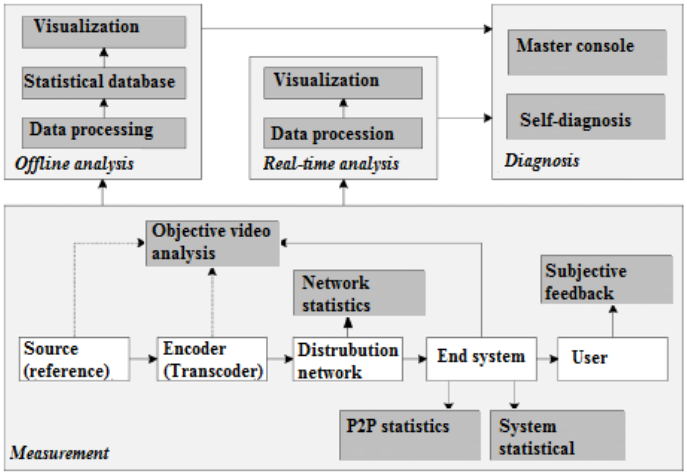

Figure 8: Proposed framework for multimodal quality of user experience for IPTV measurement [35]

In [35], it was observed that while some researchers have attempted to solve existing issues in P2P video file sharing such as transversal of firewall, flash crowds, network address translation, and authentication of contents. There is a need to develop a strategy to systematically assess the quality of P2P video service in terms of end-user perception. This was done by the authors while understudying the Lancaster Living Lab P2P based live video and video-on-demand service provider. Figure 8 shows the proposed multimodal quality of the user experience measurement framework.

The authors in [22] presented a new P2P management system for the high-speed quality of service-aware backbones. The system uses a module, which interfaces network peers and infrastructure used in communication. When a QoS constraint is about to be violated, a rerouting strategy is activated deploying virtual circuits, hitherto redundant. Another issue with P2P video streaming is a constraint in peer resources [102] coupled with a high rate of error under the P2P wireless mesh networks (WMNs) scenario.

In [98], a Fibonacci ring overlay network with distributed chunk storage for peer-to-peer VoD streaming will reduce jump latency attributable to VCR-like operation. Under this scheme, video information is split into bits at peers local storage. To reduce jump latency, some neighbours are maintained in a set of concentric rings with Fibonacci radii, thus quacking peer discovery time. Furthermore, an overlay network, which distributes the stored chunks of video, is constructed to minimize the effect of churns.

Many existing studies gave more attention to uniform chunks during seeking operation in VoD. More so, the impact of a lot of seeking requests has not been

adequately studied. The authors in [103] developed a scheme called D-splay used in indexing data chunks in peer-to-peer VoD networks. In [34], SeekStream that easily adapts to user bandwidth changes and behaviour was proposed. This will guarantee stable video streaming even under highly heterogeneous and frequent seeking operation scenarios, although increasing overhead by 4%.

Meanwhile, the telecommunication space is filled with heterogeneous devices such as mobile phones, computers, etc. with various playback capacities. Owing to that scalable video coding (SVC) have been recommended for use in obtaining homogenous, even when sources of the video are heterogeneous. Note that, SVC is used to modify the rate of flow from several sources so that availability upload capacities can be used to deliver homogeneous video quality from all sources. In SVC, video information is encoded into layers. Scalability can be spatial, temporal, and in terms of fidelity or combined scalability. Also, SVC can be used to provide differentiated video standards to peers with heterogeneous capacities [81], [104-108]. However, the quality of the delivered video is degraded by wireless streaming. Hence, the authors in [37] developed an adaptive unequal video protection strategy for small to large scale video streaming over P2P WMNs. Whereas, in [38], the authors proposed a distributed video-sharing algorithm among partner peers, along with a cross-layer design method for ensuring the video quality. Here, some problems associated with video sharing were modelled as a distortion-delay problem solved with a quality-driven scheduling algorithm. Factors considered in the models were (a) network congestions (b) encoding behaviour (c) automatic repeat request query (ARQ) (d) modulation (e) coding and finally (f) packet playback delay.

2.6. Semantic Routing and Search

Semantic routing and search are important aspects of P2P networks because they aid efficient peer discovery [56-60], [109]. The approach varies, depending on the type of overlay network, it could be structured or unstructured. The dynamic query is usually applied to unstructured P2P networks, aimed at reducing the necessary peers needed before reaching desired peers. Consequently, in [110] a dynamic query over DHT for performing a dynamic query over the structured P2P network. The searching algorithm also involves matching keywords with advertised ones. But, what if the keyword is wrongly spelt or incomplete? The authors in [109] developed a double Metaphone algorithm to phonetically match misspelt or incomplete keywords with the template.

The authors in [1] proposed a QoS-aware service discovery method implemented in two stages for unstructured P2P networks, namely; service registration stage-where functional and non-functional information is registered and service discovery stage. The proposed system, meant for elastic cloud computing was probabilistic.

In [58], the authors proposed a decentralized system for Semantic Web Services. In order to reduce overhead and complex computation, the approximate solution was sought via sampling-based method; with that assumption that a sample, which is independent and identically distributed, is present at a location to generate a set of candidate items set.

In P2P search, the efficiency of the process is highly desirable. But improving inter-peers trust could improve node searching efficiency. Owing, to this a trust-aware semantic-based query routing method for improved efficiency of the search was reported in [56]. Bloom filters were used to complete multi-keyword queries while lowering the query cost. Furthermore, in order to reduce workload overheads and enhance discovery in P2P networks, hierarchical architecture has been proposed [46]. However, for efficiency in searching, the ratio of the supernode to the ordinary node has to be optimal, to reduce the latency of lookup.

In [60], the researchers reported on an efficient technique for enhancing the effectiveness of cooperative searching of a large-scale distributed system in unstructured peer-to-peer networks. It was observed that traditional approaches do not guarantee the scalability needed to manage large and increasing semantic web services. Consequently, the authors proposed a method called 'similarity flooding' based on a scalable epidemic algorithm, which results in a high recall rate and lowered time to discover semantic web services (SWSs). Conceptually, flooding involves peers sending queries to other peers via an unstructured P2P network. The search terminates when the time-to-live of the query equals zero. The authors in [111] evaluated classic flooding, random walk and gossip-based resource searching algorithms for mobile P2P networks and methods for enhancing these algorithms with a view of using them in mobile ad-hoc networks (MANETs) was proposed. However, ref. [76] pointed out that flooding incurs large overhead. Owing to this, the researchers proposed a statistical matrix form of flooding, in which distance of transmission between neighbours, amount of shareable files, query service, and so on are incorporated into search algorithms.

In addition, research proposing bio-inspired search algorithms has been reported, such as in [57], [112]. The authors in [57] proposed maximizing search efficiency of peers' databases using a bio-inspired algorithm, reported to have better query and traffic response than both bee- and ant-inspired algorithms. A bio-inspired caching mechanism based on the Artificial Bee Colony (ABC) owing to its reliability was presented in [112]. Furthermore, the ABC algorithm was enhanced to help reduce single-point failure and over caching problems in the P2P network and also reduce energy consumption.

2.7. Peer-to-Peer Network Modelling

To effectively describe a peer-to-peer network, and to enhance its performance, there is a need to model it. The following discussion presents cases of P2P modelling in terms of the development of incentive mechanisms, optimization, trust and reputation management issues, etc. Table 4 shows a classification of the discussed models. In [72], an efficient social-like P2P method for discovering resources was proposed. The method mimics various human social behaviours, in which network connections are regarded as relationships, while peers are considered as people. Many file-sharing systems are based on unchoking algorithms or tit-for-tat. However, this reciprocal incentive scheme approach is not sufficient for designing heterogeneous P2P network, thus, the authors introduce an incentive scheme based on virtual nodes or clusters of trusted nodes that unify user devices since devices with enough resource can support devices that are poor in resources while maintaining game-theoretic properties of reciprocity [113]. There is also a need to provide incentives to peers so that they can share resources [114]. Many incentive systems and policies have been developed in recent years to balance the load and prevent free-riding in peer-to-peer (P2P) networks. One such approach is global peer ranking. Peers are rated using a metric called the contribution index in this approach. The contribution index is set up in such a way that peers are encouraged to share network resources. This strategy can achieve fairness in terms of upload to download ratio in each peer. The calculation of the contribution index, on the other hand, is not simple. It is computed in the network as a whole, distributively and iteratively, and it necessitates peer-to-peer clock synchronization. A slight clock synchronization problem can result in incorrect results [55]. Therefore, the authors in [55] suggested a simple incentive mechanism based on peer contributions that can balance the number of resources uploaded and downloaded by each peer. Because it does not require iterative calculation, it can be implemented with reduced message overhead and storage space while still maintaining strict clock synchronization.

It is worthy of note that existing P2P networks are bandwidth-intensive [115]; posing a financial burden on ISPs and deteriorating their networks. Proposed solutions such as the use of caching devices are limited in deployment by legal concerns; expansion of ISP infrastructure is not sustainable, and an increase in available bandwidth is consumed by the ever-expanding P2P network. Blocking of P2P traffic has also been suggested, but this violates the principle of net neutrality. Enforcing limits on bandwidth consumed via traffic shaping is also not effective because P2P peers can encrypt themselves.

Although predicting P2P traffic is challenging owing to the following non-linear properties of P2P networks: (a) self-similarity, (b) outburst continuity, and (c) multi-construct, some P2P networks contain harmful files, making it crucial to predict P2P traffic [116]. An architecture to measure, identify and optimize P2P, which can adapt to the unpredictable nature of the P2P network as shown in Figure 9 was proposed in [117]. However, the architecture involves traffic shaping and blocking strategies.

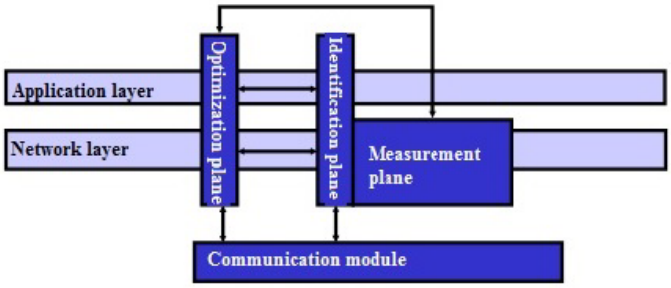

Figure 9: Architecture for P2P network prediction [117]

The authors in [118] highlighted various simple and easy to implement methods of message transmission targeted at increasing network resource utilization for low traffic scenarios. Ref. [116] used wavelet-analysis to handle the non-linear part of net traffic and Kalman filter to handle the linear part.

Both [119] and [120] address the issue of pricing of P2P content. In [120] optimal pricing files in the network was presented. Whereas, the authors in [119] discussed the issue of appropriate network pricing that benefits ISPs and peers in P2P networks without violating the principle of net neutrality, and without requiring deep packet analysis and shaping of the traffic. Knowing that identifying and monitoring traffic is crucial, the authors in [87] studied P2P network traffic using BitTorrent traffic

as a case. The authors noted that the majority of P2P traffic monitors are either in favour of internet service providers (ISP) or user-centric. Therefore, a traffic control that satisfies both ISP and P2P users was proposed. One method of improving the efficiency of P2P content sharing is locality awareness, which helps to minimize inter-domain traffic and download times for ISPs and users respectively, resulting in a win-win situation. This is easily true for homogenous systems, but hardly so for real-life peer distribution.

Table 4: P2P model classification

Ref.	Description	Purpose
[23]	PSO	Peer selection strategy
[63]	Byzantine agreement	Minimizing bouts of exchange before faulty nodes can come to an agreement
[69]		Transparency and size scalability
[22], [114]	Evolutionary game	P2P incentive mechanism
[72]	Social network	P2P resource discovery
[87]	Case study of BitTorrent traffic	P2P traffic prediction
[115]		P2P traffic prediction
[116]	Wavelet analysis and Kalman filter	P2P traffic prediction
[119], [120]		P2P pricing by ISPs
[121]	LMD and GARCH	Flash P2P traffic prediction
[122],[123	Graph theory	Characterizing P2P botnets
[124]	Incomplete and dynamic game	P2P incentive mechanism
[125]		Credit incentives for quality video upload
[126]		P2P content availability
[127], [128]		P2P trust management
[43], [129]		Peer pollution in P2P

In [121], the authors studied the use of local mean decomposition (LMD) and generalized autoregressive conditional heteroscedasticity) GARCH in traffic prediction of flash P2P videos. LMD was used to decompose the long-related flow, whereas, the short-related flow is predicted using GARCH.

Determining the size of a peer-to-peer network is another aspect that has been modelled. In [122], it was observed that this along with determining the resilience of P2P botnets could be difficult. The researchers thus presented a graph-theoretic description of the basic vulnerabilities and inherent characteristics of peer-to-peer botnets. Also, several mitigation methods for determining the resilience of current P2P botnets were reported. Meanwhile, botnets are used by persons with malicious intent, in terms of commission of financial fraud, spam and denial-of-service attacks. The authors in [123] discovered major botnet characteristics in local network traffic for User Datagram Protocol (UDP) networks. The authors hope that this will help in botnet detection. To generate a live P2P network environment, a torrent program was used during the capturing procedure. The UDP handled the majority of data transfer in a network, providing marginal transport services, non-guaranteed datagram delivery, and direct access to the IP layer's datagram service for applications. For applications that do not require the TCP standard of service, UDP is employed. The majority of the botnet's attacks were carried out through TCP.

On the other hand, ref. [69] modelled the relationship between data transparency in peer-to-peer networks and size scalability, which will aid in evaluating the extent of scalability of the system considering overheads. In order to evaluate data transparency, the following were considered: bandwidth, CPU utilization, and frequency of data request.

Meanwhile, another issue in the P2P network is the Byzantine agreement problem, which occurs when non-faulty nodes are required to cooperate irrespective of the problem caused by faulty peers. However, several bouts of exchange are needed before non-faulty peers can agree. In [63], an algorithm for reducing the required bouts of exchange was developed.

Furthermore, the authors in [114] and [124-125] observed that peers are not generous enough to share their limited resources, such as bandwidth, in a practical mobile P2P network, but only want to download, owing to their being strategic and rational. This practice is known as "free-riding." Subsequently, there is a need to both design a mechanism to incentivize the peers to share resources and a framework for measuring the incentive mechanism for the MP2P system. In [124], a dynamic and incomplete game was developed. Whereas, a framework

based on evolutionary game theory was developed in [114]. In [125], a credit incentive for peers in a network encourages the upload of multimedia files.

Furthermore, the authors in [71] presented an analysis methodology based on an evolutionary game for verifying the efficiency of an incentive mechanism for peers. Here, the client-server relationship was modelled as a game, while, considering its asymmetric properties. Inter-swarm collaboration and sharing of resources have been proposed, which involves sharing of storage and bandwidth among swarms, leading to optimized usage of resources and better content availability, although this requires content preloading. However, content preloading and coordination of inter-swarm results in additional overheads. In [125], the authors reviewed existing strategies on multi-swarm collaborations in P2P content sharing. For content to be shared, it has to be available, hence, the probability (P_k) that content is not available to a peer is given by eqn. (2) [126] and the definition of parameters are shown in Table 5.

$$P_k = \frac{1/r_k}{E\left[B_k\right] + 1/r_k} \tag{2}$$

where $E\left[B_k\right] = \frac{e^{r_k u_k} - 1}{r_k}$

Table 5: Parameter definition used for content unavailability

Notations	Definitions
r_k	Content publisher's rate of arrival
u_k	Average resident time of publisher
k	Number of files bundled for sharing

The dynamics of churn and infrastructure failure lower content availability in the P2P network. So, developing a fault-tolerant system such as the decentralized scheduling algorithm for peer-to-peer grid proposed in [82] is desirable. In the proposed system, when the node fails, the algorithm reallocates jobs of grid resources considering the cost of computation and communication required for the job.

A task select node of the grid with the smallest workload is called a computing field $com\,I$.

$$com\,I = \frac{\sum_{i=1}^{n} T_i}{A \times C_{mips}} \tag{3}$$

where T_i is the amount of computation needed by the *ith* task on queue, the number of processing elements in the node's grid is A and C_{mips} is million instructions per second that a processing element of the P2P grid resource can execute?

Trust is yet another factor that determines a peer's willingness to share a file. Furthermore, the danger of P2P networks spreading viruses and garbage data exists. Researchers are developing various trust models and architectures that will improve the file-sharing capabilities of peers [127-128]. Hence, the Eigen Trust reputation management system, which depends on a collection of pre-trusted peers, which is a major limitation, since some honest peers are ranked low have been proposed [128]. In [128], the authors presented a trust management system, in which honest peers (h) contributes to computing the overall reputation of the other peers. The maximum reputation value was given in the form of eqn. (4).

$$t_h^{(k)} = \max\left(t_1^{(k)}, t_2^{(k)}, \ldots, t_n^{(k)}\right), \text{for h} \in \text{A}_\text{i} \tag{4}$$

A model to integrate forgiveness into the Eigen Trust reputation system, which aids in amending the break-down of trust occasioned by unintentional mistakes, was proposed in [73-74]. According to [73], the following four factors should be considered in the forgiveness based model, such as (a) frequency of offence (b) current offence' severity (c) compensation (d) reciprocity of the offender.

Equations (5) and (6) from [73] show expressions for calculating direct trust and normalizing local trust respectively *i* to *j*. .

$$dt_{ij} = \begin{cases} \left(1-\alpha^{s_{ij}}\right).sat(i,j)/tr_{ij}, \; if \; s_{ij} \geq 0 \\ 0 \qquad\qquad\qquad\qquad , \text{ otherwise} \end{cases} \tag{5}$$

where s_{ij} is the local trust of i to j, α = the system parameters

$$c_{ij} = \frac{\max\left(dt_{ij}, 0\right)}{\sum_j \max\left(dt_{ij}, 0\right)} \tag{6}$$

Another trust management issue has to do with peer pollution [43], [129]. That is peers deliberately generating, which results in the degraded network for other peers in the network. The authors in [129] noted that *"video segments might be altered by any peer before being shared"*. It

was further mentioned that *"among existing proposals, reputation-based defence mechanisms are the most effective and practical solutions"*. Meanwhile, the authors in [43] proposed a trust management model given as eqn (7) and the notations are defined in Table 6:

$$T_{i,j}(t) = \alpha_{i,j} D_{i,j}(t) + \left(1 - \alpha_{i,j}\right) I_{i,j}(t) \tag{7}$$

Table 6: Pollution resistant trust management model parameter definition

Notation	Definition
$T_{i,j}(t)$	Trust that user i has on another user j at a time t ,with a value between distrust "0" and complete trust "1"
$D_{i,j}(t)$	Direct trust that user i has on user j at time t ,with a value between distrust "0" and complete trust "1"
$I_{i,j}(t)$	Indirect trust that user i has on user j at time t ,with a value between distrust "0" and complete trust "1"
$\alpha_{i,j}$	User i confidence of its direct trust over user j with value between distrust "0" and complete trust "1"
$s_{i,j}(t)$	Set of peers that have direct transactions with both peer i and peer j
$C_{i,k}(t)$	Credibility of peer k
$R_{\mathrm{k,j}}(t)$	Peer $k's$ recommendation value of user j based on previous interaction and experience

$$D_{i,j}(t) = \mathrm{e}^{-\rho N^{\rho}_{i,j}(t)} \frac{N^{c}_{i,\mathrm{j}}(t)}{N^{c}_{i,\mathrm{j}}(t) + \eta} \tag{8}$$

Note that ρ and η are positive constant, $\rho > In\left(1 + \frac{1}{\eta}\right)$

$$I_{i,j}(t) \square \frac{\sum_{k \in S_{i,j}(t)} C_{i,k}(t) R_{\mathrm{k,j}}(t)}{\sum_{k \in S_{i,j}(t)} C_{i,k}(t)} \tag{9}$$

In [23], the authors noting that optimal peer selection is difficult owing to variations in dynamic and heterogeneous capacities presented a PSO-based strategy for selecting peers. This resulted in decreased query delay and improved security.

The author in [130] thoroughly examined and expounded on numerous aspects relating to data communication, transaction propagation, and the likelihood of an interference attack that created a delay in transmission of a P2P based network. The authors also showed the impact of block size, consensus, and blockchain scalability, as well as the relationship between factors. The authors in [131] examined the use of blockchains among peers where members do not trust one another. Blockchains allow peers to interact with themselves without the use of a trusted intermediary, and in a verifiable manner.

In [132], noted that electronic voting (e-voting) is a time- and cost-effective method of conducting a voting procedure that has the advantages of allowing for large amounts of data in real-time while still requiring a high level of security. However, worries about network security and communication privacy for e-voting have grown. Securing electronic voting is a pressing issue that has become a hot topic in the field of communications and networking. How to use blockchain in a peer-to-peer network to increase e-voting security was shown. For the essential criteria of the e-voting process, a blockchain-based e-voting scheme on a P2P network is presented by combining the following ideas. A blockchain-based e-voting system for numerous candidates was been created on Linux systems in a P2P network to prove and verify the scheme. The implementation result demonstrated that it is a practical and secure e-voting system that addresses the issue of vote forgery during electronic voting. According to the author, the e-voting mechanism built on the blockchain may be immediately used for a number of networking applications.

In [133], the authors considered the issue of the privacy of transactions in Bitcoin P2P. Currently, the identity of the node that originates a communication is usually kept concealed to safeguard user privacy. However, an attacker watching the entire network can use the spread pattern of a transaction to track it back to its source via what is called rumour centrality, which is created by symmetry in the dissemination of gossip-like protocols. The authors further noted that recent research has attempted to address the problem by exploiting proxied broadcast and violating the symmetry of the Diffusion protocol, which is currently utilized in Bitcoin. However, the complexity of their design may make it difficult for them to be adopted in the actual world. Therefore, the authors suggested a transaction relay protocol with a simple yet effective design that secures the source of transaction messages. The approach does not involve the creation of propagation graphs and decreases the adversary's ability to acquire precision by opening many connections to the same node. Experimental data

demonstrated that an eavesdropper adversary's deanonymization accuracy against the proposed scheme was up to ten times lower.

2.8. Coexistence and Convergence of P2P Network and Others

In [65], P2P and cloud computing were studied and, it was noted that both networks are large-scale distributed systems with potential application to *"backup, storage, streaming content distribution, online gaming, etc."* This has however become more cogent because, in recent times, P2P cloud networking is replacing traditional internet services in computing. P2P cloud networking is currently being used to offer resources with scalability to a large number of consumers. The aim and method of providing the service utilizing cloud technology can be used to classify P2P-based cloud systems [134].

In [44], the authors presented information-centric networking for P2P communications as a candidate solution for future internet-based applications. In [64] a P2P cost-effective and performance-enhancing file sharing arrangement that involves a wireless mesh network, in which the network operator makes provision for infrastructures such as mesh router, storage capacity and P2P awareness system was discussed. In addition, the authors determined the optimal number of replicas for each file to obtain minimal costs of files in the network.

Whereas, in [66] a brief overview of P2P networking and application on convergence peer-to-peer context awareness, pointing out that this became necessary because sensors and devices should be designed to offer services based on awareness of the environment and users' intention was presented.

In [68], it was noted that in a ubiquitous environment, an RFID-based sensor system with a P2P network can be quite useful. By merging computing devices with a range of sensors, the authors created a network capable of controlling its processing and network resources. The functioning of the sensor network required context-awareness. Hence, an RFID-based sensing system that uses a peer-to-peer network to receive contextual information about the user was created. The proposed system comprises a reader, 30 sample tags, and a sample middleware application for reading, writing, and testing RFID tags, as well as the fundamental RFID equipment needed to operate and test an RFID system. It could detect users entering and exiting a location, as well as to measure their distance from the device. In addition, it is capable of determining the state of the sensor installation.

Another system that is being converged with P2P is content delivery networks (CDNs), which enhance the user-perceived quality of service owing to their use of servers at the internet edge. CDN providers are tapping into the P2P networks of their users to lower the cost of servers. Examples of peer-assisted CDN include *"BBC iplayer, MSN video, Conviva". Others are "Kankan, Livesky, Akamai NetSession, Spotify, Tudou"* [67], etc. But offering failure recovering in this type of system is challenging, therefore, the authors in [135] developed a CDNpatch, which empowers peers to compute in advance some backup content providers by maintenance algorithm and efficient information exchange at regular intervals as a solution to the aforementioned challenge. Also, the CDNPatch provides an algorithm to minimize the interruption of playbacks.

Meanwhile, in [12], [70], the researchers developed a hybrid system of CDN and P2P, in which the merits of both systems were harnessed to address the routing and resource allocation with emphasis on the economics of content delivery. The CDN/P2P based economic routing was based on an oligopolistic mechanism used in managing the content demand on servers at the internet's edge. Furthermore, the contributions of subscribers are optimized using a truthful profit-maximizing auction. In [67], the authors noted that the future of peer-assisted CDN is challenged owing to copyright issues, low reliability of P2P network, etc. and consequently presented a way of classifying the research efforts in this regard.

The authors in [45] proposed hybrid P2P network architecture for interactive streaming media to solve the disadvantages of interactive streaming media in real-time transmission, control overhead, stability, and scalability in general P2P networks. The system uses a hierarchical structure that combines a CDN, a peer-to-peer network, and a tree-mesh structure. Streaming media data is delivered to the super-nodes tree after a method for super-node selection and super-nodes tree construction is built, reducing the strain on edge servers. Meanwhile, in the case of real-time streaming media transmission, a push-pull approach is used. The edge server provides streaming media data to the asking node, which then pulls the missing streaming media data to the super-nodes tree, improving data transmission in real-time. The system may dramatically reduce end-to-end delay, streaming media distortion, and control overhead when compared to traditional P2P and basic CDN-P2P architectures, according to the simulation.

The general P2P network and cloud computing architecture is different in functionality. But researchers are examining the possibility of fussing cloud computing with peer-to-peer systems [59], [136-137]. A hybrid of these two systems was proposed for multimedia streaming in [136-137]. In [137], a review of cloud-based P2P video streaming articles between 2009 and 2014 was done. However, the authors in [59] discussed papers on applications of P2P networking on the large-scale distributed cooperative environments on cloud and P2P networks. For large and increasingly dynamic web services, centralized servers for registering are not realistic, and efficient. Also, they do not support semantic description.

3. Investigation and Management of Peer-to-Peer Networks

When an offensive file is shared among peers in a network, there may be the need to trace the originator of that file. This is usually not easy owing to the decentralized architecture of the P2P network. However, the attention of researchers has been drawn to forensic investigation of malpractices that could occur. Examples of this include the work reported in [77], where a model to identify the peer who was the first to upload a file in a Chinese community file-sharing network called *Foxy* was proposed. This can aid P2P forensics since the technique used for investigating BitTorrent seeder are inadequate for *Foxy* based on the Gnutella 2 protocol.

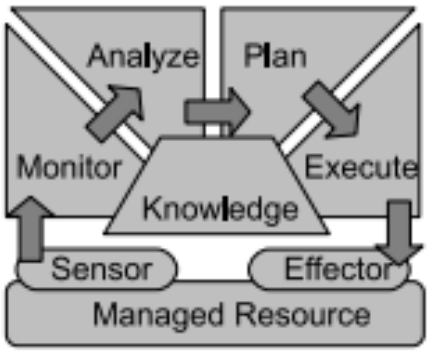

Figure 10: Autonomic Computing

Monitoring and management procedures must be used to control the quality of peer-to-peer systems. In large-scale networks with independent, unstable nodes, both tasks are difficult. A possible solution provides an extensive statistical depiction of the live state of a peer-to-peer network. The Autonomic Computing model is shown in Figure 10. In the event that a quality deviation is recognized, a predefined system state is approached by autonomous system re-configuration using autonomic computing concepts. A good monitoring scheme can prevent possible data loss when data are transferred from one node to another.

The monitoring tool shown in Figure 11 comprises of modified P2P client, a tool for message parsing, a database for archiving information collected, and a database query mechanism. A tool, which is inserted to modify a peer node in the network, shown in Figure 11 was developed in [138]. The node record logs data, timestamps and identification information.

Meanwhile, in [62], the authors developed a system that is capable of identifying P2P nodes operating in a network, through analysis of Net flow data, rather than via analysis of the properties of the content itself. Hence, cooperative communities in the network can be discovered or identified. Detecting cheating in Peer-to-peer based online gaming is challenging due to there being no central server for monitoring. Thus, the authors in [33] proposed a mechanism where players play with their deck, with no intervention from other peers. Features such as player dropout tolerance, usage for a variety of games, collusion prevention among peers were incorporated into the cheating detection mechanism.

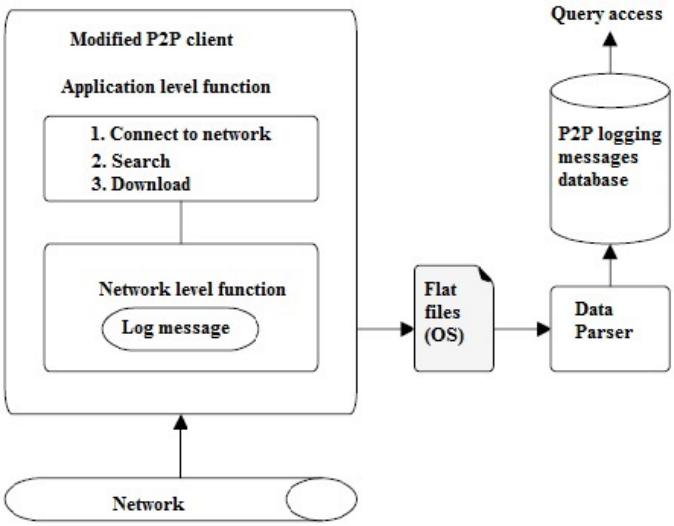

Figure 11: P2P monitor [138]

To optimize data gathering, a "trust-based minimum cost quality-aware" data collection strategy was presented in [139]. In [140], the authors proposed a P2P network-based smart grid model for edge computing, in which P2P networks were used at the edge computing layer. The model's innovation was that edge computing nodes can be utilized to gather, compute, and store data while being P2P connected, allowing them to communicate with one another after data processing. The experimental findings of the algorithm revealed that by utilizing the proposed model, there was a considerable improvement in terms of energy resource management in terms of lowering

economic costs, boosting renewable energy usage, and real-time control capabilities.

Many child sexual abuse (CSA) monitoring tools in peer-to-peer networks depends on hash value databases of identified CSA-built over time via analysis of seized devices of offender media. Hence, new or previously unknown media cannot be detected. Another challenge of monitoring CSA related activities on P2P networks has to do with the sheer large amount of files that have to be monitored. To address these limitations, the authors in [39], [42] reported a filename and media scheme based on multiple features such as video and audio word, that flags unseen or previously unknown CSA media to law enforcement agencies. It was reported that previous approaches use of automatic image content analysis yield a fair rate of detection owing to their reliance on single feature description, and still others used marginally discriminative skin detection techniques. The work on CSA monitoring in the P2P network is part of the iCOP (identifying and catching originators in P2P networks) project, and an overview of the developed toolkit is shown in Figure 12.

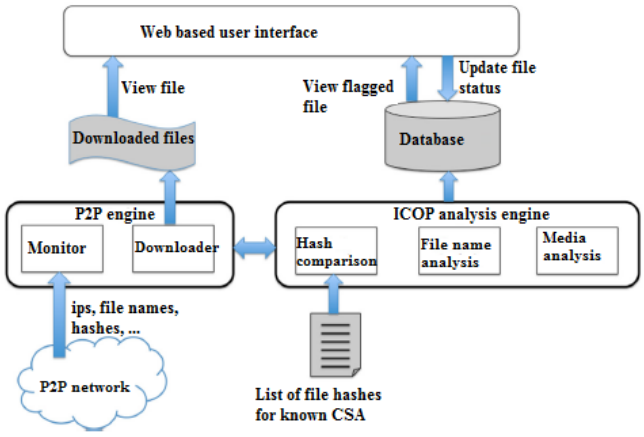

Figure 12: Structure of the iCOP toolkits adapted from [42]

4. Challenges In Peer-to-Peer Applications, Solutions and Future Trend

Whereas P2P networks have made files easily accessible and given a boost to online media streaming of video on demand, some challenges would need to be given greater attention. A pictorial description of identified research direction in P2P research is shown in Figure 13.

For instance, in [24], while highlighting the potential role of P2P network in energy-smart cities, noted the following concomitant security and privacy challenges ensuing:

- ~ Privacy/confidentiality of wireless health services system;
- ~ Privacy and security of ad hoc networks for vehicles, and;
- ~ Development of effective trust models.
- ~ Maintenance of anonymity of transactions in Bitcoin P2P in the face of an adversary, who is watching the entire network can evaluate a transaction's distribution pattern to track it back to its source.

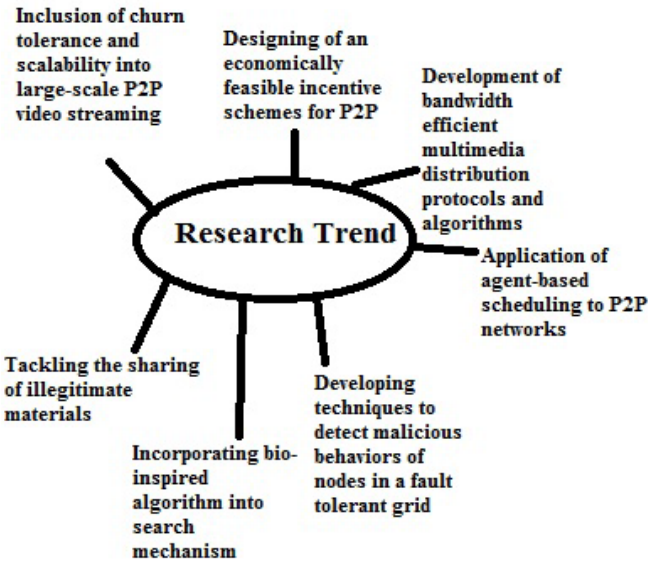

Figure 13: P2P future research trend

Another area of concern is how to prevent attackers from utilising UDP to modify data transported by UDP to attack a P2P network. In addition, the following undesirable problems emanating from peer-to-peer file sharing include [54] (a) violation of copyright laws (b) phishing scams (c) breach of confidentiality in the form of a leak of confidential information, which will need ongoing research to effectively address them.

So far the following countermeasures have been proposed: (a) the use of digital right management (b) digital watermarking of content (c) index poisoning [54]. More applications of these measures to P2P networks are expected in the nearest future.

Conceptually, index poisoning is a methodology that changes the index of illegal files in order to make them unreachable by any unauthorized peer. The shared files that were indexed are distributed over the network in advance. But cost-effectively doing this for an unstructured P2P network was the objective of [54]. In contrast, digital watermarking involves concealing a message related to a digital signal such as image, audio, and video within the signal itself. Although related to steganography, it is different from it in terms of

relatedness of the message being concealed to the actual digital signal [141].

Another area of concern is how to prevent attackers from utilizing UDP to modify data transported by UDP to attack a P2P.

Also, in the future bio-inspired algorithms could be augmented semantic techniques so that search queries are routed to the database, which possesses the most semantically matching search keyword [57]. Moreover, in terms of peer trust management, how do combining peer-trust values with file trust values affect the reputation of the management systems? This is a question that needs further research. In addition, metered access and techniques to observe malicious behaviour of grid's node could be incorporated into future fault-tolerant decentralized scheduling algorithms so as to improve nodes availability [82]. Related to this is an examination to see if attackers may use topological measurements in the P2P network to execute more successful purposeful attacks [53].

In sharing P2P files the issue of bandwidth bottleneck is common, hence, a novel algorithm for searching nodes would need to be developed. In addition, few pieces of research exist on the application of agent-based scheduling to a P2P network. Another related issue here is how to further minimise inter-peer search latency.

Further research should see the inclusion of churn tolerance and scalability into large scale P2P video streaming and the associated optimisation of "selection of supernodes and network interaction efficiency."

In addition, the design of economically feasible incentives for peer-assisted CDNs and unstructured P2P, in general, is still a subject of research.

5. Conclusion

Although, there are review articles on P2P overlay networks and technologies, additional topics such as hybrid P2P networks, modelling of P2P, trust and reputation management concerns, coexistence with other existing networks, and so on have yet to be thoroughly examined. Furthermore, existing reviews were restricted to works published in 2012 or earlier.

In this paper, a survey of current literature in the P2P network and associated emerging issues have been done. This included a state-of-the-art review of hybrid P2P, modelling and design of a peer-to-peer system, trust management issues and so on. In addition, challenges such as security and privacy constraints along with suggested solutions have been highlighted.

Finally, areas for future research have been recommended. These included the development of a more robust privacy and security scheme for P2P. We further, pointed out that copyright violations, phishing frauds and confidentiality breaches will necessitate continued research to successfully handle them.

References

[1] W. Lin, W. Dou, Z. Xu, and J. Chen, "A QoS-aware service discovery method for elastic cloud computing in an unstructured peer-to-peer network," *Concurr. Comput. Pract. Exp.*, vol. 25, no. 13, pp. 1843–1860, 2013. https://doi.org/10.1002/cpe.2993

[2] D. Hughes, J. Walkerdine, G. Coulson, and S. Gibson, "Peer-to-Peer : Is Deviant Behavior the Norm on P2P File- Sharing Networks?," *IEEE Distrib. Syst. Online*, vol. 7, no. 2, pp. 1–11, 2006. https://doi.org/10.1109/MDSO.2006.13

[3] F. Wang and Y. Sun, "Self-organizing Peer-to-peer social networks," *Comput. Intell.*, vol. 24, no. 3, pp. 213–233, 2008. https://doi.org/10.1111/j.1467-8640.2008.00328.x

[4] Q. Hofstätter, "Performance Impacts of Node Failures on a Chord-Based Hierarchical Peer-to-Peer Network," in *Networked Services and Applications - Engineering, Control and Management: 16th EUNICE/IFIP WG 6.6 Workshop*, F. A. Aagesen and S. J. Knapskog, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2010, pp. 256–258. https://doi.org/10.1007/978-3-642-13971-0_25

[5] M. Zhang, E. El Ajaltouni, and A. Boukerche, "A scheduling and load balancing scheme for dynamic P2P-based system," *Concurr. Comput. Pract. Exp.*, vol. 22, no. 10, pp. 1325–1334, 2010. https://doi.org/10.1002/cpe.1578

[6] E. K. Lua, J. Crowcroft, and M. Pias, "A survey and comparison of peer-to-peer overlay network schemes," *IEEE Commun. Surv. Tutorials*, vol. 7, no. 2, pp. 72–93, 2005. https://doi.org/10.1109/COMST.2005.1610546

[7] K. Dhara, Y. Guo, M. Kolberg, and X. Wu, "Overview of Structured Peer-to-Peer Overlay Algorithms," in *Handbook of Peer-to-Peer Networking*, X. Shen, H. Yu, J. Buford, and M. Akon, Eds. Boston, MA: Springer US, 2010, pp. 223–256. https://doi.org/10.1007/978-0-387-09751-0_9

[8] P. Linga, "Indexing in peer-to-peer system," Cornell University, 2007.

[9] A. Malatras, "State-of-the-art survey on P2P overlay networks in pervasive computing environments," *J. Netw. Comput. Appl.*, vol. 55, pp. 1–23, 2015. https://doi.org/10.1016/j.jnca.2015.04.014

[10] S. Ganguly and S. Bhatnagar, "P2P Technology," in *VoIP*, John Wiley & Sons, Ltd, 2008, pp. 87–102. https://doi.org/10.1002/9780470997925.ch7

[11] J. Han, "Distributed hybrid P2P networking systems," *Peer-to-Peer Netw. Appl.*, vol. 8, pp. 555–556, 2015. https://doi.org/10.1007/s12083-014-0298-7

[12] M. Garmehi and M. Analoui, "Envy-Free Resource Allocation and Request Routing in Hybrid CDN–P2P Networks," *J. Netw. Syst. Manag.*, vol. 24, no. 4, pp. 884–915, 2016. https://doi.org/10.1007/s10922-015-9359-3

[13] C. Hammami, I. Jemili, A. Gazdar, and A. Belghith, "Hybrid Live P2P Streaming Protocol," *Procedia Comput. Sci.*, vol. 32, pp. 158–165, 2014. https://doi.org/10.1016/j.procs.2014.05.410

[14] U. Bartlang and J. P. Müller, "A flexible content repository to enable a peer-to-peer-based wiki," *Concurr. Comput. Pract. Exp.*, vol. 22, no. 7, pp. 831–871, 2010. https://doi.org/10.1002/cpe.1465

[15] Y.-H. Chen, E. J.-L. Lu, Y.-T. Chang, and S.-Y. Huang, "RDF-Chord: A hybrid PDMS for P2P systems," *Comput. Stand. Interfaces*, vol. 43, pp. 53–67, 2016. https://doi.org/10.1016/j.csi.2015.08.008

[16] A. Polar, M. Bunruangses, K. Luangxaysanam, S. Mitatha, and P. P. Yupapin, "Overlay Fiber Network Based MNRs for P2P Networks," *Procedia Eng.*, vol. 32, pp. 482–488, 2012. https://doi.org/10.1016/j.proeng.2012.01.1297

[17] M. Amad, A. Meddahi, D. Aïssani, and G. Vanwormhoudt, "GPM: A generic and scalable P2P model that optimizes tree depth for multicast communications," *Int. J. Commun. Syst.*, vol. 25, no. 4, pp. 491–514, 2012. https://doi.org/10.1002/dac.1275

[18] W. Liu, J. Song, and J. Yu, "An Overlapping Structured P2P for REIK Overlay Network," *Physics Procedia*, vol. 33, pp. 1022–1028, 2012. https://doi.org/10.1016/j.phpro.2012.05.168

[19] A. Srivastava and P. Ahmad, "A Probabilistic Gossip-based Secure Protocol for Unstructured P2P Networks," *Procedia Comput. Sci.*, vol. 78, pp. 595–602, 2016. https://doi.org/10.1016/j.procs.2016.02.122

[20] J. Caubet, O. Esparza, J. L. Muñoz, J. Alins, and J. Mata-Díaz, "RIAPPA: A Robust Identity Assignment Protocol for P2P overlays," *Secur. Commun. Networks*, vol. 7, no. 12, pp. 2743–2760, 2014. https://doi.org/10.1002/sec.956

[21] X. Lu and P. Hui, "A Mobile Peer to Peer Content Dissemination Model to Minimize Load on Cellular Network," *2015 International Conference on Identification, Information, and Knowledge in the Internet of Things (IIKI)*. pp. 272–275, 2015. https://doi.org/10.1109/IIKI.2015.65

[22] E. P. Duarte Jr, P. Elias, Z. G. Lisandro, J. N. S. Luci Pirmez, C. A. Rossana, T. Liane, B. C. Reinaldo, and L. Alexandre, "GigaManP2P: An overlay network for distributed QoS management and resilient routing," *Int. J. Netw. Manag.*, vol. 22, no. 1, pp. 50–64, 2012. https://doi.org/10.1002/nem.785

[23] S. M. Nallakannu and R. Thiagarajan, "PSO-based optimal peer selection approach for highly secure and trusted P2P system," *Secur. Commun. Networks*, vol. 9, no. 13, pp. 2186–2199, 2016. https://doi.org/10.1002/sec.1478

[24] H. Li, H. Zhu, B. Jun, and D. Choi, "Guest editorial : Security and privacy of P2P networks in emerging smart city," *Peer-to-Peer Netw. Appl.*, vol. 8, pp. 1023–1024, 2015. https://doi.org/10.1007/s12083-015-0393-4

[25] K. Fuchs, D. Herrmann, A. Micheloni, and H. Federrath, "Laribus : Privacy-preserving detection of fake SSL certificates with a social P2P notary network," *Eurasip J. Inf. Secur.*, vol. 2015, no. 1, pp. 1–17, 2015.

[26] L. Chen, W. S. Soh, and A. Hu, "An improved Kademlia protocol with double-layer design for P2P voice communications," *2014 Communications Security Conference (CSC 2014)*. pp. 1–8, 2014.

[27] R. Pecori, "Trust-based storage in a Kademlia network infected by Sybils," *2015 7th International Conference on New Technologies, Mobility and Security (NTMS)*. pp. 1–5, 2015. https://doi.org/10.1109/NTMS.2015.7266529

[28] G. Tian, Z. Duan, T. Baumeister, and Y. Dong, "Thwarting traceback attack on Freenet," *2013 IEEE Global Communications Conference (GLOBECOM)*. pp. 741–746, 2013. https://doi.org/10.1109/GLOCOM.2013.6831161

[29] G. Tian, Z. Duan, T. Baumeister, and Y. Dong, "A Traceback Attack on Freenet," *IEEE Transactions on Dependable and Secure Computing*, vol. PP, no. 99. p. 1, 2015. https://doi.org/10.1109/TDSC.2015.2453983

[30] S. Roos, F. Platzer, J. M. Heller, and T. Strufe, "Inferring obfuscated values in Freenet," *2015 International Conference and Workshops on Networked Systems (NetSys)*. pp. 1–8, 2015. https://doi.org/10.1109/NetSys.2015.7089062

[31] K. Suto, H. Nishiyama, N. Kato, T. Nakachi, T. Fujii, and A. Takahara, "THUP: A P2P Network Robust to Churn and DoS Attack Based on Bimodal Degree Distribution," *IEEE Journal on Selected Areas in Communications*, vol. 31, no. 9. pp. 247–256, 2013. https://doi.org/10.1109/JSAC.2013.SUP.0513022

[32] F. D. A. López-Fuentes and S. Balleza-Gallegos, "Evaluating Sybil Attacks in P2P Infrastructures for Online Social Networks," *2015 IEEE 17th International Conference on High Performance Computing and Communications, 2015 IEEE 7th International Symposium on Cyberspace Safety and Security, and 2015 IEEE 12th International Conference on Embedded Software and Systems*. pp. 1262–1267, 2015. https://doi.org/10.1109/HPCC-CSS-ICESS.2015.252

[33] M. A. Simplicio, M. A. S. Santos, R. R. Leal, M. A. L. Gomes, and W. A. Goya, "SecureTCG: a lightweight cheating-detection protocol for P2P multiplayer online trading card games," *Secur. Commun. Networks*, vol. 7, no. 12, pp. 2412–2431, 2014. https://doi.org/10.1002/sec.952

[34] K. Deltouzos, I. Gkortsilas, N. Efthymiopoulos, M. Efthymiopoulou, and S. Denazis, "SeekStream: Adapting to dynamic user behavior in P2P video-on-demand," *Int. J. Commun. Syst.*, vol. 29, no. 8, pp. 1365–1394, 2016. https://doi.org/10.1002/dac.3105

[35] M. Mu, J. Ishmael, W. Knowles, M. Rounce, N. Race, and M. Stuart, "P2P-Based IPTV Services : Design, Deployment, and QoE Measurement," *IEEE Trans. Multimed.*, vol. 14, no. 6, pp. 1515–1527, 2012. https://doi.org/10.1109/TMM.2012.2217119

[36] S. Yildirim, M. Sayit, and G. Kardas, "A belief-desire-intention agent architecture for partner selection in peer-to-peer live video streaming applications," *Expert Syst.*, vol. 32, no. 3, pp. 327–343, 2015. https://doi.org/10.1111/exsy.12086

[37] H. R. Ghaeini, B. Akbari, B. Barekatain, and A. Trivino-Cabrera, "Adaptive video protection in large scale peer-to-peer video streaming over mobile wireless mesh networks," *Int. J. Commun. Syst.*, vol. 29, no. 18, pp. 2580–2603, Dec. 2016. https://doi.org/10.1002/dac.3088

[38] H. Luo, W. An, S. Ci, and D. Wu, "A distributed utility-based scheduling for peer-to-peer video streaming over wireless networks," *Wirel. Commun. Mob. Comput.*, vol. 16, no. 12, pp. 1556–1569, 2016. https://doi.org/10.1002/wcm.2614

[39] C. Peersman, C. Schulze, A. Rashid, M. Brennan, and C. Fischer, "iCOP : Automatically Identifying New Child Abuse Media in P2P Networks," In *2014 IEEE Security and Privacy Workshops* (pp. 124-131). IEEE. https://doi.org/10.1109/SPW.2014.27

[40] N. Efthymiopoulos, S. L. Tompros, A. Christakidis, K. Koutsopoulos, and S. Denazis, "Enabling live video streaming services realization in telecommunication networks using P2P technology," *Int. J. Commun. Syst.*, vol. 24, no. 10, pp. 1354–1374, 2011. https://doi.org/10.1002/dac.1250

[41] A. Alasaad, S. Gopalakrishnan, and V. C. M. Leung, "Extending P2PMesh: topology-aware schemes for efficient peer-to-peer data sharing in wireless mesh networks," *Wirel. Commun. Mob. Comput.*, vol. 13, no. 5, pp. 483–499, 2013. https://doi.org/10.1002/wcm.1115

[42] C. Peersman, C. Schulze, A. Rashid, M. Brennan, and C. Fischer, "iCOP: Live forensics to reveal previously unknown criminal media on P2P networks," *Digit. Investig.*, vol. 18, pp. 50–64, 2016. https://doi.org/10.1016/j.diin.2016.07.002

[43] X. Kang and Y. Wu, "Fighting Pollution Attack in Peer-to-Peer Streaming Networks: A Trust Management Approach," in *Information Security and Privacy Research: 27th IFIP TC 11 Information Security and Privacy Conference*, D. Gritzalis, S. Furnell, and M. Theoharidou, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2012, pp. 537–542. https://doi.org/10.1007/978-3-642-30436-1_45

[44] A.-C. G. Anadiotis, C. Z. Patrikakis, and A. Murat Tekalp, "Information-centric networking for multimedia, social and peer-to-peer communications," *Trans. Emerg. Telecommun. Technol.*, vol. 25, no. 4, pp. 383–391, 2014. https://doi.org/10.1002/ett.2814

[45] H. Yang, M. Liu, B. Li and Z. Dong, "A P2P network framework for interactive streaming media", *Proc. 11th Int. Conf. Intell. Hum.-Mach. Syst. Cybern. (IHMSC)*, vol. 2, pp. 288-292, 2019. https://doi.org/10.1109/IHMSC.2019.10162

[46] J. Li, C. Li, Z. Fang, H. Wang, and Y. Wu, "Optimal layer division for low latency in DHT-based hierarchical P2P network," *Int. J. Netw. Manag.*, vol. 26, no. 2, pp. 95–110, 2016. https://doi.org/10.1002/nem.1922

[47] Y. Ma, Z. Tan, G. Chang, and X. Wang, "A New P2P Network Routing Algorithm Based on ISODATA Clustering Topology," *Procedia Eng. Adv. Control Eng. Inf. Sci.*, vol. 15, pp. 2966–2970, 2011. https://doi.org/10.1016/j.proeng.2011.08.558

[48] D. Yang, Y. Zhang, H. Zhang, T.-Y. Wu, and H.-C. Chao, "Multi-factors oriented study of P2P Churn," *Int. J. Commun. Syst.*, vol. 22, no. 9, pp. 1089–1103, 2009. https://doi.org/10.1002/dac.1001

[49] P. Narang, S. Ray, and C. Hota, "PeerShark : Detecting Peer-to-Peer Botnets by Tracking Conversations," In *2014 IEEE Security and Privacy Workshops* (pp. 108-115). IEEE, 2014. https://doi.org/10.1109/SPW.2014.25

[50] K. Althobaiti, S. J. Alotaibi, and H. Alqahtani, "Random walk with jumps: A new query search method based on analysing Gnutella protocol," *2015 World Congress on Internet Security (WorldCIS)*. pp. 125–130, 2015. https://doi.org/10.1109/WorldCIS.2015.7359427

[51] S. Corigliano and P. Trunfio, "Exploiting sleep-and-wake strategies in the Gnutella network," *2014 International Conference on Collaboration Technologies and Systems (CTS)*. pp. 406–412, 2014. https://doi.org/10.1109/CTS.2014.6867596

[52] L. Chen, W. S. Soh, and A. Hu, "An improved Kademlia protocol with double-layer design for P2P voice communications," in *Communications Security Conference (CSC 2014)*, pp. 1–8. https://doi.org/10.1049/cp.2014.0727

[53] Y. Gao, J. Shi, X. Wang, Q. Tan, C. Zhao and Z. Yin, "Topology measurement and analysis on Ethereum P2P network", *Proc. IEEE Symp. Comput. Commun.*, pp. 1-7, 2019. https://doi.org/10.1109/ISCC47284.2019.8969695

[54] Y. Ookita and S. Fujita, "Cost-effective index poisoning scheme for P2P file sharing systems," in 2016 IEEE/ACIS 15th International Conference on Computer and Information Science (ICIS). https://doi.org/10.1109/ICIS.2016.7550732

[55] S. K. Awasthi, and Y. N. Singh, "Simplified Biased Contribution Index (SBCI): A mechanism to make P2P network fair and efficient for resource sharing". Journal of Parallel and Distributed Computing, vol. 124, pp. 106-118, 2019. https://doi.org/10.1016/j.jpdc.2018.10.002

[56] Q. Wang, J. Wang, J. Yu, M. Yu, and Y. Zhang, "Trust-aware query routing in P2P social networks," *Int. J. Commun. Syst.*, vol. 25, no. 10, pp. 1260–1280, 2012. https://doi.org/10.1002/dac.1320

[57] H. A. Kurid, T. S. Alnusairi, and H. S. Almujahed, "OBAME: Optimized Bio-inspired Algorithm to Maximize Search Efficiency in P2P Databases," *Procedia Comput. Sci.*, vol. 21, pp. 60–67, 2013. https://doi.org/10.1016/j.procs.2013.09.010

[58] A. Adala and N. Tabbane, "Discovery of semantic Web Services with an enhanced-Chord-based P2P network," *Int. J. Commun. Syst.*, vol. 23, no. 11, pp. 1353–1365, 2010. https://doi.org/10.1002/dac.1110

[59] L. Ricci, A. Iosup, and R. Prodan, "Large scale distributed cooperative environments on clouds and P2P," *Peer-to-Peer Netw. Appl.*, vol. 9, pp. 1126–1127, 2016. https://doi.org/10.1007/s12083-016-0447-2

[60] A. Boukhadra, K. Benatchba, and A. Balla, "Similarity Flooding for Efficient Distributed Discovery of OWL-S Process Model in P2P Networks," *Procedia Comput. Sci.*, vol. 56, pp. 317–324, 2015. https://doi.org/10.1016/j.procs.2015.07.214

[61] S. Ali, K. Wu, and H. Khan, "Traffic Anomaly Detection in the Presence of P2P Traffic," in *39th Annual IEEE Conference on Local Computer Networks*, 2014, pp. 482–485. https://doi.org/10.1109/LCN.2014.6925822

[62] J. Jusko and M. Rehak, "Identifying peer-to-peer communities in the network by connection graph analysis," *Int. J. Netw. Manag.*, vol. 24, no. 4, pp. 235–252, 2014. https://doi.org/10.1002/nem.1862

[63] H. Hsieh and M. Chiang, "Improvement of the Byzantine Agreement Problem under Mobile P2P Network," *IERI Procedia*, vol. 10, pp. 45–50, 2014. https://doi.org/10.1016/j.ieri.2014.09.089

[64] A. Alasaad, S. Gopalakrishnan, and V. C. M. Leung, "Replication schemes for peer-to-peer content in wireless mesh networks with infrastructure support," *Wirel. Commun. Mob. Comput.*, vol. 15, no. 4, pp. 699–715, 2015. https://doi.org/10.1002/wcm.2376

[65] H. Kavalionak and A. Montresor, "P2P and Cloud : A Marriage of Convenience for Replica Management," In: *Kuipers F.A., Heegaard P.E. (eds) Self-Organizing Systems. IWSOS 2012. Lecture Notes in Computer Science, vol 7166. Springer, Berlin, Heidelberg*, pp. 60–71, 2012.. https://doi.org/10.1007/978-3-642-28583-7_6

[66] S. Jo, G. Kim, and J. Han, "Convergence P2P context awareness," *Peer-to-Peer Netw. Appl.*, vol. 9, pp. 461–464, 2016. https://doi.org/10.1007/s12083-015-0419-y

[67] N. Anjum, D. Karamshuk, M. Shikh-Bahaei, and N. Sastry, "Survey on Peer-assisted Content Delivery Networks," *Comput. Networks*, 2017. https://doi.org/10.1016/j.comnet.2017.02.008

[68] Y. Lee, and J. Cho, "RFID-based sensing system for context information management using P2P network architecture", Peer-to-Peer Networking and Applications, vol. 11, no. 6, pp. 1197-1205, 2018. https://doi.org/10.1007/s12083-018-0636-2

[69] E. Mousavi Khaneghah, S. L. Mirtaheri, M. Sharifi, and B. Minaei Bidgoli, "Modeling and analysis of access transparency and scalability in P2P distributed systems," *Int. J. Commun. Syst.*, vol. 27, no. 10, pp. 2190–2214, 2014. https://doi.org/10.1002/dac.2467

[70] M. Garmehi, M. Analoui, M. Pathan, and R. Buyya, "An economic mechanism for request routing and resource allocation in hybrid CDN–P2P networks," *Int. J. Netw. Manag.*, vol. 25, no. 6, pp. 375–393, 2015. https://doi.org/10.1016/j.csi.2015.08.008

[71] G. Cui, M. Li, Z. Wang, J. Ren, D. Jiao, and J. Ma, "Analysis and evaluation of incentive mechanisms in P2P networks: a spatial evolutionary game theory perspective," *Concurr. Comput. Pract. Exp.*, vol. 27, no. 12, pp. 3044–3064, 2015. https://doi.org/10.1002/cpe.3207

[72] L. Liu, N. Antonopoulos, S. Mackin, J. Xu, and D. Russell, "Efficient resource discovery in self-organized unstructured peer-to-peer networks," *Concurr. Comput. Pract. Exp.*, vol. 21, no. 2, pp. 159–183, 2009. https://doi.org/10.1002/cpe.1329

[73] M. Li, J. Wang, K. Lu, C. Guo, and X. Tan, "A Novel Reputation Management Mechanism with Forgiveness in P2P File Sharing Networks," *Procedia Comput. Sci.*, vol. 94, pp. 360–365, 2016. https://doi.org/10.1016/j.procs.2016.08.055

[74] K. Lu, J. Wang, L. Xie, Q. Zhen, and M. Li, "An EigenTrust-based Hybrid Trust Model in P2P File Sharing Networks," *Procedia Comput. Sci.*, vol. 94, no. Bdstc, pp. 366–371, 2016.

[75] H. Alharbi and A. Hussain, "An Agent-Based Approach for Modelling Peer to Peer Networks," *2015 17th UKSim-AMSS International Conference on Modelling and Simulation (UKSim)*. pp. 532–537, 2015. https://doi.org/10.1109/UKSim.2015.47

[76] C. H. Lin, J. J. Zseng, and S. Y. Hsieh, "Improving the Search Mechanism for Unstructured Peer-to-Peer Networks Using the Statistical Matrix Form," *IEEE Access*, vol. 3. pp. 926–941, 2015. 10.1109/ACCESS.2015.2444872

[77] R. Ieong, P. Lai, K.-P. Chow, F. Law, M. Kwan, and K. Tse, "A Model for Foxy Peer-to-Peer Network Investigations," in *Networked Services and Applications - Engineering, Control and Management: 16th EUNICE/IFIP WG 6.6 Workshop*, G. Peterson and S. Shenoi, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2009, pp. 175–186.

https://doi.org/10.1007/978-3-642-04155-6_13

[78] C. Vélez-Rivera, E. Arzuaga-Cruz, A. A. Irizarry-Rivera, and F. Andrade, "Global data prefetching using BitTorrent for distributed smart grid control," *2016 North American Power Symposium (NAPS)*. pp. 1–6, 2016. https://doi.org/10.1109/NAPS.2016.7747904

[79] P. Kopiczko, W. Mazurczyk, and K. Szczypiorski, "StegTorrent : A Steganographic Method for the P2P File Sharing Service," in *IEEE Security and Privacy Workshops*, 2013. https://doi.org/10.1109/SPW.2013.11

[80] B. Mitra, S. Ghose, N. Ganguly, and F. Peruani, "Stability analysis of peer-to-peer networks against churn," *Pramana*, vol. 71, no. 2, pp. 263–273, 2008. https://doi.org/10.1007/s12043-008-0159-0

[81] S. Huang, E. Izquierdo, and P. Hao, "Adaptive packet scheduling for scalable video streaming with network coding," *J. Vis. Commun. Image Represent.*, vol. 43, pp. 10–20, 2017. https://doi.org/10.1016/j.jvcir.2016.11.014

[82] P. Chauhan, "Fault Tolerant Decentralized Scheduling Algorithm for P2P Grid," vol. 6, pp. 698–707, 2012. https://doi.org/10.1016/j.comnet.2014.12.009

[83] X. Meng and D. Liu, "GeTrust: A guarantee-based trust model in Chord-based P2P networks," *IEEE Transactions on Dependable and Secure Computing*, vol. PP, no. 99. p. 1, 2016. https://doi.org/10.1109/TDSC.2016.2530720

[84] A. Ullah, "mSCTP & P2P (2-layered CHORD) supported decentralized seamless mobility framework," *2015 International Conference on Emerging Technologies (ICET)*. pp. 1–5, 2015. https://doi.org/10.1109/ICET.2015.7389214

[85] Z. M. Ding and Q. Qian, "A chord-based load balancing algorithm for P2P network," *ICINS 2014 - 2014 International Conference on Information and Network Security*. pp. 91–96, 2014. https://doi.org/10.1049/cp.2014.1271

[86] J. Skodzik, P. Danielis, V. Altmann, and D. Timmermann, "HaRTKad: A hard real-time Kademlia approach," *2014 IEEE 11th Consumer Communications and Networking Conference (CCNC)*. pp. 309–314, 2014. https://doi.org/10.1109/CCNC.2014.6866588

[87] H. Y. Lee and A. Nakao, "Approaches for Practical BitTorrent Traffic Control," in *38th Annual IEEE Conference on Local Computer Networks Approaches*, 2013, pp. 382–389. https://doi.org/10.1109/LCN.2013.6761270

[88] S. Neuner, M. Schmiedecker, and E. R. Weippl, "PeekaTorrent : Leveraging P2P hash values for digital forensics," *Digit. Investig.*, vol. 18, pp. S149–S156, 2016. https://doi.org/10.1016/j.diin.2016.04.011

[89] S. Heymann and B. L. Grand, "Monitoring user-system interactions through graph-based intrinsic dynamics analysis," *IEEE 7th International Conference on Research Challenges in Information Science (RCIS)*. pp. 1–10, 2013. https://doi.org/10.1109/RCIS.2013.6577695

[90] I. Roy, B. Gupta, B. Rekabdar, and H. Hexmoor, "A Novel approach toward designing a non-DHT Based Structured P2P network architecture", in *Proceedings of 32nd International Conference on*, vol. 63, pp. 182-188, 2020.

[91] D. Fukuchi, C. Sommer, Y. Sei, and S. Honiden, "Distributed Arrays: A P2P Data Structure for Efficient Logical Arrays," *IEEE INFOCOM 2009*. pp. 1458–1466, 2009. https://doi.org/10.1109/INFCOM.2009.5062062

[92] F. D. A. López-fuentes, I. Eugui-de-alba, and O. M. Ortíz-ruiz, "Evaluating P2P Networks against Eclipse Attacks," *Procedia Technology*, vol. 3, pp. 61–68, 2012. https://doi.org/10.1016/j.protcy.2012.03.007

[93] I. Hwang and A. T. Liem, "A Hybrid Scalable Peer-to-Peer IP-Based Multimedia Services Architecture in Ethernet Passive Optical Networks," *J. Light. Technol.*, vol. 31, no. 2, pp. 213–222, 2013. https://doi.org/10.1109/JLT.2012.2227941

[94] D. Germanus, H. Ismail, and N. Suri, "PASS: An Address Space Slicing Framework for P2P Eclipse Attack Mitigation," *2015 IEEE 34th Symposium on Reliable Distributed Systems (SRDS)*. pp. 74–83, 2015. https://doi.org/10.1109/SRDS.2015.14

[95] M. Kellett, T. Tran, and M. Li, "Trust by association: A meta-reputation system for peer-to-peer networks," *Comput. Intell.*, vol. 27, no. 3, pp. 363–392, 2011. https://doi.org/10.1111/j.1467-8640.2011.00388.x

[96] W. Liu, P. Ren, D. Sun, K. Liu, and J. Wu, "TrustP2PNet: P2P Social Network with Admission Control Model based on Trust," *AASRI Procedia*, vol. 5, pp. 281–286, 2013. https://doi.org/10.1016/j.aasri.2013.10.090

[97] L. Yan, C. Zhuo, and Z. Hua, "Improving Sharing Efficiency in Online Short Video System through Using P2P Based Mechanism," *Procedia Engineering*, vol. 29, pp. 3207–3211, 2012. https://doi.org/10.1016/j.proeng.2012.01.467

[98] P. Liu, G. Huang, J. Cheng, S. Feng, and J. Fan, "Fibonacci Ring Overlay Networks with Distributed Chunk Storage for P2P VoD Streaming," *Procedia Comput. Sci.*, vol. 9, pp. 1354–1362, 2012. https://doi.org/10.1016/j.procs.2012.04.149

[99] F. Song, W. Gao, G. Zhang, D. Gao, and H. Jiang, "A P2P Based Video on Demand System for Embedded Linux," *Procedia Eng.*, vol. 29, pp. 3070–3074, 2012. https://doi.org/10.1016/j.proeng.2012.01.442

[100] S. Datta and H. Kargupta, "A communication efficient probabilistic algorithm for mining frequent itemsets from a peer-to-peer network," *Stat. Anal. Data Min.*, vol. 2, no. 1, pp. 48–69, 2009. https://doi.org/10.1002/sam.10033

[101] K. Pal, M. C. Govil, and M. Ahmed, "Slack time–based scheduling scheme for live video streaming in P2P network", International Journal of Communication Systems, vol. 31, no. 2, e3440, 2018. https://doi.org/10.1002/dac.3440

[102] M. Picone, M. Amoretti, and F. Zanichelli, "An Evaluation Criterion for Adaptive Neighbor Selection in Heterogeneous Peer-to-Peer Networks," pp. 144–156, 2009. https://doi.org/10.1007/978-3-642-04994-1_12

[103] H. Guo, J. Liu, and Z. Wang, "Frequency-Aware Indexing for Peer-to-Peer On-Demand Video Streaming," *2010 IEEE International Conference on Communications*. pp. 1–5, 2010. https://doi.org/10.1109/ICC.2010.5502373

[104] R. S. Cruz and M. S. Nunes, "A P2P streaming architecture supporting scalable media," *Peer-to-Peer Netw. Appl.*, vol. 8, no. 5, pp. 758–776, 2015. https://doi.org/10.1007/s12083-014-0284-0

[105] Y. Liu, J. Liu, J. Song, and A. Argyriou, "Scalable 3D video streaming over P2P networks with playback length changeable chunk segmentation," *J. Vis. Commun. Image Represent.*, vol. 31, pp. 41–53, 2015. https://doi.org/10.1016/j.jvcir.2015.05.012

[106] U. Cuajimalpa, "P2P Video Streaming Strategies based on Scalable Video Coding," *J. Appl. Res. Technol.*, vol. 13, no. 1, pp. 113–124.

[107] F. A. Lopez-Fuentes, "P2P video streaming strategies based on scalable video coding," *J. Appl. Res. Technol.*, vol. 13, no. Feb., pp. 113–124, 2014.

[108] M. S. Raheel, R. Raad, and C. Ritz, "Achieving maximum utilization of peer's upload capacity in p2p networks using SVC," *Peer-to-Peer Netw. Appl.*, pp. 1–21, 2015. https://doi.org/10.1007/s12083-015-0406-3

[109] M. R. Haque, R. Ahmed, and R. Boutaba, "QPM: Phonetic aware P2P search," *2009 IEEE Ninth International Conference on Peer-to-Peer Computing*. pp. 131–134, 2009. https://doi.org/10.1109/P2P.2009.5284536

[110] D. Talia and P. Trunfio, "Dynamic Querying in Structured Peer-to-Peer Networks," in *Managing Large-Scale Service Deployment: 19th IFIP/IEEE International Workshop on Distributed Systems: Operations and Management*, F. De Turck, W. Kellerer, and G. Kormentzas, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2008, pp. 28–41.

https://doi.org/10.1007/978-3-540-87353-2_3
[111] A. Arunachalam and O. Sornil, "Issues of Implementing Random Walk and Gossip Based Resource Discovery Protocols in P2P MANETs & Suggestions for Improvement," *Procedia Comput. Sci.*, vol. 57, pp. 509–518, 2015. https://doi.org/10.1016/j.procs.2015.07.374
[112] J. Loganathan, Logitha, and A. Veronica, "Distributed resource management scheme using enhanced artificial bee-colony in P2P," *2015 2nd International Conference on Electronics and Communication Systems (ICECS)*. pp. 1035–1039, 2015. https://doi.org/10.1109/ECS.2015.7124737
[113] R. Julius, M. Wichtlhuber, P. Heise, and D. Hausheer, "vINCENT : An Incentive Scheme Supporting Heterogeneity in Peer-to-Peer Content Distribution," in *39th Annual IEEE Conference on Local Computer Networks*, pp. 19–27, 2014. https://doi.org/10.1109/LCN.2014.6925752
[114] K. Lu, S. Wang, G. Cui, M. Li, and H. Liaqat, "Multi-reciprocity Policies Co-evolution Based Incentive Evaluating Framework for Mobile P2P Systems," *IEEE ACCESS*, vol. 5, pp. 3313 - 3321, 2016. https://doi.org/10.1109/ACCESS.2016.2630736
[115] G. Goth and T. Commission, "ISP Traffic Management: Will Innovation or Regulation Ensure Fairness?," *IEEE Distributed Systems Online*, vol. 9, no. 9, pp. 1–4, 2008. https://doi.org/10.1109/MDSO.2008.27
[116] H. Zhi-jie, W. Ru-chuan, and D. Xiao-yang, "A Novel P2P traffic Prediction Algorithm Based on Hybrid Model," *Phys. Procedia*, vol. 25, no. 1, pp. 1218–1225, 2012. https://doi.org/10.1016/j.phpro.2012.03.223
[117] I. Dedinski, H. DeMeer, L. Han, L. Mathy, D. P. Pezaros, J. S. Sventek, and X. Y. Zhan, "Cross-Layer Peer-to-Peer Traffic Identification and Optimization Based on Active Networking," in *Active and Programmable Networks: IFIP TC6 7th International Working Conference*, D. Hutchison, S. Denazis, L. Lefevre, and G. J. Minden, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2009, pp. 13–27. https://doi.org/10.1007/978-3-642-00972-3_2
[118] C.-H. Hsu, C.-G. Hsu, S.-C. Chen, and T.-L. Chen, "Message transmission techniques for low traffic P2P services," *Int. J. Commun. Syst.*, vol. 22, no. 9, pp. 1105–1122, 2009. https://doi.org/10.1002/dac.1010
[119] Z. Li and Q. Liao, "Network pricing: can both ISP and P2P benefit?," *Int. J. Netw. Manag.*, vol. 24, no. 6, pp. 433–449, 2014. https://doi.org/10.1002/nem.1869
[120] R. Casadesus-Masanell and A. Hervas-Drane, "Peer-to-Peer File Sharing and the Market for Digital Information Goods," *J. Econ. Manag. Strateg.*, vol. 19, no. 2, pp. 333–373, 2010. https://doi.org/10.1111/j.1530-9134.2010.00254.x
[121] J. Yimu, Y. Yongge, Z. Chuanxin, J. Chenchen, and W. RuChuan, "Research of a Novel Flash P2P Network Traffic Prediction Algorithm," *Procedia Comput. Sci.*, vol. 55, pp. 1293–1301, 2015. https://doi.org/10.1016/j.procs.2015.07.140
[122] C. Rossow, D. Andriesse, T. Werner, and F. Fkie, "SoK : P2PWNED — Modeling and Evaluating the Resilience of Peer-to-Peer Botnets," in *IEEE Symposium on Security and Privacy*, 2013. https://doi.org/10.1109/SP.2013.17
[123] N. Z. M. Safar, N. Abdullah, H. Kamaludin, S. Abd Ishak, and M. R. M. Isa, "Characterising and detection of botnet in P2P network for UDP protocol" *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 18, no. 3, pp. 1584-1595, 2020. https://doi.org/10.11591/ijeecs.v18.i3
[124] J.-S. Hua, S.-M. Huang, D. C. Yen, and C.-W. Chena, "A dynamic game theory approach to solve the free riding problem in the peer-to-peer networks," *J. Simul.*, vol. 6, no. 1, pp. 43–55, 2012. https://doi.org/10.1057/jos.2011.11
[125] X. Kang and J. Yang, "Viewing experience optimization for peer-to-peer streaming networks with credit-based incentive mechanisms," *Comput. Networks*, vol. 114, pp. 67–79, Feb. 2017. https://doi.org/10.1016/j.comnet.2017.01.005
[126] Z. Wang, C. Wu, L. Sun, and S. Yang, "Strategies of collaboration in multi-swarm peer-to-peer content distribution," *Tsinghua Sci. Technol.*, vol. 17, no. 1, pp. 29–39, 2012. https://doi.org/10.1109/TST.2012.6151905
[127] Z. Yulan and J. Chunfeng, "Research of Trust Model in P2P File-Sharing System," *Procedia Environ. Sci.*, vol. 12, pp. 1208–1212, 2012. https://doi.org/10.1016/j.proenv.2012.01.409
[128] H. A. Kurdi, "HonestPeer : An enhanced EigenTrust algorithm for reputation management in P2P systems," *J. King Saud Univ. - Comput. Inf. Sci.*, vol. 27, no. 3, pp. 315–322, 2015. https://doi.org/10.1016/j.jksuci.2014.10.002
[129] M. Tauhiduzzaman and M. Wang, "Fighting pollution attacks in P2P streaming," *Comput. Networks*, vol. 79, pp. 39–52, 2015.
[130] S. Rahmadika, S. Noh, K. Lee, B. J. Kweka, and K. H. Rhee, "The dilemma of parameterizing propagation time in blockchain P2P network". Journal of Information Processing Systems, vol. 16 no. 3, pp. 699-717, 2020. https://doi.org/10.3745/JIPS.03.0140
[131] K. Christidis and M. Devetsikiotis, "Blockchains and Smart Contracts for the Internet of Things," IEEE Access, vol. 4, pp. 2294–2303, 2016. 10.1109/ACCESS.2016.2566339
[132] H. Yi . "Securing e-voting based on blockchain in P2P network". EURASIP Journal on Wireless Communications and Networking, vol. 1, pp. 1-9, 2019. https://doi.org/10.1186/s13638-019-1473-6
[133] F. Franzoni, and V. Daza, "Clover: An anonymous transaction relay protocol for the bitcoin P2P network", Peer-to-Peer Networking and Applications, vol. 15, no.1, pp. 290-303, 2022. https://doi.org/10.1007/s12083-021-01241-z
[134] S. Jo, and J. Han, "Convergence P2P cloud computing". Peer-to-Peer Networking and Applications, vol. 11, no. 6, pp. 1153-1155, 2018. https://doi.org/10.1007/s12083-018-0661-1
[135] C.-C. Wang and Y.-D. Lin, "CDNPatch: A cost-effective failover mechanism for hybrid CDN-P2P live streaming systems," *Int. J. Commun. Syst.*, vol. 29, no. 17, pp. 2517–2533, 2016.
[136] N. Thomas, M. Thomas, and K. Chandrasekaran, "Multimedia Streaming using Cloud-Based P2P Systems," *Procedia Comput. Sci.*, vol. 57, no. Icrtc, pp. 25–32, 2015. https://doi.org/10.1002/dac.3193
[137] N. Wahidah, B. Ab, K. Jenni, S. Mandala, and E. Supriyanto, "Review On Cloud Computing Application In P2P Video Streaming," *Procedia - Procedia Comput. Sci.*, vol. 50, pp. 185–190, 2015. https://doi.org/10.1016/j.procs.2015.04.082
[138] T. Myneedu and Y. Guan, "Evidence Collection in Peer-to-Peer Network Investigations," in *Advances in Digital Forensics VIII: 8th IFIP WG 11.9 International Conference on Digital Forensics*, G. Peterson and S. Shenoi, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2012, pp. 215–230. https://doi.org/10.1007/978-3-642-33962-2_15
[139] Y. Ren, Z. Zeng, T. Wang, S. Zhang, and G. Zhi, "A trust-based minimum cost and quality aware data collection scheme in P2P network". *Peer-to-Peer Networking and Applications*, vol. 13, no. 6, pp. 2300-2323, 2020. https://doi.org/10.1007/s12083-020-00898-2
[140] W. Hou, Y. Jiang, W. Lei, A. Xu, H. Wen, and S. Chen, "A P2P network based edge computing smart grid model for efficient resources coordination". *Peer-to-Peer Networking and Applications*, vol. 13 , no. 3, pp. 1026-1037, 2020. https://doi.org/10.1007/s12083-019-00870-9
[141] M. Averkiou, "Digital Watermarking." *Department of Computer Science University of Cyprus*

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Analytical Framework to Minimize the Latency in Tele-herbal Healthcare Service

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ABSTRACT: Telemedicine is using telecommunications and IT and other ICT tools to widen healthcare services to remote rural areas. ICT global coverage, multicasting ability, and the high capacity of satellites in GEO can be served as an instrument to widen and enhance the high quality of healthcare service to remote rural areas. Long end-to-end latency could be attributed to the GEO satellites that demean the performance of data communications that can lead to underutilization of the high available capacity due to high link errors and the long latency. The real latency of GEO satellites could be 200ms or above, which can leads to capacity utilization as lower as 37% with a maximum of 458kbps obtainable capacity of the test from LAUTECH Ogbomoso (service provider). The TCP performance can be enhanced through the adoption of other necessary transmission protocols for testing and investigating any possible modifications to improve the performance over the satellite and hybrid channels network. TCP performances largely depend on its loss recovery. To minimize latency, the network must have the necessary resources to provide quality communication within the shortest latency times to perform its required real-time transmission. To transmit from node to node it needs a minimum of 3123.2 1KB and a maximum of 5683.2 1KB packets to go from each connection.

KEYWORDS: Analytical framework, Healthcare service, Herbal medication, Latency, Packet loss, Telediagnosis, Tele-herbal, Transmission

1. Introduction

With the technological advancement, to develop converged broadband network, there is a need to have enhanced the NGNs and advanced multimedia services, the potential has been increased for the delivering of various e-Health services to the end-users "anywhere and anytime". E-health can be regarded as the application of ICT tools in delivering healthcare services to patients at a distance [1]. There are varieties of e-health services currently in existence, this includes health information networks, EHR, telemedicine services, wearable and portable systems that communicate with health portals, and other ICT-based tools (used for disease prevention, diagnosis, treatment, health monitoring, and lifestyle management). As Nigeria population is increasing rapidly, it has been projected by year 2030 the population will rise from 200 million to 250 million. It has lower healthcare practitioners that can meet the needs of the populace; hence most healthcare professional has traveled to other countries for better pay. Most Nigerians live in rural areas with health challenges, such as malaria, tuberculosis, HIV, and other related diseases. Some Nigerians living in less populated areas with no access to medical care due to the lack of medical facilities may not benefit from telediagnosis as a result of connectivity. But those living in urban areas are digitally connected and have advanced healthcare. There are policies made by the government to improve the standard of living of the population in both urban and rural areas to make the necessary infrastructure for healthcare services [2].

Telemedicine will be very helpful to the healthcare services to the people of Nigeria as it has the potential to aid the delivery of quality medical care to remote rural areas if properly implemented. For the tele-herbal services, the use of modern technology such as IT to extend access to high quality herbal medical care and

offered improved healthcare services with aid of remote diagnosing, treatment, and accessibility of patient information to remote areas in reducing the distance and barriers cost [3]. To increase the physical data rate, share the common network infrastructure and network virtualization, there is a need to consider the 3GPP or other modern technology device to support the network slicing and reliable communication [4].

2. Related works

In 2005, the WHA resolution was hopeful that countries will take the advantage of potential offered through e-health application to strengthen the health systems which led to the inauguration of the TTF in the workshop held in Brussels in 2006 with the mandate to develop a comprehensive representation of telemedicine opportunities to Africa countries through modern technology [5]. The Nigeria government swung into action by the formation of a telemedicine unit under the NASRDA so that the unit can make use of NigComSAT 1 to perform tele-surgery from selected hospitals across Nigeria with services from experts in various teaching hospitals across the six geographical regions shown Figure 1 [6].

The NigComSAT 1 and other ICT tools could have a serious impact on healthcare services but implementing telemedicine in Nigeria is faced with challenges with ICT tools (such as internet accessibility, and electricity supply) especially in the rural areas. Though the initiatives and research are at infant stages and insufficient to solve Nigeria's medical care problems. Hence there is a need to be complemented with herbal medication using the WAVA principle as shown in Figures 2 [7].

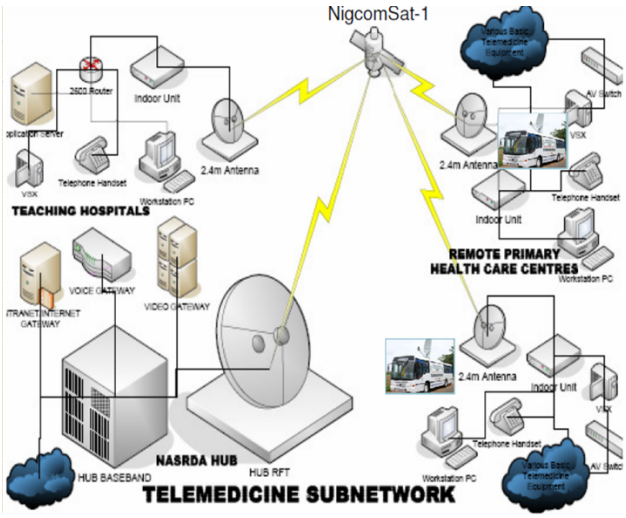

Figure 1: NigComSAT 1 Telemedicine Network [6]

There are different modalities in which telemedicine allows real-time interaction in a video conference environment this includes the necessary pieces of equipment for both audio and video capturing and reproduction with other connected link other related equipment through the ISDN or IP. The quality of Video and audio will depend on the success of a video conference [8]. In a collaborative telediagnosis, sharing of images of the scars and adaption can be transmitted across to client stations to monitor the scar excision to ascertain the removal of the cells of cancer or not. This study aimed at adapting to the changing the initial needs, to emerging needs, and changes in contexts in conformity with the current technologies [9]

Allowing tele-consultants to share data with others on a remote diagnosis of patients, the tele-consultants need a high level of information available to validate the required result. WAVA adaptation determines the specific devices to be used while the server determines and reports the best quality or capacity of data needed to meet the requirements of the devices. More so, the quality of the resolution and compression rate can be determined on the adaptation of the encoding type used [10]. For proper telediagnosis, there must be Videoconferencing equipment at both sites connected utilizing broadband lines to facilitate the treatment of patients [11]. These sites are connected with the use of ISDN lines with the combination of both local and remote web applications. This enables seamless integration of the necessary medical equipment stationed at the patient's location for easy diagnosing [12, 13]. VAGABOND was designed to familiarize the practitioners and network levels with the possible binomial probability needed to trigger the practitioner's adaptations. Therefore, probabilities are calculated based on the retained video packets and those received [14].

A Wi-Fi-based mask-type laryngoscope was designed to complement the effort of medical personnel during the COVID-19 pandemic in order to minimize and reduce the chances of contamination and spread of the disease to the medical field. There is a tendency for the disease to infect other medical facilities during the spread. Thus, there is a need for the operator and patient separation to avoid further spreading of the disease this led to the instructions to wear the mask remotely using the Smartphone app. If there is an emergence, practitioners waiting outside the room can interrupt the procedure and ensure the patient's safety. In this Wi-Fi-based contactless mask endoscopy system, the delay in video streaming can be evaluated by comparing the frame rate and image over direct Wi-Fi connectivity [15].

For telemedicine modalities to be effective in facilitating real-time communication of remote healthcare information there should be an integrated optical-wireless based network to provide high super broadband, ultra-low-latency connection link for data, voice, video,

and image transmission through the network. Mobility services enable efficiencies in telediagnosis workflows in the healthcare environment which is critical to provide cost-effective and efficacious care to patients. Secure mobile networking requires using industry-standard security protocols, which control authentication, heighten data encryption, minimize latency, and support roaming among access points, and voice is more sensitive to latency and loss than other kinds of data traffic [16].

Therefore, for a telediagnosis in a tele-herbal environment, latency is one of the issues that cannot be ignored and it cannot be avoided due to transmission delay. It is a significant problem to get ethical realism with such delays. To avoid high packet loss, international communication regulations need to put into consideration that the packet loss rate should not exceed 5.0% through network transmission [17].

3. Methodology

3.1. Analytical framework for telediagnosis in tele-herbal environment

To achieve this, an analytical framework was designed to enhance the tele-herbal consultant's connectivity in Figure 2.

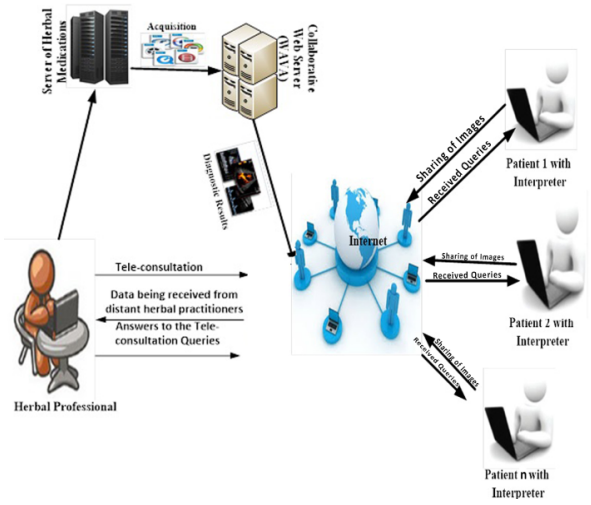

Figure 2: Framework to minimize the latency in Tele-herbal healthcare Service [7]

However, it was assumed that the tele-herbal consultants have different types of connections to the e-herbal health service stations either through (internet or Wi-Fi or 3G), and other terminals with different capabilities. For efficient multimedia service delivery over a multi-access network converged, the core IP networks and 3GPPs need to evolved and probes into the packet system, as a result representing a milestone development of standard for mobile broadband industry. Thus, the tele-herbal consultants can receive same data from the adapted result by means of WAVA, that adapt the web service and distribute the recorded video conference to other consultants during telediagnosis (n1, n2, n3…nN) connected to the server.

The sequence diagram, Figure 3 explained how the objects in the analytical framework interact with each other. The objects identified in the framework are the patients and tele-herbal consultants using the designed interface.

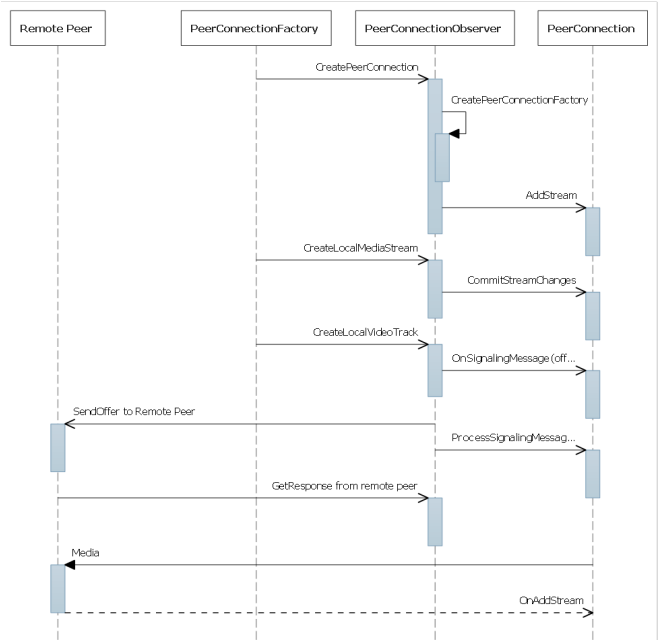

Figure 3: Sequence Diagram of Collaborative WAVA based Herbal telediagnosis

3.2. Quality of service Requirements for E-Herbal Services

The quality of service for a given VoIP call needs to be maintained even if the call is being delivered to a wired or wireless endpoint. E-herbal quality of services is expressed and classified in table 1. The quality of service depends on the services received by the patients from the tele-herbal consultants. End-to-end delay and jitter have to be minimized for VoIP packets to provide optimal audio quality and videoconferencing services. In an e-health organization, maintaining a high quality of service is very necessary to establish priority across the WLAN during data transmission.

Table 1: Quality of service requirements for e-herbal services

Application Type	**Throughput**	**Delay**	**Jitter**
Telediagnosis	Very High	Yes	No
Teleconsultation	High	Yes	Yes
Telemonitoring	Very Low	No	No

Tele-education	High	No	No
Access to HER	Low	No	No

3.3. Packet loss during tele-herbal transmission: problems, causes, and solutions

Table 2 shows the lists and other factors that may be considered when practicing tele-herbal services.

Table 2: Requirement for tele-herbal service

Factor	**Discussion**
Cost	Direct (hardware equipments, software packages) and Indirect (staffing, storage space)
Distance	Time zones and downtime (Nearness to site to avoid failure)
Education	Tele-herbal consultants expectations and acceptable diagnosis
Network	Firewalls, Bandwidth limitation, and security
Computers	well-matched hardware equipments with up-to-date OS and antiviral software
Maintenance	Update support, IT/IS maintenance staffs, and 24 hours availability of herbs
Images	Pictorial images of patient diseases, test carried out, and storage
Metadata	Accessing patient information and previous diagnosis
Workflow	Handling diagnosis for prescription
Regulations	Validation, , billing and QA measures
Medico-legal	malpractice coverage, Credentialing, and licensing
Human	Lack of enthusiasm by tele-herbal consultant, training, and monitoring performance

3.4. Research Questions

i. What causes latency in tele-herbal services?
ii. What is the maximum average latency in telediagnosis?
iii. What are the problems associated with packet loss?
iv. Why do packets go missing?
v. What are the solutions to these packet losses?

The solution to the questions above:

i. Latency in tele-herbal healthcare service can occur as a result of transmission media, packet size, packet loss and jitter, signal strength, propagation delays, malfunction of computer devices, or storage delays.
ii. For enhanced network connectivity, the normal latency of the connecting device transmitting data, voice, or video among the tele-herbal consultants should be between 5 and 40 ms when using a cable Modem but if the distance is far then expect the latency to be higher.
iii. The problems associated with packet loss during tele-herbal consultation are a result of slow loading times, closed connections, loading interruptions, missing information, or out-of-date information in real-time situations.
iv. The packets that go missing during tele-herbal services as a result of network congestion, hardware capacity, bottlenecks, damaged hardware, network virus (bugs), or wireless networks (Wi-Fi) are open to some unpredictable elements.
v. The solutions or remedies to packet losses during tele-herbal services are checking connections, using a cable connection, restarting routers and other hardware, replacing defective and inefficient hardware, and keeping network device software up-to-date.

3.5. Mathematical Model Description

A model was formed to compute the packet loss and total latency. The response time between the tele-herbal healthcare stations and the server can be affected as a result of the physical distance between them. Total latency comprises of communications and network latency. Therefore, service latency is the total time it takes data to travel from one tele-herbal healthcare station to the server and vice versa. Large data were generated during the transmission as a result of traffic and workload can leads to high network latency.

Let assume,

$i = \{i1, i2 \ldots .ii' \ldots .ij\}$ consists of nodes that produce a set of data, $d = \{d1, d2 \ldots \ldots, di' \ldots dj\}$ generate the workload $w = \{w1, w2 \ldots wi' \ldots wj\}$ on the servers and denoted as $f = \{f1, f2 \ldots fi' \ldots fk\}$

$$Li, j' = ln * Hi, j' \quad (1)$$

Ln is the unit delay, H *(i, j')* count from *Li* to *Fj'*.

Li, j' represents communication or service latency. *P (k, j')* represent computing latency and *N(i, j')* represent network latency that depend on the gateways. The total latency can be defined as

$$Li, j', k = Li, j' + P(k, j') + N(i, j') \quad (2)$$

The end-to-end video delay was assumed by the users as the sum of the communication delays incurred in the real-time (for video encoding, segmentation, capturing, and transmission). *TCES* represents (video capturing, encoding, and segmentation) delay at the sender, *TN* (transmission delay between the sender and receiver), *TS* represent server processing time, while *TD* is for segmentation time. Therefore,

$$T = TCES + TN + TS + TD \quad (3)$$

To have the general idea about the latency induced using the analysis with the TCP protocol; realistic tests are performed with aid of the Internet between five working stations behind proxies and firewalls and located in five NODES with high-quality bandwidths capacities.

Packet Loss from Latency Evaluation

The time required to transmit audio or video signal is called latency or media link delay. Preferably, latency can be closed to zero as possible in any transmitting network. Network latency is computed as:

Propagation time = (Frame Serialization Time) + (Link Media delay) + (Queuing Delay) + (Node Processing Delay if known). Latency is the same as link media delay

It will be dangerous if the quality of packet loss is greater than 5.0%. The probing packets are computed as::

$$X_n = \begin{cases} 1, packet\ lost\ with\ probabilty\ p \\ 0, packet\ received\ with\ probability\ 1-p \end{cases} \quad (4)$$

$$X_N = \frac{(X_1 + X_2 + \cdots X_N)}{N} \quad (5)$$

X_N is packet loss rate for the 5 NODES

4. Results and Discussion

Table 3: Packet loss Analysis for NODE1 in 21 days

Day	Packet Sent	Packet Delivered	Lost packet	Loss %	Available %
1	21242	20251	991	4.67	95.33
2	20156	19427	729	3.62	96.38
3	21641	21048	593	2.74	97.26
4	21755	21117	638	2.93	97.07
5	22295	21597	698	3.13	96.87
6	21204	20547	657	3.10	96.90
7	22904	22347	557	2.43	97.57
8	23582	22607	975	4.13	95.87
9	22620	21634	986	4.36	95.64
10	23465	22622	843	3.59	96.41
11	23198	22551	647	2.79	97.21
12	20137	19193	944	4.69	95.31
13	21627	20816	811	3.75	96.25
14	22654	21936	718	3.17	96.83
15	20245	19363	882	4.36	95.64
16	23402	22857	545	2.33	97.67
17	24989	24208	781	3.13	96.87
18	20344	19426	918	4.51	95.49
19	23923	23277	646	2.70	97.30
20	23737	22882	855	3.60	96.40
21	24986	24252	734	2.94	97.06

Table 4: Packet loss Analysis for NODE2 in 21 days

Day	Packet Sent	Packet Delivered	Lost Packet	Loss %	Available %
1	23006	22346	660	2.87	97.13
2	24486	23799	687	2.81	97.19
3	24454	23561	893	3.65	96.35
4	24095	23365	730	3.03	96.97
5	21632	20916	716	3.31	96.69
6	23285	22586	699	3.00	97.00
7	24093	23227	866	3.59	96.41

8	20497	19726	771	3.76	96.24
9	24050	23468	582	2.42	97.58
10	23556	22810	746	3.17	96.83
11	20766	19786	980	4.72	95.28
12	20294	19696	598	2.95	97.05
13	21024	20501	523	2.49	97.51
14	21026	20419	607	2.89	97.11
15	23759	23240	519	2.18	97.82
16	22713	22060	653	2.88	97.12
17	22553	21707	846	3.75	96.25
18	20349	19415	934	4.59	95.41
19	21388	20840	548	2.56	97.44
20	24853	24336	517	2.08	97.92
21	22912	22204	708	3.09	96.91

Table 5: Packet loss Analysis for NODE3 in 21 days

Day	Packet Sent	Packet Delivered	Lost Packet	Loss %	Available %
1	22801	21952	849	3.72	96.28
2	21446	20792	654	3.05	96.95
3	23459	22869	590	2.52	97.48
4	21339	20520	819	3.84	96.16
5	21477	20940	537	2.50	97.50
6	23352	22646	706	3.02	96.98
7	23260	22452	808	3.47	96.53
8	23578	22639	939	3.98	96.02
9-	22985	22017	968	4.21	95.79
10	20623	19815	808	3.92	96.08
11	23381	22844	537	2.30	97.70
12	23052	22209	843	3.66	96.34
13	23557	22759	798	3.39	96.61
14	24277	23593	684	2.82	97.18
15	21434	20435	999	4.66	95.34
16	22367	21739	628	2.81	97.19
17	22020	21031	989	4.49	95.51
18	22786	22162	624	2.74	97.26
19	23519	22570	949	4.04	95.96
20	22799	22010	789	3.46	96.54
21	23216	22485	731	3.15	96.85

Table 6: Packet loss Analysis for NODE4 in 21 days

Day	Packet Sent	Packet Delivered	Lost Packet	Loss %	Available %
1	20883	20122	761	3.64	96.36
2	20565	19621	944	4.59	95.41
3	21769	20793	976	4.48	95.52
4	23987	23425	562	2.34	97.66
5	23635	22836	799	3.38	96.62
6	23456	22730	726	3.10	96.90
7	20893	20204	689	3.30	96.70
8	23847	22901	946	3.97	96.03
9	22757	21773	984	4.32	95.68
10	23914	23163	751	3.14	96.86
11	20116	19293	823	4.09	95.91

12	20005	19087	918	4.59	95.41
13	22337	21620	717	3.21	96.79
14	24451	23667	784	3.21	96.79
15	24266	23709	557	2.30	97.70
16	22243	21668	575	2.59	97.41
17	21248	20322	926	4.36	95.64
18	24907	24025	882	3.54	96.46
19	20521	19717	804	3.92	96.08
20	21733	20785	948	4.36	95.64
21	24027	23209	818	3.40	96.60

Table 7: Packet loss Analysis for NODE5 in 21 days

Day	Packet Sent	Packet Delivered	Lost Packet	Loss %	Available %
1	24622	24006	616	2.50	97.50
2	23208	22649	559	2.41	97.59
3	23951	23258	693	2.89	97.11
4	22135	21525	610	2.76	97.24
5	23222	22468	754	3.25	96.75
6	20127	19501	626	3.11	96.89
7	20234	19717	517	2.56	97.44
8	22838	22072	766	3.35	96.65
9	21181	20183	998	4.71	95.29
10	24282	23354	928	3.82	96.18
11	24497	23656	841	3.43	96.57
12	24415	23524	891	3.65	96.35
13	22698	21947	751	3.31	96.69
14	22610	21807	803	3.55	96.45
15	20567	19687	880	4.28	95.72
16	20448	19750	698	3.41	96.59
17	23066	22166	900	3.90	96.10
18	24295	23565	730	3.00	97.00
19	21011	20076	935	4.45	95.55
20	23632	22664	968	4.10	95.90
21	24910	24375	535	2.15	97.85

Table 8: Packet Loss Rate Analysis for the 5 NODES in 21 days

Days	NODE1 %	NODE2 %	NODE3 %	NODE4 %	NODE5 %
1	4.67	2.87	3.72	3.64	2.50
2	3.62	2.81	3.05	4.59	2.41
3	2.74	3.65	2.52	4.48	2.89
4	2.93	3.03	3.84	2.34	2.76
5	3.13	3.31	2.5	3.38	3.25
6	3.1	3	3.02	3.1	3.11
7	2.43	3.59	3.47	3.3	2.56
8	4.13	3.76	3.98	3.97	3.35
9	4.36	2.42	4.21	4.32	4.71
10	3.59	3.17	3.92	3.14	3.82
11	2.79	4.72	2.3	4.09	3.43
12	4.69	2.95	3.66	4.59	3.65
13	3.75	2.49	3.39	3.21	3.31
14	3.17	2.89	2.82	3.21	3.55
15	4.36	2.18	4.66	2.3	4.28
16	2.33	2.88	2.81	2.59	3.41

17	3.13	3.75	4.49	4.36	3.9
18	4.51	4.59	2.74	3.54	3
19	2.7	2.56	4.04	3.92	4.45
20	3.6	2.08	3.46	4.36	4.1
21	2.94	3.09	3.15	3.4	2.15

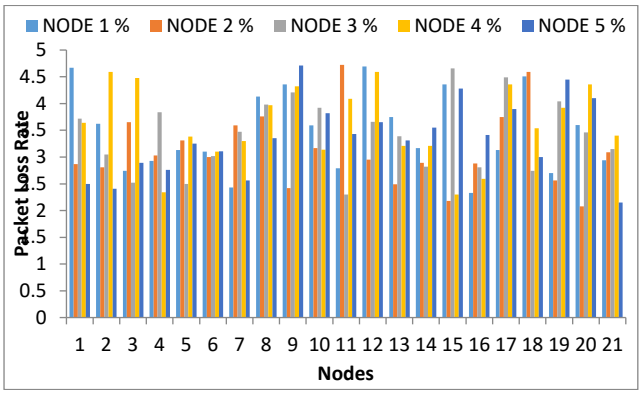

Figure 4: Bar graph for Packet Loss Rate Analysis for the 5 NODES table 8

Table 9: Packet Loss at each NODE

Nodes	Loss rate %
NODE1	3.461
NODE2	3.133
NODE3	3.417
NODE4	3.611
NODE5	3.362

X_N is the actual packet loss rate for N = 5 (as in table 8 above)

$\frac{3.461+3.133+3.417+3.611`+3.362}{5}$ =3.397% average packet loss.

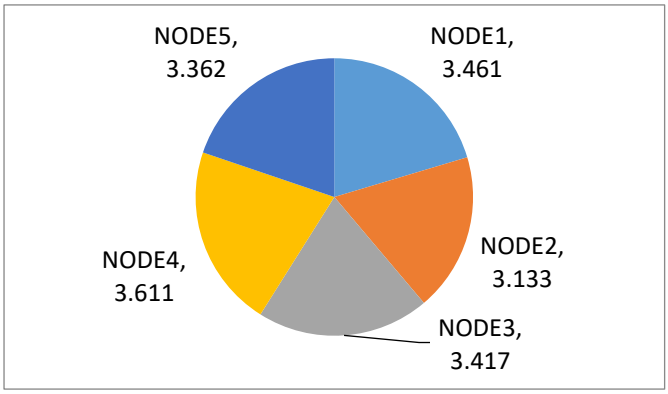

Figure 5: Pie graph for Packet Loss at each NODE table 9

Table 10: Packet Transmitted at each Node

No	NO	NO	NO	NO	NO
1	5120	4096	4096	1024	5120
2	3072	1024	2048	6144	2048
3	5120	3072	3072	2048	3072
4	1024	7168	6144	5120	4096
5	1024	6144	8192	3072	3072
6	2048	9216	5120	6144	1024
7	5120	4096	3072	5120	1024
8	3072	8192	6144	4096	4096
9	4096	2048	9216	7168	5120
10	5120	2048	7168	7168	3072
11	5120	8192	1024	3072	3072
12	2048	7168	7168	6144	4096
13	3072	8192	8192	3072	7168
14	1024	6144	5120	5120	7168
15	2048	2048	6144	4096	3072
16	3072	5120	1024	3072	7168
17	3072	4096	5120	3072	5120
18	2048	6144	8192	6144	6144
19	4096	3072	1024	5120	3072
20	2048	3072	7168	3072	7168

Table 11: Average Packet transmitted at each node

Node	Packet
NODE1	3123.2
NODE2	5017.6
NODE3	5683.2
NODE4	4454.4
NODE5	4249.6

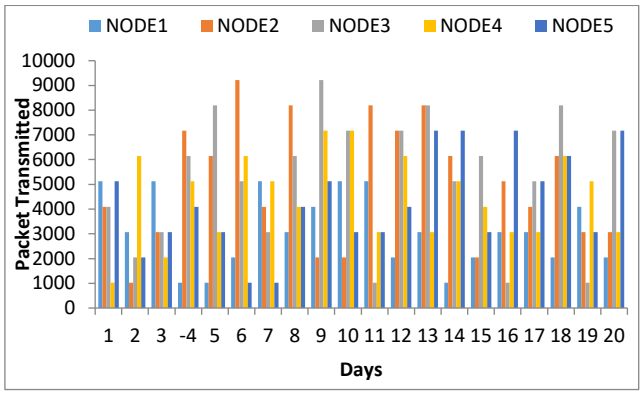

Figure 6: Bar graph for Packet Transmitted at each Node table 10

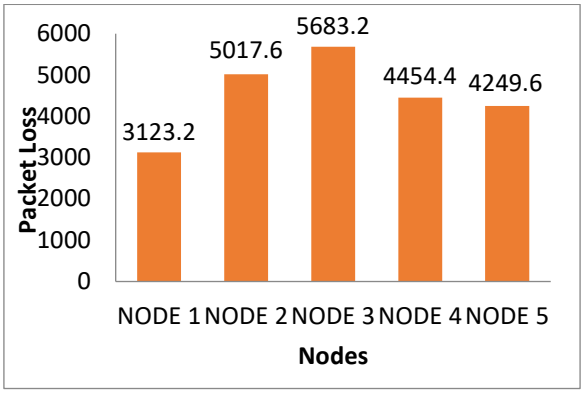

Figure 7: Bar graph for Average Packet transmitted at each node table11

Table 12: Frame Serialization Time

Node	Packet	S
NODE1	3123.2	0.0003904
NODE2	5017.6	0.0006272
NODE3	5683.2	0.0007104
NODE4	4454.4	0.0005568
N-ODE5	4249.6	0.0005312

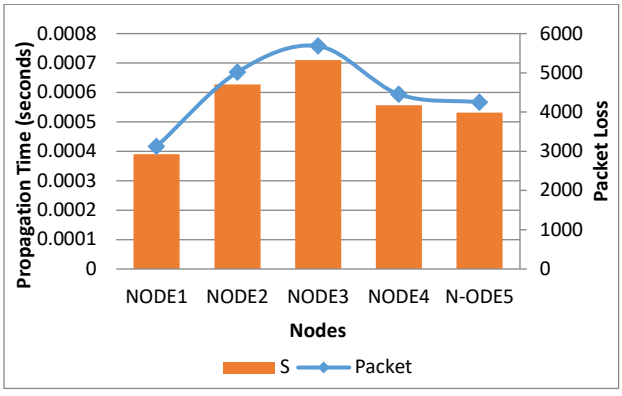

Figure 8: Bar graph for Frame Serialization time showing propagation time table 12

Propagation Time at NODE1

Link Media Delay = 0.04 second

Queuing Delay = 0.0 [assume no congestion]

Node Processing Delay = 0.0 [No delay]

Propagation Time at NODE1 = 0.0003904+ 0.0400000 + 0.0 + 0.0

= 0.0403904 seconds for 3123 1KB packets pass through network

NODE1 through Connection Channel 1

Propagation Time at NODE2

Link Media Delay = 0.04 seconds]

Queuing Delay = 0.0 [assume no congestion]

Node Processing Delay = 0.0 [No delay]

Propagation Time at NODE2 = 0.0006272 + 0.0400000 + 0.0 + 0.0

= 0.04006272 seconds

= 40.6 milliseconds for 5017 1KB packets pass through network

NODE2 through Connection Channel 2

Propagation Time at NODE3

Link Media Delay = 0.04 seconds

Queuing Delay = 0.0 [No congestion]

Node Processing Delay = 0.0 [No delay]

Propagation Time at NODE3 = 0.0007104+ 0.04 + 0.0 + 0.0

= 0.0407104 seconds

= 40.7milliseconds for 5683 1KB packets pass through network

NODE3 through Connection Channel 3

Propagation Time at NODE4

Link Media Delay = 0.04 seconds

Queuing Delay = 0.0 [No congestion]

Node Processing Delay = 0.0 [No delay]

Propagation Time at NODE4 = 0.0005568+ 0.0400000 + 0.0 + 0.0

= 0.0405568 seconds

= 40.6 milliseconds for 4454 1KB packets pass through network

NODE4 through Connection Channel 4

Propagation Time at NODE5

Link Media Delay = 0.04 seconds

Queuing Delay = 0.0 [No congestion]

Node Processing Delay = 0.0 [No delay]

Propagation Time at NODE5 = 0.0005312+ 0.0400000 + 0.0 + 0.0

= 0.0405312 seconds

= 40.5 milliseconds for 4249 1KB packets to pass through network

NODE5 to go through Connection Channel 5

Table 3 through 7 shows the analysis of packet loss from the five NODES in 21 days. Table 8 shows the detailed packet loss rate analysis from the five nodes in 21 days. Table 9 show the packet loss rate in conformity with the claims of [10] Precisions quality of images loss during transmission and this confirms [9] collaborative applications which allow tele-herbal consultants to share data among others as shown in table 10. The analysis in table 11 show average packets transmitted at each node is at minimal in conformity with the international communication rules and regulation that says that packet loss rate should not exceed 5% table 9. Table 12 shows the computational propagation time at each node that ranges from 3123 1KB to 5683 1KB packets among the five NODES with a maximum of 40.6 milliseconds during the transmission of packets. Figures 4 through 8shows the graphical representation of tables 8 though 12 that shows the major analysis of the packet losses in the 5 nodes and serial propagation time.

5. Conclusion

The analytical framework is an innovative model in which the tele-herbal centers will handle videoconferencing data exchange in heterogeneous systems involving multiple NODES with different bandwidths and computation capacities. The framework was designed as a model for the application of telediagnosis for the tele-herbal to provide alternative healthcare services to the patient at a remote distance. To avoid packet loss, an analysis was conducted among the sites (nodes) for 21 days. This is done by comparing the total packet sent and the packet delivered during the transmission which is the difference between percentage packet loss and available bits after the transmission. The devices used by herbal healthcare generate a large volume of data. Therefore, the processing can lead to delay in services provided to other teleconsultants in this telediagnosis environment. To minimize the high latency between tele-herbal consultants and servers, a framework was designed to reduce packet loss during data transmission. This framework's main goal is to help tele-herbal consultants in their medical diagnosis of patients using the analytical framework to minimize the latency in telediagnosis. To have low-latency networks during transmission, it is very important to determine how and where latency occurs and what methods can apply to reduce it. This paper investigated how the delay accumulates from the transmission of patents data among tele-consultants and sending packets, the trade-off between latency and other network performance indexes tele-herbal consultants with an enhanced hardwire and smart devices to reduce traffic offloading to the receivers. Therefore, for quality communication necessary network resources must be available shorten latency time.

Abbreviations

3GPP	Third Generation Partnership Project
EHR	Electronic Health Record
GEO	Geostationary Earth Orbit
ICT	Information Communication Technology
IP	Internet Protocol
ISDN	Integrated Services Digital Network
IT	Information Technology
ITU	International Telecommunication Union
LIS	Laboratory Information System
NASRDA	National Airspace Research and Development Agency
NGNs	Next Generation Networks
OS	Operating System
RTO	Retransmission Timeout
RTP	Real-Time Protocol
RTT	Round Trip Time

TCP	Transmission Control Protocol
UPS	Uninterrupted Power Supply
VAGABOND	Video Adaptation GAteways, Based ON transcoDing
WAVA	Web Services Automatic Video Adaptation
WHA	World Health Assembly
WHO	World Health Organisation
WLAN	Wireless Local Area Network

Conflict of Interest

The authors declare no conflict of interest.

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References

[1] Lea Skorin-Kapov and MajaMatijasevic. Analysis of QoS Requirements for e-Health Services and Mapping to Evolved Packet System QoS Classes. International Journal of Telemedicine and Applications Volume 2010. doi:10.1155/2010/628086

[2] United Nations. "World Population Prospects: Key Findings and Advance Tables". The 2017 Revision, Department of Economic and Social Affairs, Population Division, Working Paper No. ESA/P/WP/248, 2017.

[3] Ogirima, S.A.O, Arulogun, O.T. Baale, A.A. and Oyeleye, C. A. (2021b). Perception of herbal practitioners on the application of modern technology to healthcare delivery in Nigeria. Informatics in Medicine Unlocked. http://www.elsevier.com/locate/imu

[4] AdlenKsentini, Pantelis A. Frangoudis, Amogh PC, and NavidNikaei. Providing low latency guarantees for slicing-ready 5G systems via two-level MAC scheduling. EURECOM Sophia Antipolis

[5] Anas A. Bisu, Andrew Gallant, Hongjian Sun, Katharine Brigham, and Alan Purvis, Telemedicine via Satellite: Improving Access to Healthcare for Remote Rural Communities in Africa978-1-5386-5051-6/18/$31.00 c 2018 IEEE

[6] James, K. G., Odimayomi, P. K., and Shaba, A. H. Telemedicine Development in Nigeria". National Space Research and Development Agency, Abuja, Nigeria.

[7] Ogirima, S. A. O. Collaborative and Adaptive Framework for Telediagnosis and Prescription in Herbal Medicine.", A Ph.D. Thesis in Partial fulfillment of the requirement for the award of Doctor of Philosophy (Ph.D.) Degree in Computer Science, Department of Computer Science and Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria pp. 1-227, 2018.

[8] Claudio, M. A. de Ol. L., Alexandra, M. V. M., Érica, B. R., Silvia, M. P., Leandro, S. X. da S., and Mário, J. J. Videoconferences. Systematization and Experiments in Telemedicine. Radiol Bras 2007; 40(5):pp341–344.

[9] Kassab, K., Jean-Christophe, L., Jean-Baptiste, A., Franck, M. and Christian, P. Scars collaborative telediagnosis platform using adaptive image flow. https://hal.archives-ouvertes.fr/hal-00790426 pp 1-12

[10] Sanchez-Santana, M., Jean-Baptiste, A., Betbeder, M. and Lapayre J. A tool for telediagnosis of cardiovascular disease in a Collaborative and Adaptive Approach. Journal of Universal Computer Science, 19: 1275-1294

[11] Lai, J. C. K., Woo J., Hui, E., and Chan, W. M. Telerehabilitation -- a new model for community-based stroke rehabilitation. Journal of Telemedicine and Telecare, 10: 199- 205.

[12] Wiborg, A.M.D. and Widder, B.M.D.P. for the TSG. (2003). Teleneurology to provide Stroke Care in Rural areas. The Telemedicine in Stroke in Swabia (TESS) Project. Stroke; 34: 2951-2956.

[13] Reinhard-Langmann, H. H., Harald, J., Sergio, D. C. O., Zoe, G. V., Amilcar, B. G., Maria, T. and Mijares, P.2011). TeleMedSys – Web-based Telemedical System for rural Areas", REV 2011 - www.rev-conference.org 4: 1-4

[14] Ronnie, M. P., Jean-Christophe L., and Eric G. (2017). Development of an Adaptive Videoconferencing Framework for Collaborative Telemedicine. International Conference On Computer Supported Cooperative Work in Design, Apr 2017, Wellington, New Zealand. Hal-02991559.

[15] Moon Y, Hyun J, Oh J, Lee K, Lee YS, Kim JK A. Wi-Fi–Based Mask-Type Laryngoscope for Telediagnosis during the COVID-19 Pandemic: Instrument Validation Study. Journal of Medical Internet Research 23(10):e31224 doi: 10.2196/31224 https://www.jmir.org/2021/10/e31224 PMID: 34518154.

[16] Chowdhury, A., Chien, H-K., Khire, S., Fan, S-H., Jayant, N., and Chang, G-K. Converged Broadband Optical and Wireless Communication Infrastructure for Next-Generation Telehealth. 978-1-4244-6376-3/10/$26.00 ©2010 IEEE.

[17] International Telecommunication Union, ITU: committed to connecting the world. Available at: http://www.itu.int/en/Pages/default.aspx (accessed 2 July 2016)

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Comparative Analysis of *Curcuma longa* Rhizome and *Tectona grandis* Leaves Extracts as Green Indicators versus some Synthetic Indictors in Acid-Base Titration

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ABSTRACT: The work considered comparative analysis of CRI (*Curcuma longa* rhizome extract indicator) and TLI (*Tectona grandis* leaves extract indicator) as green indicators versus some synthetic indicators in acid – base titration involving HCl-NaOH, CH_3COOH-NaOH, CH_3COOH -NH_4OH, and HCl-NH_4OH. The codes used were SA (strong acid), SB (strong base), WA (weak acid) and WB (weak base). 10 mL of the base with three drops of the CRI, TLI, MO (methyl orange), and PL (phenolphthalein) were used. Prior to the titrations, the extracts of *Curcuma longa* rhizome and *Tectona grandis* leaves were tested for their colours in acidic and basic media. Also, the UV-visible absorptions of the extracts were determined. There were sharp colours of yellow (for CRI) and red (for TLI) in acid and brown (for CRI) and black (for TLI) in base media. Meanwhile, CRI absorbed (absorbance of 0.83-0.85) substantially at 400-450 nm, but gave lesser absorption at 500-800 nm with absorbance of 0.55-0.24. On the other hand, TLI was found with higher absorbance (0.09) at 400 nm and lesser absorption (absorbance ~0.04) at 720 nm. The titre values of 10.95±0.95 mL (SA-SB), 13.75±0.15 mL (WA-SB), 2.15±0.15 mL (WA-WB), 1.85±0.05 mL (SA-WB) and 11.70±0.3 mL (SA-SB), 13.45±0.45 mL (WA-SB), 2.15±0.05 mL (WA-WB), 2.20±0 mL (SA-WB) were obtained for CRI and TLI, respectively. The results matched with the values 12.25±0.15 mL (SA-SB), 13.90±0.7 mL (WA-SB), 2.10±0.2 mL (WA-WB), and 3.00±0.6 mL (SA-WB) of PL and MO, respectively. It will be beneficial to us to replace the use of MO and PL as indicators with CRI and TLI, because these green indicators are more benign and also effective. This will facilitate the eradication of toxicity accruing from synthetic indicators, MO and PL. In the future, we are looking out to determining the pKa and stability of these natural indicators.

KEYWORDS: Green acid-base indicators, Synthetic indicators, Toxicity, *Curcuma longa*, *Tectona grandis*

1. Introduction

This There is dearth of basic science teaching materials in most undeveloped worlds because of high cost of such reagents and chemicals. Thus, it has become imperative that ardent scientists look out for possible improvisation of science teaching materials and reagents so as to maintain science knowledge dissemination for overall growth and development of mankind [1]. Furthermore, the natural resources, plants are ever thought to be vast and viable reservoir from which human can derived arrays of feedstock in addition to food for numerous in institutions of human facet. In such a manner, the overdependence on petroleum (a finite resource) for myriads of raw materials for our industries and allied purposes can be substantially shifted to renewable source. In view of this, there has been high quantum of surge about sourcing/ deriving chemicals from plant-based origin [2–9]. More recently, Green Chemistry has also underscored the need for sustainable development, which partly provides the use of benign and renewable materials instead petrochemicals [10]. In a nutshell, the derivation of

products from biomass entails overall reduction in environmental pollution for better wellbeing of humanity.

Now, one important classical reagent used in acid-base titrations is indicator. Indicators are usually added in small quantity to a solution to determine the acidity or alkalinity of the solutions [11]. Most of the pH indicators are weak organic acids or bases, which have tendency to accept or donate electrons. They are supposed to exhibit distinct coloration in acid, base, or neutral medium. In that way they will be effective for the detection of end point in acid-base titration [1,11]. Unfortunately, nowadays commonly used indicators are expensive and shows some toxic and hazardous effect [12 - 13]. Thus, we need to look out for indicators from natural sources in order to avoid unwanted deleterious effects of synthetic indicators. In fact, commonly used synthetic indicators have some harmful effects which are oftentimes ignored. For example, a commonly used indicator phenolphthalein has carcinogenic properties which may cause ovarian cancer. Methyl orange causes local skin destruction or dermatitis. Also, the repeated exposure of the methyl orange will impart lung damage and also eye irritation. Methyl red is capable of causing cancer and neurological disorder. Therefore, these indicate the harmful effects of the synthetic indicators to human, and the environment in general. More so, because of these unwanted and toxic effects of synthetic indicators, there has been high advocacy for natural/ green acid-base indicators [12]. These natural indicators should be easily available, easy to prepare, simple to extract out, less toxic, inexpensive, and eco-friendly [12 - 13]. Again, coloured flower/ plants have potentials as natural indicators due to the presence of anthocyanin, quinine, flavones, flavonoid etc [12]. Besides, intense/sharp colour is desirable so that very little quantity of indicator is used; the volume of the indicator itself should not affect the pH of the solution [11 - 12].

Therefore, natural fruits, vegetable, and flower indicators; apple skin, beets, blueberries, cabbage (red), cherries, cranberries, red or purple grapes, onions red, peaches, plums, radish skin, rhubarb skin, strawberries, tomato leaves, turnip skin dahlias, daylilies, geraniums, hibiscus, hollyhocks, hydrangeas, blue iris, morning glories, mums (purple), pansies, peonies, petunias, poppies, roses (red, pink), violets etc [14] have come onboard. Turmeric has also been demonstrated in the past as natural indicator. Main indicator characteristic compound of turmeric is curcumin. In acidic solution (pH < 7.4) it turns yellow, whereas in basic (pH >8.6) solution it shows bright red [13]. Other constituent present are volatile oils including turmerone, atlantone and zingiberone, sugars, proteins, and resins [13]. In [15], *Euphorbia mili, Erythrina varigata,* and *Nelumbo nucifera* methanolic and aqueous extract were positively used as acid-base indicator in titrations [15]. These green indicators were attested to be a very useful, economical, simple, accurate, and eco-friendly [15]. According to the results obtained from acid-base titrimetric analysis with plant (*Tagetes Erecta, Impatiens Balsamina,* and *Tecoma stans*) indicators, the tire values of these green indicators were insignificantly different from the synthetic counterparts [12]. However, rosa double delight flower did not give colour change for neither SA-SB nor WA-WB titration [12]. Other plants too, such as; daffodils, daisies, dandelions, marigolds, and mums (yellow) do not effectively give indicator properties [14]. In the titration of 0.1 M HCl – 0.1 M NaOH; 24.75±0.16 mL, 24.60 ± 0.32 mL, 24.70 ±0.23 mL, 24.55 ±0.21 mL, 24.65±0.18 mL, 24.60±0.17 mL, and 24.70±0.14 mL titre values were obtained for Bougainvillea, Oleander, Flamboyant, Chinese rose, Pumpkin, Dutchman's pipe, and phenolphthalein, respectively [1]. In this study we report comparative analysis of CRI (*Curcuma longa* rhizome extract indicator) and TLI (*Tectona grandis* leaves extract indicator) as natural/ green indicators versus some synthetic indicators in acid-base titration. The results have importance in teaching of chemistry and science at large. It would also facilitate teachers' interest toward improvisation of teaching / learning material and learners' capacity for solving problems.

2. Materials and Methods

2.1. Materials/ Apparatus/ Reagents

100 mL beakers, mortar and pestle, measuring cylinder, 50 mL burette, 20 mL pipette, 100 mL conical flask, 1000 mL volumetric flask, funnel, white tile, clamp. Distilled water, 0.1 M hydrochloric acid, 0.1 M acetic acid, 0.1 M sodium hydroxide, 0.1 M ammonium hydroxide, UV-1800 Shimadzu UV-Visible spectrophotometer.

In addition, 5.748 mL (CH_3COOH), 5.86 mL (NH_4OH), and 8.7 6 mL (HCl) were separately transferred into 1000 mL volumetric flask and enough distilled water was added to mark to give a stock solution of 0.1 M CH_3COOH, 0.1 M NH_4OH, and 0.1 M HCl, respectively. Whereas 0.1 M NaOH was prepared by dissolving 4 g of NaOH pellets in 500 mL beaker using distilled water and was transferred in 1000 mL volumetric flask and enough distilled water was added to mark.

2.2. Methods

2.2.1. Sample Collection and Identification

Curcuma longa (turmeric) rhizome and *Tectona grandis* (teak) (see Figure 1 below) were collected from Makurdi municipal area of Benue State -Nigeria. The samples were subsequently identified by Mr. J. I. Wenga of the Dept. Biological Science, Benue State University, Makurdi - Nigeria.

Figure 1: Curcuma longa rhizome and Tectona grandis leaves

2.2.2. *Sample Preparation and Extraction*

About 30 g of the *Curcuma longa rhizome* and *Tectona grandis* leaves were washed and rinsed with distilled water to remove dirt. The rhizome of *Curcuma longa* and *Tectona grandis* leaves were separately triturated in mortar and about 5 g each transferred into 100 mL beakers. 20 mL of distilled water was added into each sample and left for 4 h for effective extraction. Thereafter, the mixture was filtered using whatman filter paper No.41 and the filtrates then collected into indicator bottles for the research work as similarly reported [1, 13].

2.2.3. *Titration Procedure*

0.1 M acid was titrated against 10 mL 0.1 M base using 3 drops of the indicator (synthetic and natural). Different acid-base combinations (HCl/NaOH, CH_3COOH/NaOH, CH_3COOH/NH_4OH and HCl/NH_4OH) were adopted.

3. Results and Discussion

3.1. *Colour Results for CRI and TLI in different Media*

The extracts from *Curcuma longa* rhizome and *Tectona grandis* leaves were found to show different colours in acidic and basic solutions. The products, CRI gave different sharp colours in acid (yellow) and base (brown). Whereas, TLI produced black colour in base and red colour in acid (see Figure 2). This then become a potential as previously demonstrated, for their ability as indicators in acid-base titration.

In [15], it was observed that many natural products around us like turmeric, mangosteen skin, and purple cabbage can be used as indicator of acid and base because these materials give a different color in acid, alkali, and neutral media. In addition, the UV-visible absorptions of the extracts were carried out between 300-800 nm. Higher absorption of UV-visible radiation for the CRI was found at 400-450 nm with absorbance of 0.83-0.85 and less absorption was found at 500-800 nm with absorbance of 0.55-0.24. For TLI, the λmax for the TLI was found at 400 nm with absorbance of 0.09 and lesser absorption was found at 720 nm with absorbance slightly above 0.04. Compounds that can absorbed in this region of the UV-visible radiation are conjugated and aromatic compounds. Hence, curcumin, flavonoids, flavonols, anthocyanins, quinines, quinones, and carotene are likely present in these extracts as previously established [12].

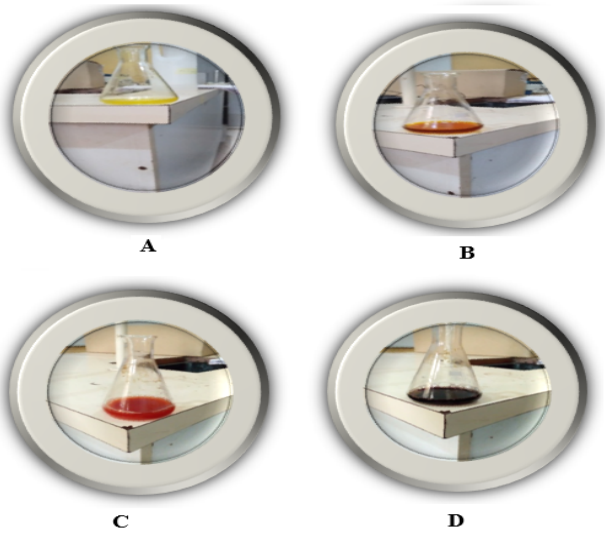

Figure 2: Colour change of the indicators in acidic and basic solution (A = CRI in acid (yellow); B = CRI in base (brown); C = TLI in acid (red); and D = TLI in base (black))

3.2. *Results of the Acid- Base Titration Analysis*

The titrimetry result using natural indicators (CRI and TLI) and some synthetic indicators are shown in the Table 1 as follows. The titre values obtained with the CRI and TLI were similar to those of the synthetic indicators. Different acid-base combinations (HCl-NaOH, CH_3COOH-NaOH, HCl-NH_4OH, and CH_3COOH-NH_4OH) were employed during the titrations.

For the titration involving HCl-NaOH, it was found that the titre values of 10.95±0.95 mL and 11.70±0.3 mL for CRI and TLI, respectively were similar to that of PL (12.25±0.15 mL) as indicated in Table 1. In addition, for the SA -SB titration, there was colour change of the solution from pink to colourless for PL. Using CRI in the titration, brown to yellow colouration change was observed. Meanwhile, black to red change in colour was shown during the titration of the SA-SB with the usage of TLI.

Similarly, in the titration of WA-SB, the titre values of 13.75±0.15 mL, 13.90±0.7 mL, and 13.45±0.45 mL were obtained for CRI, PL, and TLI, respectively. All the indicators used (natural and synthetic) gave titre values that are absolutely comparative to one another. CRI changed from brown to yellow; whereas the TLI indicator showed black colour that changed into red during the WA-SB titration. Then PL produced colouration change of pink to colourless (find the details in Table 1). It was also reported in [13] that turmeric and PL produced endpoint values of 8.0 ±0.2 mL and 7.5 ± 0.02 mL in the course of titration of HCl -NaOH [13].

Table 1: Comparison of the titrimetric titre values for some synthetic and natural indicators

Acid-base	Titre value for PL or MO/ mL	Colour change for PL/ MO	Titre value for CRI/ mL	Colour change for CRI	Titre value for TLI/ mL	Colour change for TLI	Literature titre values mL [16]
SA-SB	12.25±0.15(PL)	Pink to colourless	10.95±0.95	Brown to yellow	11.70±0.3	Black to red	8.97 ± 0.0577* 8.87 ± 0.0577 (PL) *
WA-SB	13.90±0.7 (PL)	Pink to colourless	13.75±0.15	Brown to yellow	13.45±0.45	Black to red	12.23 ± 0.0577* 12.07 ± 0.0577 (PL)*
WA-WB	2.10±0.2 (PL)	Pink to colourless	2.15±0.15	Brown to yellow	2.15±0.05	Black to red	- -
SA-WB	3.00±0.6 (MO)	Yellow to red	1.85±0.05	Brown to yellow	2.20±0	Black to red	15.17 ± 0.0577* 14.57 ± 0.0577(PL) *

SA-SB (strong acid -strong base) = HCl-NaOH, WA-SB (weak acid – strong base) = CH_3COOH-NaOH, WA-WB (weak acid – weak base) = CH_3COOH-NH_4OH, and SA-WB (strong acid – weak base) = HCl- NH_4OH; PL= phenolphthalein indicator, MO= methyl orange indicator, CRI = *Curcuma longa* Rhizome extract Indicator, and TLI = *Tectona grandis* Leaves extract Indicator. The titre values are mean of triplicate titrations ± the standard deviations. * literature titre values for *Bougainvillea glabra* green indicator in [16].

In this work again, it can be seen that in WA-WB titration, TLI showed black colour that turned into red at the end of the titration with the titre value of 2.15±0.05 mL. This titre value was relatedly similar to that of 2.10±0.2 mL (in PL) and 2.15±0.15 mL (in CRI). The titrimetric colour change of CRI was from brown to yellow, while PL colour change was still pink to colourless.

Furthermore, the titre values obtained for the titrations of SA-WB were 3.00±0.6 mL, 1.85±0.05 mL, and 2.20±0 mL for MO, CRI, and TLI, respectively. The titre values of the natural indicators coincided to that of MO (synthetic and common indicator) yet again. The MO colour change was yellow to red. Brown to yellow change in colour was shown for CRI; whereas, TLI was from black to red as shown in Table 1 and Figure 2. The results have shown that the bioderived materials, CRI and TLI are efficient and effective for use as acid-base indicators in comparison to MO and PL. In comparison to other researchers, we have seen higher titre values for the titrations involving WA-WB and SA-WB than the ones found in this report. This is likely due to misjudgments of the colour change before the actual endpoint. However, most of previous studies also reported that both synthetic and natural/ green indicators can give similar results, hence green indicators are suitable enough to replace synthetic ones where applicable.

More so, the trend of our results agreed with other investigators that did work on natural/ green indicators [1, 11-12,16]. For instances, the titrimetric titre values obtained in [16] using *Bougainvillea glabra* extracts indicator in WA-SB titration was 12.23 ± 0.0577 mL; and 12.07 ± 0.0577 mL with PL in same experiment [16]. In another development, the findings in [1] obtained the endpoint value for flamboyant extract indicator as 24.70±0.23 mL which was also similar to the PL (24.70±0.14 mL) during the titration of HCl-NaOH. According to the report in [11], titre values of 11.0± 0.155 mL and 11.1±0.154 mL for MO and vinca flower extract indicators, respectively were observed for HCl-NaOH titration. Whereas, for HCl-NH_4OH, the titre values were found as 4.2±0.118 mL and 4.2±0.106 mL for PL and vinca flower extract indicators, respectively [11]. In same vein, titre values obtained in [12] for the natural indicator from *Tagetes erecta* in HCl – NaOH and CH_3COOH-NH_4OH titration; 8.0 mL and 10.8mL, respectively; were quite same as those found with MO (8.2 mL and 11.2 mL, respectively) and PL (8.0 mL and 11.2mL, respectively) [12]. The results have shown that CRI and TLI can supplant MO and PL as indicators in acid-base titration. This is also in conformity to the pursuit of green chemistry advancement of the reduction of environmental pollution and use of renewable materials at least [10, 17–21].

4. Conclusion

The work considered the comparative analysis of CRI and TLI as natural/ green indicators versus some synthetic indicators in acid – base titration. Prior to the titration experiments, CRI and TLI were tested for their peculiar colours in acidic and basic media. Therefore, sharp colours of yellow (for CRI) and red (for TLI) in acid and brown (for CRI) and black (for TLI) in base media were obtained. More so, the substantial absorption in the UV-Visible region highly implicated the presence of curcumin, flavonoids, flavonols, anthocyanins, quinines, quinones, and carotene in these natural materials, CRI and TLI. Thus, the titre values of 10.95±0.95 mL (SA-SB), 13.75±0.15 mL (WA-SB), 2.15±0.15 mL (WA-WB), 1.85±0.05 mL (SA-WB); and 11.70±0.3 mL (SA-SB), 13.45±0.45 mL (WA-SB), 2.15±0.05 mL (WA-WB), 2.20±0 mL (SA-WB) were obtained using the natural indicators CRI and TLI, respectively. The results matched or coincided with the

titre values of 12.25±0.15 mL (SA-SB), 13.90±0.7 mL (WA-SB), 2.10±0.2 mL (WA-WB); and 3.00±0.6 mL (SA-WB) of the synthetic indicators PL and MO, respectively. Thus, since these green indicators are effective, easily available, easy to prepare, less toxic, inexpensive, and eco-friendly it would be possible to replace the MO and PL indicators in conventional laboratories with CRI and TLI as much as possible. This will also facilitate the eradication of environmental toxicity accruing from synthetic indicators.

5. Conflict of Interest

The authors declare no conflict of interest.

6. Acknowledgment

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7. References

[1] M. D. Garba and S. Abubakar, "Flower Extract As An Improvised Indicator In Acid – Base Titration," *Chemsearch J.*, vol. 3, no. 1, pp. 17–18, 2012.

[2] K. Asemave, "Bioactivity of Arachis Hypogaea Shell Extracts against Staphylococcus aureus and Pseudomonas aeruginosa," *Prog. Chem. Biochem. Res.*, vol. 4, no. 3, pp. 331–336, 2021, doi: 10.22034/PCBR.2021.290653.1190.

[3] K. Asemave and S. A. Ujah, "Determination of the Chemical Composition of Banana Leaves Wax," *Int. J. Appl. Sci. Curr. Futur. Res. Trends*, vol. 11, no. 1, pp. 23–30, 2021.

[4] K. Asemave and D. Ayom, "Assessment of Azadirachta indica and Moringa oleifera Leaves Powders as Alternative Coagulants for Water Purification," *Int. J. Appl. Sci. Curr. Futur. Res. Trends*, vol. 11, no. 1, pp. 13–22, 2021.

[5] K. Asemave and S. S. Ode, "Proximate and Antinutritional Analyses of Seed, Pulp and Peel of Aframomum angustifolium (Sonn.) K. Schum," *Org. Med. Chem IJ*, vol. 7, no. 4, pp. 001–005, 2018, doi: 10.19080/OMCIJ.2018.07.555720.

[6] K. Asemave, "Biobased Lipophilic Chelating Agents and their Applications in Metals Recovery," University of York, UK, 2016.

[7] J. R. Dodson *et al.*, "Bio-derived materials as a green route for precious & critical metal recovery and re-use," *Green Chem. (RSC)*, pp. 1–15, 2015, doi: 10.1039/C4GC02483D

[8] K. Asemave and T. T. Anure, "The bioactivities of the neem (seeds, leaves and their extracts) against Callosobruchus maculatus on Vigna Subterranean L," *Prog. Chem. Biochem. Res.*, vol. 2, no. 3, pp. 92–98, 2019, doi: 10.33945/SAMI/PCBR.2019.3.2.

[9] K. Asemave and T. A. Asemave, "African Shea Butter as a Staple and Renewable Bioproduct," *Int. J. Sci. Res.*, vol. 4, no. 12, pp. 2133–2135, 2015, doi: 10.21275/v4i12.nov152415.

[10] T. T. Philip, K. Asemave, and G. Obochi, "Comparative Assessment of Phytochemicals in Four (4) Varieties of Ananas Comosus (l.) Merr Peels," *Prog. Chem. Biochem. Res.*, pp. 1–10, 2020, doi: 10.22034/PCBR.2020.240534.1111.

[11] S. U. Kokil, D. G. Joshi, and R. L. Jadhav, "Catharanthus Roseus Flower Extract As Natural Indicator In Acid Base Titration, 2007" *http://www.articlesbase.com/science*

[12] S. Garg, A. Garg, P. Shukla, J. Mathew, D. Vishwakarma, and S. Sen, "Investigation Of Plant Source As Natural Indicators For Acid Base Titration To Reduce The Use Of Harmful Chemicals In Some Extent," *IJBPAS, January*, vol. 7, no. 1, pp. 64–70, 2018.

[13] N. B. Patil, A. A. Patil, K. B. Patil, and M. N. Wagh, "A Natural Indicator From Rhizomes Of Curcuma Longa (Turmeric)," *EPRA Int. J. Res. Dev.*, vol. 3, no. 12, pp. 138–143, 2018.

[14] "Flinn Scientific. Natural Indicators," 2016. https://www.flinnsci.com/api/library/Download/75bfca43b9da4346a173bf3ac21fd68a

[15] S. H. Burungale and A. V. Mali, "Natural indicator as a eco-friendly in acid base titration," *J. Chem. Pharm. Res.*, vol. 6, no. 5, pp. 901–903, 2014.

[16] N. Kapilraj, S. Keerthanan, and M. Sithambaresan, "Natural Plant Extracts as Acid-Base Indicator and Determination of Their pKa Value," *HindawiJournal Chem.*, 2019, doi: 10.1155/2019/2031342.

[17] K. Asemave and E. Thank-God Ocholongwa, "Archives of Chemistry and Chemical Engineering Investigation of the Alternative Green Procedure for Lassaigne's Test (Quantitative focus)," 2019, https://escientificpublishers.com/assets/data1/images/ACCE-01-0007.pdf

[18] K. Asemave, T. P. Tarhemba, and G. O. Obochi, "Evaluation of Some Nutritional Profile of Pineapple (Ananas comosus (L.) merr) Rinds," *Int. J. Green Herb. Chem.*, vol. 9, no. 1, pp. 026–037, 2019, doi: 10.24214/IJGHC/HC/9/1/02637.

[19] K. Asemave, "Comparative Analysis of Soap made from different composition of Mango Kernel Oil and Coconut Oil with two other Commercial Soaps," *Chem. Res. J.*, vol. 6, no. 3, pp. 75–83, 2021.

[20] K. Asemave, F. Byrne, T. J. Farmer, J. H. Clark, and A. J. Hunt, "Rapid and efficient biphasic liquid extraction of metals with bio-derived lipophilic β-diketone," *RSC Adv.*, vol. 6, no. 98, 2016, doi: 10.1039/C6RA24104B.

[21] K. Asemave, "Greener Chelators for Recovery of Metals and Other Applications," *Org. Med. Chem. Int. J.*, vol. 6, no. 4, pp. 001–011, 2018, doi: 10.19080/OMCIJ.2018.06.555694.

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