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INNOVATIVE SYSTEMS DESIGN & APPLICATION

Edited By

Dr. Balaji K.

CIIR Books and Publications

Contents

Preface

Concepts of innovation have gotten a lot of attention. management and public interest in recent years of organizational theory. Generally speaking, these To encourage creativity, writers have recommended universal organizational structures, methods, and procedures. These normative organizations must typically the fewest possible layers of hierarchy and be systems and processes are comparatively lacking. Formally many of these universal notions, systems, hinder innovation and creativity. Provide the policies, guidelines, and rules, it was claimed. which support and defend bureaucratic conduct. These common examples of creative businesses essentially disregard the need for effective use of missions or present operations of the organization. Organizations undoubtedly need to promote innovations in to adopt adaptable techniques that guarantee viability in a dynamic setting. But to claim that the whole organization adopts structures, systems, and procedures that encourage innovation is an unworkable prescription. efficient, everyday activities in the present businesses offer the earnings and revenues that Investing may be used to foster fresh and innovative ideas, services, goods, and procedures.

Numerous businesses have acknowledged the impossibility of a general idea for encouraging creativity across the board. a number of plans, including new venture firms and splintered off subsidiaries have created to foster differentiation and fresh ideas while exploring other business opportunities recognizing inherent efficiency in existing operations, creative organization's goals, roles, and settings vary from those of existing corporate or operating teams, and emergency planning ideas suggested for different management and theory of organization. different structures for the early integration of innovations after segregation has depending on the nature and degree of what has another example of creativity is the creation of jobs based on comparable contingencies. Clearly the systems method of design and the properties of the finished product systems and processes must also take into account these fundamental organizational variations. An alternative viewpoint on the creation of formal systems, and the organizational systems will ensure the design approaches utilized for them are more compatible with the distinctive qualities of different organizational units. For many, this offers a unique conundrum designers and analyzers of systems.

Most of the time, systems staff members have received training to implement practices that boost productivity by using routines and uniformity in organizational jobs and responsibilities. Based considering contingency design, a systems designer must account for his actions to a stable. steady-state the organization's operations or learn new skills, attitudes and knowledge. Sadly, there is little study. There is either theory or that suggests certain formal systems, if any, which ones should be used in organizational units tasked with different kinds of innovation. However, they are again virtually universally offered. concepts. This book will look at the roles and characteristics of organizational units to distinguish between those that are more adaptable to conventional systems design techniques, as well as those for which new innovative create design procedures. certain desirable. Formal systems' qualities that would be more suited for the organization's innovative divisions are given priority next. Last but not least, various system considered in terms of their applicability to units that are effective and inventive.

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CHAPTER 1

INTRODUCTION TO SMART MUSIC PLAYER

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Recent studies in the area of music psychology have established that listening to music causes listeners to encounter a variety of distinct emotions. It has been shown that musical interests are closely tied to emotions and personal characteristics. The parts of the brain that deal with emotions and mood also control the meters, timbre, rhythm, and pitch of music [1]. A user's emotional reaction to musical composition is influenced by a wide range of outside elements, including genders, age, geographies, personal tastes, moods, and contexts, such as time of the day and place. Despite these outside considerations, people may consistently classify compositions as being joyful, sad, exuberant, or calm. Lyrics and auditory attributes are the two primary areas of research in the present investigation of emotion-based optimization techniques. Due to the language barrier, we put our efforts into gathering and analyzing audio elements from contemporary American and British English songs to map those data to four essential moods. Results from automatic music descriptions utilizing a few mood categories are interesting [2]. The oldest and most natural manner of expressing emotions, moods, and sensations is via facial expressions. We divide facial features into four categories for the sake of this manuscript: joyful, sad, furious, and neutral. The major goal of this research is to develop an affordable music player that develops a sentiment-aware playlist depending on the user's emotional state. The program is meant to use as few system resources as possible. The user's sentiment is determined by the sentiment module. The music categorization platform pertinent and crucial voice data from a song. To suggest songs to the consumer, the recommendation component integrates the findings from the emotion generator and the music description module [3].

Module for Classifying Music

This section discusses the method used to match the attitude of each music with its identification. Using trimming audio feature extraction methods like LibROSA, audio pitch, and others, we were capable of recovering the songs' acoustic properties. We trained a synthetic neural network using these characteristics, and it effectively characterizes the songs into 4 groups with an effectiveness of 97.69%. In Figure 1, the identification procedure is also shown. The demeanour of a person needs to be communicated about their present emotional state, thus according to psychologists. Additionally, they divided the various facial emotions into five groups: surprise, joy, surprise, and enthusiasm. Psychologists have also shown that regardless of culture, all people have an intrinsic ability to understand emotions from facial expressions.

Due to its importance as a method of entertainment and sometimes as a therapeutic tool, music makes a significant contribution to the quality of a person's life. Technology and communications have advanced over the years in the twenty-first century. Fast forward, rewind, variable playback frequency, local playback, and broadcasting playback with simulcast streams are just a few of the features that have been included in many music players. Although these functionalities meet the minimum criteria, there remains a long way to go before computerized music classification and playlist selection based on the listener's current emotional state can be achieved.

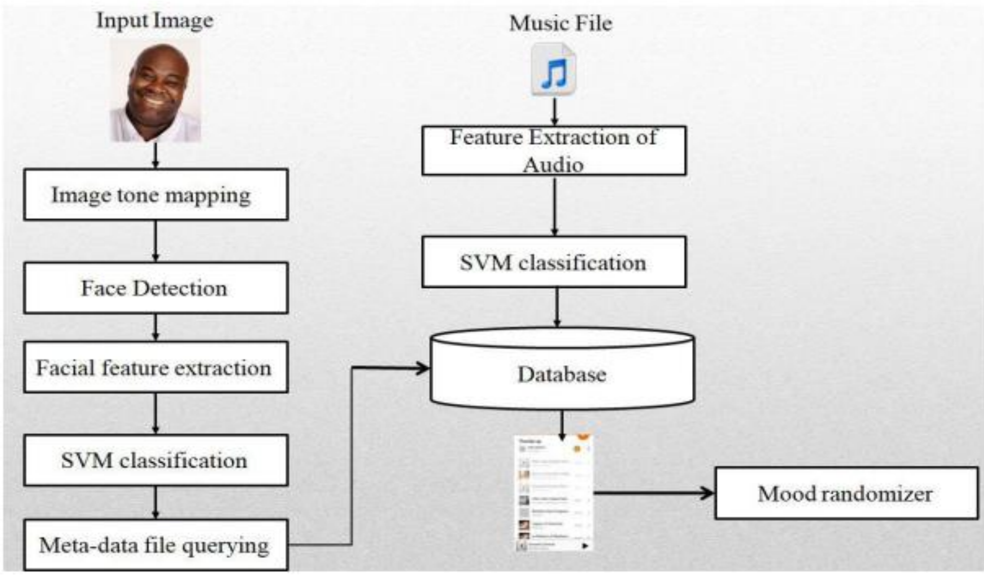

Figure 1: Illustrated the Block Diagram of the System Architecture [4]**.**

Thus, the computerized playlist segmentation based on different classes of emotions and moods was made possible by integrating Audio Emotion Recognition (AER) and Music Knowledge Discovery (MIR) algorithms into conventional music production. While MIR extracts information from an audio signal by investigating certain audio characteristics including pitch, tempo, metre, timbre, rhythm, energy, frequency, etc [5]., AER organizes the received audio signals by putting into consideration numerous audio aspects into discrete categories of emotions and moods. Even though manual song classification and playlist creation have just been eliminated in both AER and MIR, they are still unable to effectively integrate a human-compassion music player. The current generation of music production may categorise music based somewhat on artist, album, genre, frequency of plays, most recently played, etc. but still not based on the feelings such music evokes [6].

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CHAPTER 2

MODULE DESCRIPTION

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There is majorly involves three practical modules:

i. Emotion extraction module
ii. The audio feature extraction module
iii. Emotion-audio recognition module

There are two distinct programs for extracting emotional expression and audio features: the audio extraction of features module and the emotion extraction module. By requesting the audio meta-data file, the Emotion-Audio recognition module carries out even the mapping of modules. The playlist that is constructed for a person following their current mood or feeling is the result of combining the two preceding modules [1].

Emotion Extraction Module

A webcam may be used to preserve a static picture of a child's body, or it can be retrieved from the computer drive. Tone mapping, a kind of image processing application, is applied to the picture underhand to bring back its natural contrast. The picture is converted to the binary image format after image processing applications. The frontal cart characteristic of the Viola and Jones method, which exclusively identifies upright as well as face forwarding properties with a minimal given threshold set throughout the range of 16–20, is analyzed to recognize the face. The facial feature separation block receives its input from the Viola and Jones Face detection block's production. For several mathematics and measurement, we make use of the main characteristics of a human face, such as the eyes, cheeks, and nose [2].

The audio feature extraction module

A list of songs is provided to this module as input. Songs could use some preparation considering that they are audio files. The Internet-sourced multichannel signal is then converted to 16-bit PCM mono signals with a changeable sample rate of 48.6 kHz. The signal is modified using an Audacity approach [3]. This same obtained preprocessed transmitter is then subjected to a digital sound feature extraction process. Functionality like rhythm toning are harvested using the MIR 1.5 Toolbox, the pitch is extracted using Chroma Toolbox, and other functionalities like centroid, spatial frequency flux, spectral roll-off, kurtosis,15 and MFCC coefficients are removed using the Auditory Toolbox [4]. Eight subcategories of audio signals-sad, joy-anger, joy-surprise, joy-excitement, joy, anger, sad and others have been established:

i. Songs that generate joy include those that are energetic, spirited, and fun.
ii. Songs that sound exceedingly melancholy are characterized as sad music.
iii. Songs about uncompromising attitudes or retaliation are part of the category of rage.

iv. Songs that yell and scream in a fun manner fall within the happiness group.

v. The Sad-Anger classification is for songs with a highly sorrowful tone and an angry emotion.

vi. The Joy Excitement group is for songs that express joy as well as enthusiasm.

vii. Songs that feign indignation or delight fall under the umbrella of Joy and surprise. 8. All other songs have been classified as others.

Emotion Audio Recognition Module

The database contains the identified emotions as meta-data. By making a query on the meta-data information, mapping is done. An Emotion-Audio unification module is used to map and connect the audio feature extraction and emotion extraction modules. The mapping of visual appearance to audio features is shown in the following figure. There are twelve audio features listed in Figure 1: joy, sadness, anger, joy-anger, sad-anger, joy-excitement, joy-surprise, and others. There are five facial features-sad, joy, anger, happiness, and excitement and eight audio features. For instance, the algorithm will show music in the joy, joy-anger, joy-excitement, and joy-surprise categories if a face picture input is evaluated as joy [5].

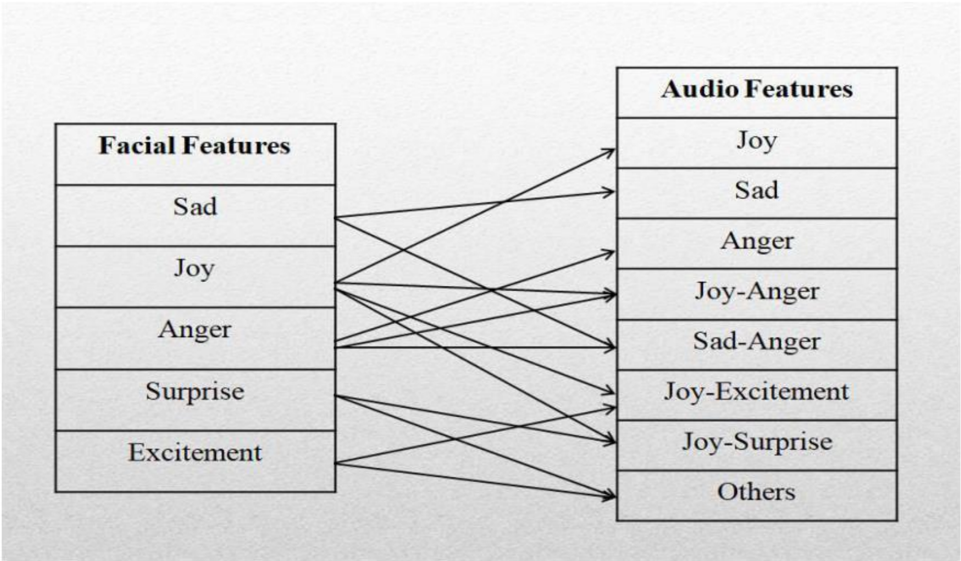

Figure 1: Displaying the Module for Mapping Process

It is well-accepted that music has a severe emotional impact on people. Both the primitive and modernized man may unwind and calm throughout the melody of the music after the day's labor and hard work. Studies have shown that rhythm itself is a profound sedative. The vast majority of individuals, however, struggle with choosing songs, particularly those that reflect their present feelings. People will be less inclined to search for the songs they would like to listen to when they see extensive lists of unsorted music [6] The majority of clients just choose songs at random from the song library and play them using the music player. The overwhelming majority of the time, the songs that are played don't reflect the user's prevailing mood. As an example, an unhappy individual could listen to hard rock music to help them feel better. The person is unable to look through his enormous playlist for all of the loud pop tunes. The person preferred playing all of the music he had rather than picking them at random. Additionally, this conventional way of looking for and choosing tracks becomes boring quickly. The procedure has been used for a few years [7].

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CHAPTER 3

IMAGE PROCESSING METHODS

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Image processing techniques are used in various types of applications. Biometrics is currently a very active area of research spanning several sub-disciplines such as image processing, pattern recognition, and computer vision. The main goal of biometrics is to build systems that can identify people from some observable characteristics. The biometric modalities are of three type's physical, behavioural and a combination of physical and behavioural modalities. The physical modalities are based on the measurement of the human body parts which includes iris recognition, fingerprint, shape, and position of fingers. These traits remain unaltered throughout a person's life. The behavioural modalities are related to changes in human behaviour over time including signatures and voice patterns [1].

The combination of both modalities depends upon physical as well as behavioural changes. Face detection is the first step of a face recognition system as it automatically detects a face from a complex background. The face recognition process appears to be promising in various fields such as law enforcement applications, secure information systems, multimedia systems, and cognitive sciences. Some challenges in face recognition are pose variation, occlusion, image orientation, illuminating condition, facial emotion and gender individuality. Facial emotion means to convey feelings, of happiness, sadness and confidence in humans. The tremendous worldwide interest in intelligent biometric techniques in face detection and facial emotion recognition is fueled by the myriad of potential applications.

Current research in the field of music psychology has shown that music induces a clear emotional response in its listeners. Musical preferences have been demonstrated to be highly correlated with personality traits and moods. The meter, timber, rhythm and pitch of music are managed in areas of the brain that deal with emotions and mood. Undoubtedly, a user's affective response to a music fragment depends on a large set of external factors, such as gender, age, culture, personal preferences, emotion and context e.g. time of day or location [2].

However, with these external variables set aside, humans can consistently categorize songs as being happy, sad, enthusiastic or relaxed. Current research in emotion-based recommender systems focuses on two main aspects, lyrics, and audio features. Acknowledging the language barrier, we focus our efforts on audio feature extraction and analysis of modern American and British English songs to map those features to four basic moods. Automatic music classification using some mood categories yields promising results. To solve these limitations, this project proposes a mobile music player application which can recommend songs based on the user's emotions. To classify the user's emotions, the proposed application applies both the heart rate and face image. When the application receives a user's heart rate from a smart band or a face image from a mobile camera, it analyses the user's emotions. Then, it suggests songs whose moods are relevant to that user's emotion [3].

Facial Expression

A facial expression can be expressed through the motions or from one or more motions, movements or even positions of the muscles of the face. These movements transmit the emotional status of an individual. Facial expression can be adopted as voluntary action as an individual can control his facial expression and show the facial expression according to his will. For example, a person can make the eyebrow closer and frown to show through the facial expression that he is angry. On the other hand, an individual will try to relax the face's muscles to indicate that he is not influenced by the current situation. However, since the facial expression is closely associated with the emotion, thus it is mostly an involuntary action. It is nearly impossible for an individual to insulate himself from expressing emotions [4]. An individual may have a strong desire or will not to express his current feelings through emotions but it is hard to do so.

An individual may show his expression in the first few micro-second before resuming a neutral expression. Since the work of Darwin in 1872, behavioural scientists had actively involved in the research and analysis of facial expression detection. In 1978, Suwa et al. presented their early attempt at the idea of automatic facial expressions analysis by 2 tracking the motion of twenty identified spots on an image sequence. After Suwa's attempt, there are a lot of signs of progress in developing computer systems to help humans to recognize and read the individual's facial expression, which is a useful and natural medium in communication. Facial expression analysis includes both detection and interpretation of facial motion and the recognition of expression. The three approaches which are displayed in Figure 1, enabled the automatic facial expression analysis (AFEA) include:

i. Face acquisition,

ii. Facial data extraction and representation,

iii. Facial expression recognition.

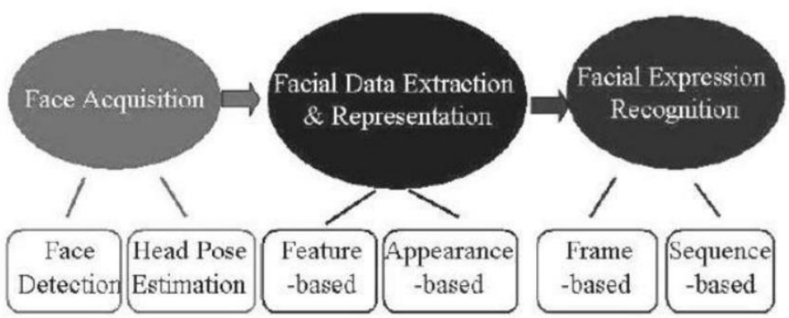

Figure 1: Represented the Basic Structure of Facial Expression Analysis Systems [5]**.**

The Emotion Based Music Player is a device developed aimed to detect the emotion of an individual, and play the lists of music accordingly. First, the individual will reflect his emotion through facial expression. After that, the device will detect the condition of the facial expression, analyze it and interpret the emotion. After determining the emotion of the individual, the music player will play songs which can suit the current emotion of the individual. The device will focus on the analysis of the facial expression only which does not include head or face movement [6].

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CHAPTER 4

FACE EMOTION RECOGNITION SYSTEM

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It is suggested to use revolutionary facial emotion detection techniques based on video frames. Depending upon the input video frames used, emotion may be detected and recognized. Image quality measurements are used to establish an image's quality. An algorithm first determines the face area on a human face, and then the skin and non-skin parts of the face are separated using skin color segmentation in the RGB color space [1]. Following segmentation, the border of the non-skin parts, mainly the eyelids and mouth, are extracted using geometrical techniques. Then, by determining the dimensions of the Nile river basin, the emotions are determined. Image capture, pre-processing, face identification, segmentation, geometrical processing, and area computation are all features of the suggested technique. The system then categorises the input and produces an output that is an expression (mood), based on the expression taken from the real-time graphical input, once after checking for the existence of a face that used the face identification technique [2].

- **Image Acquisition:**

Identification of facial expressions uses static images or imagery sequences. Although color photos may communicate more information about expression, such as flushing, they are less common for facial image identification. 2-D grey scale face images are. Future photographs will favour the same owing to the availability of low-cost contrast enhancement technology. Cameras, smartphones, and other communication cameras are utilized for access and understanding [3].

- **Pre-processing:**

Pre-Processing is an essential milestone in the whole process just because it improves the input picture's quality picture and helps find important data by reducing noise and smoothing it out. Redundancy in the photograph without image detail is removed. Screening and normalizing the picture to provide a consistent size and rotational photograph are also included in from before.

- **Segmentation:**

Image segmentation reduces it into useful causes. The procedure of segmenting a picture means separating it into homogeneous, personality sections that correspond to the various objects present in the image based on texture, edge, but also intensity [4].

- **Feature Extraction:**

One interesting aspect of a visual is feature extraction. It includes information on the face image's shape, movements, color, and texture. It takes the necessary information out of the picture. Feature extraction greatly decreases the information in the photograph when compared to the original, which also has benefits regarding storage.

- **Classification:**

The output of the feature extraction step is matched by the classification stage. The segmentation step helps in the proper classification of face images by classifying them and characterizing them.

Classification is tedious work since many elements might have an impact on it. The step of classification, also known as feature selection, consists of extracting information and processing it into groups according to predetermined criteria [5].

- **Display Music:**

Now that the visual information of emotion has been formally considered. The system chooses and broadcasts music based on emotions some of which are identified.

Working Methods

A webcam or the solid state drive may be used to capture the incoming picture for the system. To bring back the original contrast of the photograph, tone mapping is employed with low-contrast photographs similar to this one. As a result, the "one-vs.-all" paradigm of SVM is used for training and classification, which successfully enables multi-class characterization. The input for the Music Recognition system block is the user's playlist. We create a collection and play the music using emotion. The proposed scheme has been tested and experimented with the use of a built-in camera, therefore the whole cost of installation is almost minimal. Average expected time for the program's different components. Few technologies have been proposed that can create an emotion-based music playlist using emotional responses, even though many methods have been developed to extract facial appearance and audio functionalities from speech signals. Current designs of the system applications are also capable of creating an automatically generated playlist using hardware resources, also including sensors or EEG systems, which helps raise the cost of the design that is recommended [6].

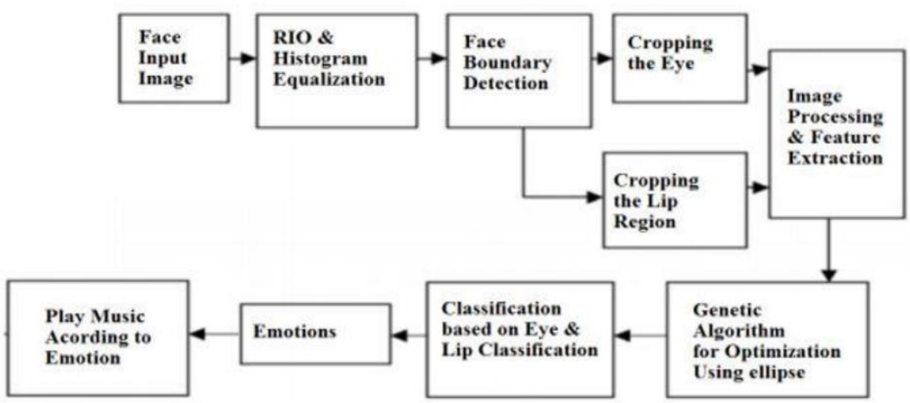

Figure 1: Illustrated the Basic Structure of Facial Expression Analysis Systems [7]**.**

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CHAPTER 5

ALGORITHM USED FOR ARTIFICIAL INTELLIGENCE

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Various algorithm that are used for:

- Represent video as frames.
- Examine the video frame picture input.
- A grayscale version of the picture.
- Apply the median, wiener, and Gaussian filters to improve the input picture.
- Determine which filter has the best PSNR and RMSE values.
- Use the viola-jones algorithm to find the face area.
- Crop the area around the face using the bounding box approach.
- Use a threshold value to separate skin-free areas.
- Use morphological techniques to extract the non-skin region's continuous borders.
- Use a mask to hide the image's original border.
- Remove the mouth area. The area is computed using the mouth region's extraction.
- Based on the value of the region, identify facial emotions.
- The system first uses the face detection procedure to see whether there are any faces in the input. It then identifies the input and produces an emotion-based somewhat on expression that was taken from the real-time graphical input [1].

Deep Learning

Machine learning, in turn, is a branch of artificial intelligence, and deep learning is one of those subfields (AI) for a symbolic image of this connection. The main objective of AI is to develop a combination of algorithms and methods that can be utilized to address issues that people intuitively and almost instinctively solve but that are otherwise extraordinarily difficult for computers to handle. Identifying the contents of a picture is a job that a person can do with virtually no effort, but it has proved to be quite challenging for algorithms to complete. This is a fantastic illustration of this class of AI challenges. While the area of artificial intelligence (AI) includes a diverse range of research on autonomous machine reasoning inference, planning, heuristics, etc., the machine learning specialization focuses more on information processing and learning from data [2].

Inspired by the organization and function of the brain, Artificial Neural Networks (ANNs) are a family of computer science algorithms that learn from the knowledge and specialized in pattern identification. As we can see, deep learning is a member of the ANN algorithm family, and the names are sometimes used considered to be synonymous [3]. You might be pleasantly surprised to hear that the field of deep learning has existed for more than 60 years. It has progressed by various names and incarnations depending on research trends, hardware and datasets that seem to be readily available at the time, and the most important widely used approaches by well-known research groups at the time. A brief overview of deep learning's collective memory will be then followed by a discussion of what makes a neural network deep and then an introduction to the idea of hierarchical studying, which has helped keep learning transform into one of the greatest accomplishments in contemporary machine learning and artificial intelligence [4].

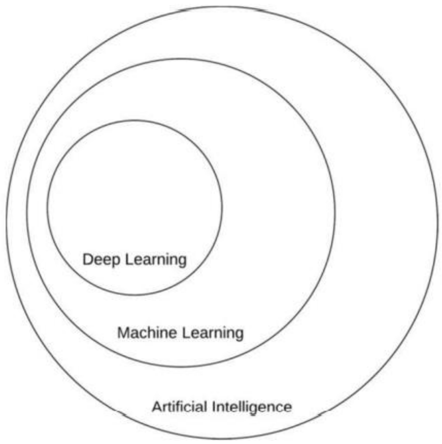

Figure 1: Represented the Venn diagram Describing Deep Learning.

Convolutional Neural Network

Every layer in a CNN applies a unique set of filters typically dozens or thousands of them and then mixes the output before passing it on to the next layer. A CNN mechanically learns learning values for some of these filters during training.

Our CNN could pick up on the following in the context of picture classification:

- In the first layer, use raw pixel data to find edges.
- Identify forms that are blobs in a couple of layers by using these edges.
- In the top layers of the network, use these shapes to find higher-level elements like face structures, automobile components, etc [5].

These more advanced attributes are used by the final CNN layer to forecast the image's contents. An image convolution in terms of deep learning is the element-wise convolution of two matrices preceded by a sum.

- Consider two matrices with the same number of dimensions.
- Just multiply them by themselves, element by element; this isn't the dot product.
- Add all of the components [6].

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CHAPTER 6

FACE PLAYER

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Nowadays, it is important to recognize human faces since it enables both organizations and individuals to interpret a person's feelings. It may be used in any situation in which recognizing is crucial for determining emotional mood. Communication is adversely affected by emotional factors. There are several ways to recognize emotions; they may be portrayed verbally or nonverbally. A linguistic form of communication is the voice (Audible) [1]. Non-verbal communication also includes gestures, movement postures, facial expressions, and performance. Understanding social interactions, making important decisions, and human relationships are all aided by social intelligence. Something that improves a person's life is music. One of the hot ideas right now in several sectors that proposes an answer to myriad problems is mood recognition based on emotion [2]. When they cannot choose tunes that match their inner feelings, the majority of music lovers find themselves in a stressful scenario. Once again, technology and multimedia advancements have been made, with more features like fast forward, backward, variable playback frequency that seeks and system application, local playback, watching online playback with simulcast streams, including volume manipulation, genre classifications, and so on. However, even though these capabilities suit the user's fundamental requirements, the user is still required to actively browse through the music list and choose songs depending on his contemporary state of mind and action [3]. Therefore, a system that can optimize human effort in manually conducting the son according to different experiences is required.

Difficulties with the Current System

At the moment, the music listeners are set up following a playlist of songs. No matter the way we're feeling, the playlist's songs will play completely randomly. Sometimes we want to play a song that fits our mood, but to do so, we have to manually check the playlist, which takes time. The succeeding song may not be of this very same genre or mood once the first has been chosen. Every time, we had to choose singles from the playlist based on how we felt. As a result, it is both time-consuming as well as annoying. This calls for the creation of less time-consuming, simple-to-use applications that will play music following our mood. By adopting a camera to capture the customer's facial features, the suggested application might extract the user's emotions and subsequently identify the user's mood. The idea is put into practice using the SVM algorithm and the Haar cascade. The calculation of numerous features in the source image depends in large part on image processing [4]. The Haar cascade is used for noise reduction, feature derivation, and contrast picture contrast, although the SVM algorithm is used for sentimental analysis. We are putting into practice an efficient approach for song suggestions from the playlists based on facial expressions.

Active Modules

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i. **Frame Extraction/Live Camera**

With the application's live camera, users may upload or take pictures, and the software can subsequently extract individual frames from videos. These frames are stored locally on the computer and type, frames are 640x480 in size.

ii. Face Detection: To recognize faces in photos, use the Haar cascade Classifier.

iii. Picture pre-processing Apply preprocessing to the photos, such as noise reduction and normalization after we have the faces.

- **RGB to Gray Scale Image:** Convert the RGB values of each pixel in the image to a grayscale representation.
- **Image Normalization:** To prevent eye strain or mental distraction from the visuals, normalization modifies the range of pixel intensity levels.
- **Noise Removal:** Removing acquisition flaws that cause pixel values that don't accurately represent the true intensities of the actual picture.

iv. **Feature Extraction:**

An input layer and convolution layers make up an SVM. On the availability of the training dataset, SVM will characterize the features. The image's facial features, such as the nose, lips, and eyes, are extracted and converted into points as follows:

- Eyebrow raises
- Upper eyelid to eyebrow distance
- Inter-eyebrow distance
- Upper eyelid
- Mouth width
- Mouth Open

v. **Feature Calculation:**

The placement of the eyes, mouth, and nose on a person's face is determined by the calculation of all extracted characteristics at this step. Face motion is detected based on this computation.

vi. **Emotions Detection and Music Recommendation:**

SVM classifier is used to identify the emotions of happy, neutral, and sad using the retrieved characteristics. A certain song from either the playlist is played depending on the user's emotion, such as joyful, sad, furious, or relaxed during a party [5].

Next for Emotion-Based Music Player

Given that the backend is currently operating correctly, the next stage would be to include more intricate deep learning and machine learning models. The Template Matching technique is a deep learning-free machine learning method. Therefore, sometimes it fails to recognize the user's face in a single frame of the camera broadcast. However, if we employed an object identification method like SSD or YOLO, it may boost the user experience by correctly identifying the face each time [6].

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CHAPTER 7

USING THE INTERNET OF THINGS, A SMART AGRICULTURE MONITORING SYSTEM

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India's population is mostly dependent on agriculture. The largest component of the Indian economy is agriculture. The relocation of people from the rural region to an urban area is a barrier to agriculture. There is a need for agriculture to progress to halt this exodus. The conventional irrigation method needed a lot of labour, time, and physical labour. An automated smart agricultural system may reduce this. A fully automated smart agricultural system may help farmers save time, money, and energy. Because sensors can provide real-time information about agricultural land, smart agriculture is a new concept. This study makes a case for internet-of-things-based smart agriculture. This system makes use of the benefits of modern technologies like Node MCU, the Internet of Things, and wireless sensor networks. The fundamental goal of this strategy is to leverage the Internet of Things (IoT) for automated smart farming. This system uses the appropriate sensor to keep track of temperature, humidity, and wetness. It uploads data to the cloud using a Node MCU and can be accessed via an Android app. Farmers may also get live weather forecast updates to be informed about impending weather changes [1] .

RESET BUTTON

There is a reset button on the Arduino, much like the original Nintendo. By pushing it, any running code on the Arduino will be restarted and the reset pin will be momentarily connected to the ground. If the code doesn't repeat but we still want to test it many times, this might be quite helpful. However, unlike the original Nintendo, blowing on the Arduino often doesn't solve any issues.

Po LED INDICATOR

On the circuit board, there is a small LED next to the word "ON" just below and to the right of the word "UNO". When we connect Arduino to a power source, this LED ought to turn on. There is a strong possibility that something is amiss if this light does not turn on. Recheck the circuit now [2].

TX RX LEDs,

Transmit is shortened to TX while receiving is shortened to RX. In electronics, these marks are often used to identify the pins used for serial transmission. TX and RX appear in our instance on the Arduino UNO twice: first by digital pins 0 and 1, and again adjacent to the TX and RX indication LEDs. When our Arduino is receiving or transferring data (such as when we're putting new software onto the board), these LEDs will provide us with some great visual cues.

LCD stands for liquid crystal display. It is a specific form of the electronic display module that is used in a variety of circuits and electronics, including those found in TVs, computers, calculators, mobile phones, and other electronics. Seven segments and multiple segment light-emitting diodes are most often used in these displays. The main benefits of using this module are its affordability, simplicity of programming, animations, and limitless capacity to display custom characters, original animations, etc [3]–[5].

The use of modules to let light pass from one layer sheet to another layer is the basic concept of LCDs. Because the modules shake and line up at a 90-degree angle, the polarised sheet may transfer light through it. Each pixel's presentation of information is handled by the molecules. The light-absorbing technology is used to display the number on each pixel. For the light's angle to change and show the value, molecules must move. The black area becomes values and digits on the grid pixels since the human eye will see the brightness of the remaining area. We can see that the data will be located in the region where light is absorbed. The information will reach the molecules and remain there until it is time for them to change.

PRIMARY IC

An IC, or integrated circuit, is a black object with all the metal legs. Imagine it as the Arduino's brain. The primary integrated circuit (IC) in the Arduino varies significantly depending on the type of board used, although it is often from the ATMEL Company's ATmega range of ICs. This might be crucial since, before loading a new programme from the Arduino software, we might need to know the IC type along with the board type. The top side of the IC often has this information written on it. Reading the datasheets is often a smart idea if we want to learn more about the differences between different ICs [6].

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CHAPTER 8

INTRODUCTION TO UNDERWATER COMMUNICATION

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The use of laser light to transmit information across great distances is one of the most intriguing advancements in telecommunications. The emergence of a less expensive communication system is required due to the rising costs, the scarcity of space in crowded urban areas, as well as the fast advancements in the Internet of Things (IoT). The use of lasers for signal transmission has been made feasible by developments in the field of semiconductor lasers, which eliminates the need for hidden cables and broadcast rights. Laser communication has thus attracted a lot of research and development due to the growth of space technology applications and the significance of wireless sensor networks. The concentration of energy to exceptionally high intensities that maintain a reasonably constant intensity across extended distances owing to minimal divergence is a noteworthy characteristic of laser technology [1].

The primary benefits of this technology over RF and fiber optic communication are its high levels of transmission security and dependability. In addition to land and air, the sea has grown to be a crucial component of military strategy and must be linked with network-centric communication. It could be crucial in network-centric warfare in the future. Free space laser communications enable unmanned aircraft systems to effectively complete intelligence, target acquisition, surveillance, or reconnaissance tasks by providing broad bandwidth and high-security capabilities [2], [3]. One of the most promising options for underwater communication is laser-based technology. The majority of lasers are unable to pass through water because they are absorbed by it, but blue-green lasers, whose wavelength is between 470 and 570 nm, have the lowest energy fading rates in the water at 0.155 and 0.5 dB/m. This property of blue-green lasers in the water is known as the window effect.

Long-range connections may be used for ground-to-aircraft, and ground-to-satellite, but rather building-to-building communication or sending data via guided laser beams. In comparison to air, laser communication presents quite distinct difficulties in the water. Laser attenuation in water is a major barrier to underwater communication since it is about 1000 times greater than in air. The kind of laser (CW or Q-switched laser) is heavily influenced by this exponential variance, and the impractical diameters of CW lasers prevent their usage over extended distances. Underwater laser communication has a dynamic problem as a result of sea turbulence or variations in salt content in various seas. A key part in creating an unbroken communication connection is played by problems at the sea-air interface for aerial platforms to underwater communication. These problems reduce the transmission's actual baud rate [4], [5].

Particularly for inter-satellite or Earth-satellite connectivity, telecommunications have begun to utilize free-space laser technology. They make it possible to transmit data at a very high throughput rate, such as from watching the surface of the Earth. Even while this kind of communication is

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now used in the space sector pretty often, it could soon be used in other contexts. A scenario where stealthy, low-latency data exchanges between underwater vehicles, high-throughput, or with airplanes would significantly improve strategic advantage is the undersea environment. The signal range, data rate, or reception delay of current underwater communication methods employing acoustic or radio frequency waves are severely constrained. By eliminating these obstacles, laser communication might revolutionize undersea telecommunications. There is a lot of research being done on this topic right now. The first demonstration procedures, such as the sharing of data and the usage of Skype, have been verified even though this study is still in the early stages.

Laser technology still has significant drawbacks, however. To begin with, for a laser to transmit in an aquatic environment, its wavelength must be in the visible blue-green region (between 400 and 550 nm). These frequencies are uncommon since optical communication typically occurs at infrared wavelengths (between 1000 and 1550 nm), which are ineffective in aquatic situations as they would be absorbed by the water in only a few meters. Additionally, much like air turbulence, the light beam is susceptible to aquatic turbulence. The signal's strength and phase are lowered by turbulence, which lowers the transmission of information and its quality [6].

Due to severe, frequency-dependent attenuation or surface-induced pulse dispersion, the data rates of acoustic communication are limited to tens of thousands of kilobits per second for ranges of a kilometer and less than a thousand kilobits per second for ranges up to 100 km. Optics-based underwater communication offers a substitute method with high data speeds. However, because of the exceedingly difficult underwater environment, which is characterized by significant multi-scattering and absorption, the distance between the transmitter and the receiver must be minimal. To get a highly effective data strategy for underwater communication, a rate 34 orthogonal coded on-off keying modulation system with bit error performance is presented.

The primary feature of a communication system is the transmission of data with a decreased bit error rate (BER). It is a crucial factor to take into account while simulating a communication system, particularly a communication channel, since causes of error at the sending and receiving ends may be more precisely modeled and optimized. The most popular and straightforward (from the standpoint of implementation) modulation method for a CW laser beam is called ON-OFF Key (OOK). It is the ideal option for airborne laser communication. Laser attenuation in water is about 1000 times more than in air, resulting in a massive and rapidly changing power consumption for underwater communication. Higher power is practically constrained by the size of CW lasers. The switched pulse laser is the best option for high peak power requirements, but it limits the kind of modulation that may be used. In another potential modulation method, the entire communication channel length decreases as a result of pulse width modulation (PWM), which changes the energy of the Q-switched pulses.

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CHAPTER 9

EMERGING UNDERWATER COMMUNICATION TECHNOLOGY

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Emerging underwater communication technology developed for commercial sea resource exploration, military warship-to-submarine communication, and satellite-to-submarine communication is a compelling research topic. Presents three carriers, namely acoustic waves, microwaves, and optical waves, all of which are applicable for underwater communication, but also exhibit specific practical problems [1]. Among these, the underwater acoustic wave (UWAC) system can be applied only in low-noise environments for low-speed content. This is because of its strong attenuation in seawater, exhibiting inverse proportionality to the wavelength, as well as its significant propagation delay and the low signal-to-noise ratio (SNR) of data in the context of background ocean noise, as shown in figure 1.

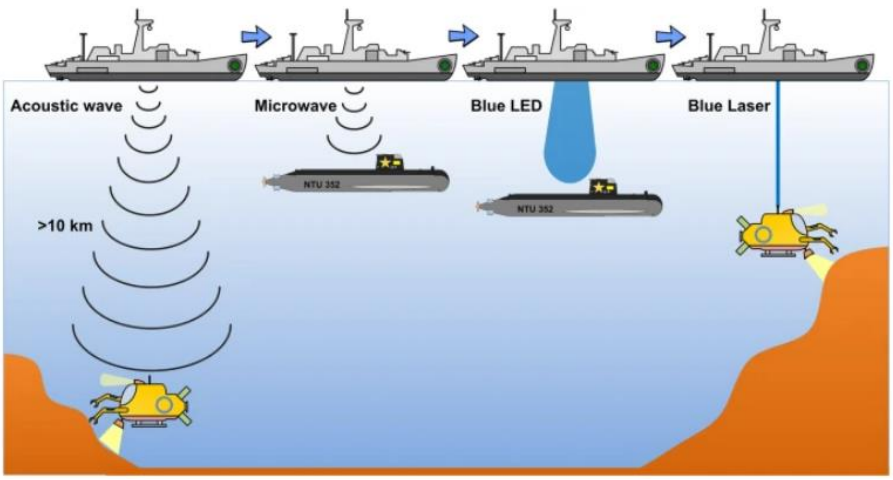

Figure 1: Illustrate a Diagram of a system for underwater communication.

Since both types of sensors employ unique wireless signals that only function in their respective media, underwater sensors, and land-based sensors cannot now exchange data. In water, radio waves that propagate through air decay extremely quickly. Sonar signals transmitted by underwater equipment often reflect off the surface without ever penetrating. For a range of applications, including ocean research and submarine-to-plane communication, this results in inefficiencies and other problems [2].

Researchers from the MIT Media Lab have created a system that uniquely addresses this issue in a work that will be presented at this week's conference. A sonar signal is sent from an undersea transmitter to the water's surface, where it causes minute vibrations that correspond to the 1s and 0s delivered. These minute alterations are picked up by an extremely sensitive sensor above the surface, which then decodes the sonar signal. "Using wireless communications to traverse the air-water barrier has proved difficult. The goal of our study, according to Fadel Adib, an assistant professor at the Media Lab, is to make the barrier itself become a communication channel. He co-wrote the article with Francesco Tonolini, one of his graduate students [3].

The "translational acoustic-RF communication" (TARF) technology is still in its infancy. However, he claims that it is a "milestone" that might lead to new water-air communication possibilities. The technique would save military submarines from having to surface to communicate with aircraft, thereby jeopardizing their position. Additionally, data from marine life monitoring underwater drones wouldn't need to be regularly sent to researchers during lengthy deep dives.

Helping with underwater aircraft search efforts is a potential new use. Adib claims that a plane's black box, for example, may have acoustic transmitting beacons. "If it periodically broadcasts a signal, you could utilize the system to pick up that signal.

TRANSLATING VIBRATIONS

The technology solutions used today to solve this wireless communication problem have several limitations. For instance, buoys have been created to capture sonar waves, interpret information, and transmit radio signals to aerial receivers. But they could stray and disappear. Many must also traverse significant expenses, which makes them unusable for communications between submarines and the surface, for example.

The TARF has an underwater acoustic transmitter that uses an ordinary acoustic speaker to broadcast sonar signals. The signals are sent as pressure waves with various frequencies that correspond to various data bits. For instance, if the transmitter wants to communicate a 0, it may send a wave that travels at 100 hertz, or it can send a wave that travels at 200 hertz. A few micrometer-high ripples in the water are created when the signal strikes the surface, and they match those frequencies [4].

TRANSDUCER RF

Transducers are devices that, using an antenna, may transform analog data into electrical signals or the opposite in open-air wireless communication. For correctly integrated functioning for underwater wireless communication in EM wave propagation, a big-size reception antenna is needed if the frequency range shifts from ELF to VLF. B. Review of the Literature on EM Waves for Underwater Communication Long-distance EM transmission was employed on a terrestrial basis in ancient times, and examination was the essential first step in further research. The submarine was able to communicate a few characters each minute in an underwater environment because of the EM frequency range (30Hz to 300Hz, which is an exceptionally low frequency). Similar research on the propagation of EM waves in seawater was discussed experimentally. Robotic swarms were used to test the process of EM communication between the water's surface and underwater. By comparing EM waves to acoustic and optical waves, it can be shown that they have different propagation characteristics underwater. Attenuation may readily impact electromagnetic (EM) transmission in shallow water, thus using deployed unmanned vehicles (UUVs) or remotely operated vehicles (ROVs) may be a solution. The UWSNs have been studied based on medium access control (MAC), and they play a crucial role in the tightly organized design for effective communication [5].

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CHAPTER 10

USE OF WATER AS A PROPAGATION MEDIUM

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The low data rate that is possible owing to the usage of low frequencies is one of the primary issues in underwater communications, where the main emphasis is on expanding distances and bandwidth. On the other side, researchers are working to make underwater equipment use less energy. The transmission over great distances is hampered by the intense backscattering induced by water's suspended particles. Using acoustic and ultrasonic communications systems is another option to increase connection, although these systems are hampered by murky water containing big particles [1]. Only small distances may be covered via radio frequency (RF) technologies, which are seldom ever able to attain data speeds of up to 100 MB/s. A submerged optical connection is used for underwater laser communication, with water serving as the transmission medium. The new LLCD-based communication technology has the capacity to achieve undersea communication that is 10,000 times more efficient than other conventional approaches, in contrast to the other conventional undersea methodologies that send the beam over a wide angle with both the reduction in range and data rates [2].

SCANNER FUNCTION FOR ACQUISITION

The majority of autonomous systems operating above sea level rely on GPS technology for locating and timing information; however, GPS signals cannot pass over water. Large, expensive navigation systems including gyroscope, accelerometer, or compass data are used by submerged vehicles. When the equipment is submerged for an extended length of time, the location calculation's noise sensitivity causes many mistakes in the hundreds of meters. Because acoustic signals travel more slowly than radio waves, using them for communication and verification underwater is impossible. Over a 1.5-kilometer distance, acoustic signals travel back and forth in two seconds. Additionally, when a signal travels through water, it is impacted by refraction, absorption, or scattering, which causes attenuation, a progressive drop in strength, which is much more pronounced in liquid than in air. Underwater, there is a significant amount of signal reflection due to acoustics [3]. The signal may reflect off the seabed and other subaerial geological features, such as the ocean's surface and layers of water that are separated by variations in temperature and density. One of the most difficult situations where communication handling is very tough is the shallow water and reef formations.

It is highly challenging for an underwater terminal to find and establish a connection with the incoming narrow optical beams because of these location uncertainties. Narrow-beam Lasercom performed three fundamental operations pointing, acquisition, and tracking to get around these challenges. A transmitter terminal puts out a wider beam that will ultimately scan the receiver location the area of estimated uncertainty. The incoming beam may be swiftly translated across an area with a large milliradian-class using the acquisition scanning feature, which makes it simple for the companion terminal to identify the beam. Beam detection aids in maintaining the beam's focus on the lasercom terminal's acquisition and communication detectors. A more focused and dependable system is created by the bidirectional employment of acquisition and tracking at transmit and receive terminals [4].

FEATURES FOR WIDEBAND SIGNALING

The accurate identification of the two vehicles is made possible by the broad bandwidth signaling elements in the communication waveform after the two lasercom terminals have locked onto one another and are conversing. With precise accuracy to a few millimeters, the wide bandwidth signaling function helps determine the relative heading and range between vehicles. Six members of the lasercom team recently tested two underwater vehicles to see how well the system communicated. In their testing, the cars looked for and found one another in less than a second while simultaneously sending hundreds of terabytes of data.

THE PHOTON-STARVED CHANNEL: MODULATION AND INFORMATION CAPACITY

A high-speed optical communication method called as a "photon-starved channel" was shown by LLCD. The system with the lowest overall signal flux in relation to the data rate is known as a photon-starved channel. The photon-starved pathways include both subsea and deep space communications. The use of optical bandwidth and single-photon sensitive detectors improved photon efficiency in the case of LLCD. Multiple bits of data may be sent because to LLCD's usage of a 16-ary pulse position modulation PPM signaling technique at 5 GHz. The machine can calculate the greatest efficiency possible using PPM and single-photon sensitive receivers since PPM signaling and single photon receivers are compatible with the underwater environment [5].

DYNAMIC RANGE OF COMMUNICATION SYSTEMS

The lasercom system's terminals are built to be able to transmit high data rates across a great distance. The terminals would be made to work with modest power levels that might vary depending on the water's clarity. By reducing the propagation distance by a few extinction lengths or by clarifying the water, this sturdy device can tolerate distances that are closer than its maximum range. Lasercom is able to produce ground-breaking Gigabyte/Sec class communication in such a wide dynamic range.

Many prior submarine communication systems were built to use very powerful wide-beam optical power transmitters, but these systems never performed as well as they might have. Using actively-aimed transmitters and photon-counting receivers built with very sensitive waveforms and potent error correction, this novel underwater transmission technique may reach notable performance. Additionally, the capacity to transfer data at speeds ranging from megabit to gigabit per second across a wide range of distances would pave the way for a lot of research and development in the field of underwater communication. With its very accurate and effective space laser technology, Lasercom can improve the submarine defensive system. This highly data-rated, dependable communication technology has the potential to significantly alter underwater vehicle operating procedures and pave the way for the creation of next-generation, highly accurate underwater vehicles [6].

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CHAPTER 11

FACTORS THAT AFFECT ELECTROMAGNETIC COMMUNICATION IN A SUBAQUATIC ENVIRONMENT

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Depending on the characteristics of the water channel or the marine environment, EM communication may be impacted by several factors, such as fixed bandwidth limitations, power resources, challenging water channel conditions, turbidity, and a variety of noises in the surrounding underwater environment [1].

PROPAGATION ACROSS MANY PATHS

The most significant EM wave propagation from air to water phenomenon that influences signal propagation performance has been taken into consideration. In RF communication, the refraction angle or losses are also taken into account. Signals from high permittivity may be launched that would be roughly parallel to the water's surface thanks to the obtuse refractive angle. Due to the necessity of AUVs as well as UUVs nodes to floating buoys in deep water, communication is made feasible. The deep sea sensor network is developing patching devices at the same time. In deep saltwater, electromagnetic waves are used for long-distance communication because they travel along a single route with the least amount of resistance. In shallow water, the multipath propagation of EM waves may be advantageous for signal transmission [2] .

ANTENNA

The enormous antennas are needed for RF transmission from the surface to the ocean. The most portable practicable approach that has been considered is a magnetic sort of antenna. An electrical dipole antenna type for lateral electromagnetic waves that is specified in the appropriate article is required for consideration.

NEED FOR UNDERWATER SENSORS

Data gathered from additional sensors should be able to be stored by underwater sensor nodes. Several sensor network nodes collect data from other kinds of sensors and keep track of the physical characteristics like pressure, temperature, and water flows velocity. As a result, the underwater sensor nodes may need a considerable buffer capacity to store data before signal transmission. Underwater sensor networks have a problem with energy efficiency, so measures are being taken to decrease it. Due to the technical characteristics of underwater nodes, more energy is needed to send signals than to receive and process data, hence the energy needed should be greater. Because they are difficult to repair and recharge, power batteries are the fundamental problem in UWSN topologies. To lessen this specific feature, the design must be accurate and excellent [3]. The research on optimum sensor node placement in UWSNs also calls for increased

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signal transmission and reception efficiency. When in good shape, they can work in hostile environments.

PROPOSED FUTURE

Proposed Future for UWC, RF connectivity provides fantastic future possibilities that allow for the exploration of the otherwise prohibited ocean and undersea environment. With the use of electromagnetic signaling, signals may travel further while being unaffected by noise in shallow water and severe environmental conditions. The purpose of deploying RF communication is to acquire high bandwidth data rates and the potential to overcome difficulties in shallow and crowded water. Extremely low frequencies (ELF) can travel great distances, but high frequencies (HF) suffer losses due to significant attenuation. It is frequently argued how to use ultra-high frequency (ULF) to medium frequency (ME) bands in the future. Utilized for short-range underwater communication, electromagnetic waves might be enhanced and utilized for long-distance communication in the deep ocean with the right antenna design. Antenna design, bandwidth, transmitting power, and noise would be regarded as the most important issues to be resolved in an underwater electromagnetic communication system. E. Conclusion There are few uses for underwater RF communication, notably for military purposes [4]. The study of electromagnetic waves in conjunction with digital technologies and signal compression methods. It contains several assets that fill a suitable niche for underwater use. UWSNs are used to conveniently monitor underwater activity and coastal erosion using electromagnetic waves. Due to its unique benefits over optical and acoustic kinds of communication, RF-based communication is employed on the physical layer.

The use of the OWC technology in the undersea environment at high frequencies opens up new possibilities in the future. The system's performance and effectiveness might be enhanced by the UWOC strategy. The use of UWSNs is strongly advised for high energy and bandwidth optical signal transfer between sensor nodes and also base stations through AUVs or ROVs. Thus, extensive and fruitful research is needed to create more sophisticated and affordable light-emitting receiving sources. There are several uses for the terrestrial link's high data transfer rate of around 10 Gbps that can be used with the FSO technology as well. In a heterogeneous network system, optical networks find applications because of their cheap cost, low power consumption capacity, or high compatibility. Through the use of robotic sensor networks, an acoustic-optic hybrid communication system may provide high data transfer rates [5].

The ability to establish a network connection between floating devices using underwater communication when the channel or communication environment has important difficulties and difficulties. The technologies mentioned provide a potential remedy and a thorough comprehension of the deployment procedure. To increase the likelihood of successful communication, the 5G wireless networking approach is planned to support RF, acoustic, and optical signal carriers.

The architecture of UWSNs, one of the emerging technologies, is complex and challenging for signal propagation, but the design of the appropriate network nodes holds the key to understanding and determining effective data analysis between source and receiver with the necessary data rates for possible communication. A unique channel modeling to establish conceptualizing network communication to flexible or fixed network nodes is fairly tough, according to the relevant communication technologies required. The technological problems, difficulties, and potential future directions in underwater environmental communication have been examined in this research [6].

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CHAPTER 12

UNDERWATER AND OTHER EMERGING TRENDS IN LASER COMMUNICATION

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A method known as underwater laser communication uses laser propagation to send data from one location to another. The technique is beneficial in situations when it is not feasible to make physical connections using fiber optic cables because of prohibitive prices or other factors. In order to enable full duplex (bi-directional) communication capabilities, Free Space Optics (FSO) technology is dependent on connection between FSO-based optical wireless terminals, each of which consists of an optical transceiver. Each optical wireless terminal employs a laser LED as an optical source, and a telescope to send light to the receiver via the atmosphere. A pin photodiode and avalanche photodiode is used in the receiver to change the optical input into an electrical output. The receiver is made up of an electronic viewfinder and an opto-electronic front end [1].

The US military and NASA were the first to develop FSO technology for fast and secure data transfer. It has been utilized in a variety of ways for more than three decades to establish quick communication linkages in distant areas. FSO technology has been more widely accepted over time in the telecommunications sector, notably in the context of business campus networking, as shown in figure 1 and figure 2. FSO technology offers a huge promise for short-distance wireless communications because of its tremendous bandwidth capacities and the global unlicensed nature of the transmission spectrum. In addition to the obvious benefits of underwater laser communication at high speeds, these transmissions are also cheap, resilient to jamming, and have a low signal-to-noise ratio. Line-of-sight, however, is a significant drawback. Both in free space and underwater, the fundamentals of laser communication between two computers are essentially the same. However, elements like water salinity and turbidity that affect performance underwater must be taken into account [2].

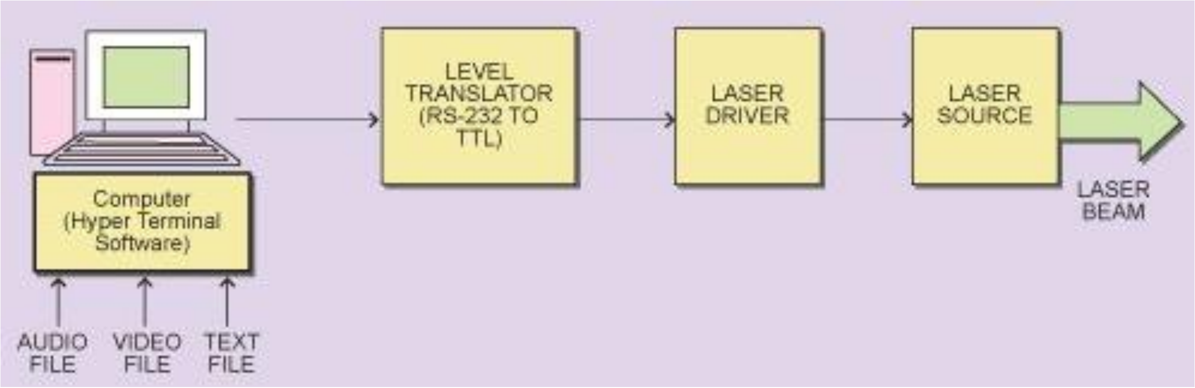

Figure 1: Illustrate the transmitter block schematic.

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In this study, it is suggested that the design of the real underwater communication system revolve on a green laser module whose strength will be adjusted by the intelligence signal that will be sent. The signal is demodulated on the receiver side using an appropriate photo-sensor-based circuit. The computer interface on the transmitter or receiving sides uses RS-232. The laser is modulated using the RS-232 serial interface once the data file to be transferred is transformed into a serial bit stream. The serial bit stream is retrieved when the laser beam is identified on the receiver side. In the PC, the bit stream is changed back to the desired format. The article's last section explores the benefits of laser communication over optical communication underwater as well as new ideas and how they're being put into practice [3].

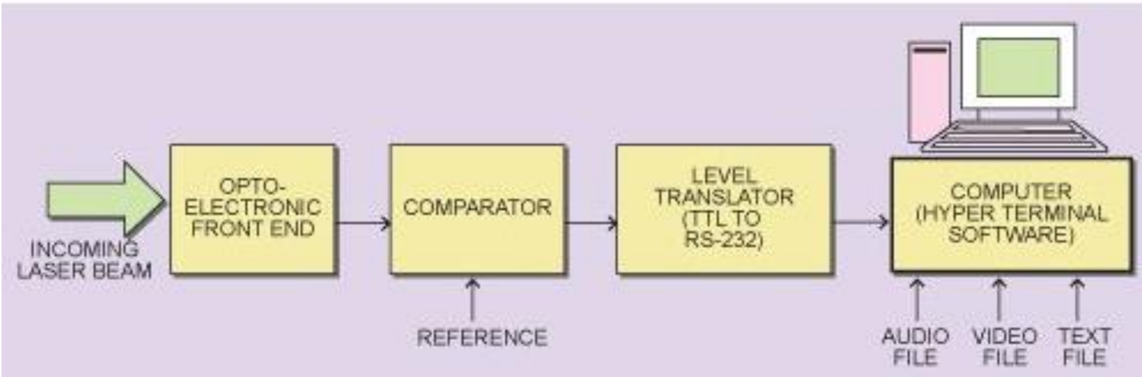

Figure 2: Illustrate the receiver block schematic.

TRANSMITTER

The hyper terminal software that comes with MS Windows and is accessible on the PC is used to convert the data file on the PC that will be communicated to another distant PC into a serial bit stream in RS/EIA232 format. The integrated circuit (IC) MAX232 is used in the next step to transform this serial bit stream (representing data) into TTL compatible pulses. This driver/receiver is a dual EIA232 device. It contains two separate TTL/CMOS-to-EIA232 receivers and two independent EIA232-to-TTL/CMOS drivers on the same chip. The EIA232 bit stream from the transmitter has been transformed into equivalent 5.0-volt TTL/CMOS-compatible pulses using one of the receivers [4].

The non-inverting adder circuit, built around the LM324 low noise op-amp, is then fed the TTL-compatible output pulses. The DC voltage that may be varied from around 0.6 volt to 1.8 volts is the adder's other input. TTL pulse amplitude may also be changed. To achieve the proper driving current via the laser diode, this is necessary. The entire laser diode driver circuit includes this circuit. A constant current source driver circuit built around the op-amp LM324 and an npn Darlington transistor is fed by the output of this circuit. The voltage present at this op-terminal amp's 3 and the amount of resistance RE together determine the size of the continuous current [5].

The laser utilized has an output power of 10 mW and is a diode-pumped solid state laser operating at 532 nm (green). Due to its low attenuation in water, green laser is employed for underwater laser communication lines. The suggested high-power green laser has a lot of promise since it combines high power, low signal noise, high brightness, as well as high repetition rates [6].

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CHAPTER 13

FUTURE CHALLENGES OF UNDERWATER OPTICAL COMMUNICATION (UWOC)

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UWOC has already become a reality as a result of academic and corporate research efforts. Furthermore, there are still many unanswered issues in this field of study, which is still in its early stages. The following paragraphs provide some suggestions for potential UWOC research challenges. Today, a huge variety of terrestrial devices employ wireless communications often. The military, business, and scientific communities are very interested in the use of wireless communications in the underwater environment. Due to its effectiveness in communicating over long distances underwater, acoustic systems are now the subject of extensive study to further this technology. In-depth research is done to enhance the effectiveness of auditory communication routes [1].

Its performance is nonetheless influenced by the physical laws of the universe, which include Doppler's spread, time-varying multi-path propagation, high transmission losses, high latency, and bandwidth limitations. These restrictions prevent autonomous underwater vehicles (AUV) from using acoustic communication to transmit high-resolution real-time video [2]. As a result, additional technology is required to enable broadband underwater communications; in fact, real-time video transmissions are increasingly valuable for underwater applications due to their use in teleoperating underwater vehicles and remotely monitoring underwater stations. Even though RF waves are the more prevalent and widely utilized technology in terrestrial communications due to their nature, they are not suited for usage underwater due to their significant attenuation. Additionally, because of its poor performance characteristics, such as high bit error rates, significant and unpredictable propagation delays, and limited bandwidth, traditional acoustic underwater communication is especially susceptible to malicious assaults.

TRANSMITTER TECHNOLOGIES

It is necessary to build effective and reliable tunable lasers in the violet-blue-green zone to get around the underwater channel's dynamics, which impacts the optical signal's total attenuation. Additionally, it would be intriguing to investigate the creation of a laser whose operating wavelength precisely matches one of the Fraunhofer lines in the solar spectrum to lessen background noise [3].

DETECTOR TECHNOLOGIES

Deep sea deployment of several underwater platforms makes it imperative to create UWOC systems with extremely effective photodetectors. Biologically-inspired quantum photosensors

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(BQP) have been suggested as a way to learn from the photosynthesis carried out by bacteria at depths of up to 2000 m in the ocean. Even at a depth that is completely black to the naked eye, photosynthetic organisms like green sulfur bacteria employ complex molecular antenna systems to effectively absorb and use weak light that originates from solar radiation or hydrothermal vents. Experimental proof of the quantum effect in energy transfer has been shown. Self-assembled J-Aggregates molecules are ideal candidates because they exhibit quantum transport at ambient temperature across a large number of chromophores, which may be utilized as antennas to gather light. It is imperative to create gadgets that resemble this natural photo-sensing process since they are predicted to outperform the existing detection capacities of APD or PIN detectors with quantum efficiencies of about 90% in the blue-green range. As a result, there is a tremendous research opportunity for researching and creating more sophisticated BQP for the following-generation UWOC systems [4].

LINK MISALIGNMENT

One of the problems with LOS UWOC systems is link misalignment, which is still an active area of study. Modulating retro-reflectors (MRR), smart transceivers, or RF/acoustic/optical hybrid systems have all been presented as ways to lessen the pointing or tracking needs of moving underwater platforms, particularly autonomous underwater vehicles (AUVs) and remotely controlled vehicles (ROVs). Therefore, it is crucial to deploy and evaluate smart transceivers and MRR-integrated UWOC systems in a real underwater environment for misalignment mitigation.

TRANSMISSION SCHEMES

The multiple-input multiple-output (MIMO) transmission system can lessen the impacts of turbulence-induced fading and physical obstacles, which are two of the main degrading factors of underwater channels. By temporally combining many light sources to record multipath data streams, MIMO improves the signal-to-noise ratio (SNR) overall.

MODELING OF CHANNELS

The problem of UWOC channel modeling is almost addressed with the recent development of precise and practicable mathematical models for the undersea turbulence channel. More system-level testing, such as those involving vertical link arrangements, must be carried out in a true underwater environment, however [5].

Despite the challenging underwater environment, UWOC research has made considerable strides recently. After giving a quick summary of the most recent UWOC research, we gave a thorough analysis of optical light sources and detecting systems in this review study. For UWOC applications, a focus is made on UV-blind and single-photon detectors. We also discussed new developments in UWOC channel modeling that were based on observed data and took into consideration the effects of turbulence caused by air bubbles, salinity, and temperature. The main benefit of these novel channel models based on observed data is that they have straightforward mathematical structures, which makes them appealing from the perspective of performance analysis. There is still much to learn about this study topic, which is still in its early phases. We anticipate that this survey will provide academics with a solid grasp of UWOC and act as a manual for UWOC system developers [6].

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