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Computerized Prison Monitoring Application Based on Knowledge Engineering

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***Abstract* - This study is mostly about making and using advanced computer vision techniques and voice analysis algorithms to keep an eye on security threats in prisons and find them in real time. The main goal is to make correctional facilities safer and more secure by finding and stopping unauthorized ownership of equipment, suspicious behavior between prisoners and visitors, violent behavior between prisoners, and strange events and activities. With the help of computer vision technology and voice pattern analysis, the system aims to change the way prisons keep people safe by giving them more ways to be watched while still respecting their right to privacy. The study looks at how well these technologies work compared to traditional methods, with a focus on making detection and reaction faster and more accurate. The results and methods of this study add to the creation of a monitoring system that is reliable, efficient, and puts the safety of prisoners, visitors, and staff at correctional facilities first.**

Keywords: Prison monitoring, Knowledge engineering, Security threats, Real-time monitoring, Advanced computer vision, Voice analysis algorithms, Unauthorized equipment detection, Suspicious behaviour detection, Violent behaviour detection, Abnormal events and activities, Privacy rights, Prison security, Visitor interactions, Facial recognition, Surveillance systems, Detection algorithms, Python, PyCharm, OpenCV, PyTorch, TensorFlow, Machine learning, Deep learning, Anomaly detection, Convolutional Neural Networks, Natural Language Processing, Facial expressions, Hate/offensive language patterns, Facial analysis, Unauthorized items, Weapons detection, Facial recognition technology, Violent behaviour identification, Prison safety.

I. INTRODUCTION

The contemporary prison environment presents a complex array of challenges, from ensuring the safety of inmates and staff to upholding the fundamental principles of human rights. To address these multifaceted issues and herald a new era in prison security and safety, this research introduces a groundbreaking innovation – the Computerized Prison Monitoring Application. Rooted in the principles of Knowledge Engineering, this comprehensive system comprises four primary components: Track and Detect Abnormal Events and Activities, Suspicious Behavior Detection when Prisoners Interact with Visitors, Unauthorized Equipment Detection, and Track and Detect Violent Behaviors between Prisoners. Each of these components constitutes a pivotal element of our holistic approach to prison management, offering advanced technological solutions to age-old security concerns while steadfastly upholding the principles of privacy and respect for all individuals within the correctional facility.

This research paper seeks to provide an exhaustive exploration of these four core components and to showcase their collective potential in reshaping the paradigm of prison security. Through the adept utilization of cutting-edge technologies, including computer vision, machine learning, and voice pattern analysis, our Computerized Prison Monitoring Application aspires to revolutionize the operational framework of correctional facilities. Its fundamental objective is to prioritize the safety and security of prisoners, visitors, and staff while simultaneously addressing resource limitations and enhancing the overall efficacy of prison management.

In the ensuing sections of this paper, we will embark on an in-depth journey into the methodologies, results, and implications of each component, elucidating how our pioneering approach can lead to penitentiary environments that are not only more secure but also more humane. As we delve into the intricate details of each component, it will become evident that the Computerized Prison Monitoring Application represents a critical advancement in correctional technology. It is poised to redefine the contours of prison security, augmenting the ability to detect, prevent, and respond to security threats in real time, all while preserving the dignity and privacy of those incarcerated.

Beyond the immediate applications within correctional facilities, the implications of this research extend to the

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broader discourse on modernizing and improving prison systems. As we continue to face evolving challenges in criminal justice, our innovative approach presents a beacon of hope for a safer and more humane future. By harnessing the power of knowledge engineering and technology, we aim to chart a course toward prisons that not only safeguard society but also facilitate rehabilitation and reintegration. The Computerized Prison Monitoring Application is more than a tool; it is a testament to our commitment to a just, secure, and enlightened society, where even behind prison walls, the principles of fairness and humanity endure.

II. LITERATURE REVIEW

The development of a Computerized Prison Monitoring Application based on Knowledge Engineering represents a significant advancement in the field of prison security. This literature survey explores relevant research studies that inform and support the four main components of this innovative application: Track and Detect Abnormal Events and Activities, Suspicious Behavior Detection when Prisoners Interact with Visitors, Unauthorized Equipment Detection, and Track and Detect Violent Behaviors between Prisoners.

A) Track and Detect Abnormal Events and Activities

In the pursuit of monitoring and detecting abnormal events and activities within prison facilities, researchers have made substantial contributions. Haritaoglu et al.[1] introduced a pioneering system known as "W4." This system laid the foundation for real-time surveillance by employing computer vision techniques to track and analyze the movements and interactions of individuals within video frames. By utilizing statistical analysis, the system aimed to detect unusual behaviors, setting the stage for the use of computer vision in identifying abnormal events in crowded settings.

Building upon this foundation, Zhang et al. [2] explored motion-based features and local binary patterns for anomaly detection in surveillance videos. Their research demonstrated the effectiveness of computer vision techniques in capturing unusual behaviors, especially in crowded environments. They paid particular attention to motion patterns and texture features to identify anomalies, such as sudden movements or unexpected interactions.

Smith et al. [3] extended the scope of computer vision-based anomaly detection by incorporating deep learning techniques. Their research focused on the development of a deep neural network architecture trained on a large dataset of prison surveillance videos. The network was designed to automatically learn and extract complex features from video frames, enabling it to identify subtle abnormal behaviors.

B) Suspicious Behavior Detection when Prisoners Interact with Visitors

The interaction between prisoners and visitors represents a critical aspect of prison security. In this context, studies such as the one by MadasuHanmandlu et al.[4]focused on the detection of suspicious behavior during face-to-face interactions. They developed methods to monitor eye and other facial features' movements to identify potential signs of suspicious activities. This research contributed to the understanding of using facial analysis as a means of detecting abnormal behaviors, particularly in scenarios where verbal communication might be limited or monitored.

Furthermore, Rohit Rastogi's work[5] extended this concept by considering the social perspective of suspicious activity detection in facial analysis. Their research explored how facial expressions, particularly those reflecting negative emotions or tension, can indicate potentially harmful discussions between prisoners and visitors. This social context adds a layer of sophistication to the detection of suspicious behavior during interactions.

C) Unauthorized Equipment Detection

The unauthorized possession of equipment within prisons poses significant security risks. Several studies have addressed this challenge. "Weapon Detection using Artificial Intelligence and Deep Learning for Security Applications"[6] research paper focused on weapon detection using artificial intelligence and deep learning. Their research showcased the potential of machine learning algorithms in identifying concealed items such as weapons. By training deep learning models on weapon-related data, they demonstrated the feasibility of recognizing weapons in surveillance footage.

Furthermore, the research of “Automatic handgun detection alarm in videos using deep learning”[7] addressed the detection of handguns in videos using deep learning techniques. Their study focused on automatic handgun detection alarms and illustrated the capabilities of deep learning in recognizing specific objects, even in challenging video scenarios. This research underscores the potential for using advanced technologies to detect unauthorized equipment within prison environments.

D) Track and Detect Violent Behaviors between Prisoners

Violent behaviors among prisoners are a pressing concern for prison authorities. Research in this area has sought to address this issue. M. A. Saleem Durai and G. Sreenu [8]investigated intelligent video surveillance techniques, emphasizing crowd analysis for the detection of unusual activities. Their research delved into the complexities of identifying violent behaviors in crowded scenes. They

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proposed methods for tracking and analyzing movements within crowds, aiming to detect and mitigate violent incidents effectively.

Additionally, Piotr Bilski et al.'s work [9]focused on the development of a CCTV-camera-based system for detecting anomalous behaviors in penitentiary institutions. Their study contributed insights into tracking and detecting violence within prison facilities specifically. They emphasized the importance of surveillance technology in addressing security concerns related to violent behaviors among prisoners.

Furthermore, the research conducted by Ruchi Jayaswal and Manish Dixit [10] presents a significant contribution to the field of anomaly classification, particularly through the utilization of deep transfer learning. Their work sheds light on innovative approaches for detecting and categorizing unusual behaviors, including acts of violence, within the complex and challenging confines of public crowded environments.

III. METHODOLOGY

This study employs a knowledge engineering approach to build an automated prison surveillance program. The term "knowledge engineering" refers to the practice of gathering, analyzing, and using information to address difficult issues. The approach taken in this investigation entails making use of knowledge engineering methods to develop a program for more effective incarceration monitoring. Researchers hope that by employing knowledge engineering concepts, they will be able to develop a system that is both powerful and smart enough to collect and analyze data from a wide variety of sources within a correctional facility. The methodology is based on the idea that the best way to keep tabs on and manage a prison's activities is to use knowledge representation, reasoning, and decision-making procedures.

A) Track and detect violence behaviors between prisoners

The proposed methodology for detecting violent behaviours among prisoners through the integration of computer vision and audio processing is a multi-faceted approach aimed at enhancing the accuracy and robustness of identification. The methodology leverages two distinct branches: computer vision and audio processing, to comprehensively analyse human interactions within a prison environment.

In the computer vision component, the Mediapipe Python library is utilised to extract human skeletons from video footage, capturing intricate movement patterns. This raw skeletal data is then subjected to analysis, wherein a Long Short-Term Memory (LSTM)-based Recurrent Neural Network (RNN) is employed. LSTMs are chosen due to their ability to capture long-term dependencies and intricate patterns in data sequences. By training the model with sequences of both fight movements and normal activities, the network learns to discern subtle nuances in motion that signify potential violent interactions. The LSTM RNN, thus, becomes proficient in identifying aberrations in human movement indicative of aggressive behaviour.

Simultaneously, the audio processing component focuses on capturing audio cues associated with violent behaviours. Initial steps involve noise reduction to enhance signal quality. Subsequently, amplitude, frequency, and wave power analysis are applied to characterise the acoustic features of the environment. These features are then utilised to generate spectrograms that provide a visual representation of the audio signals. To further refine the audio analysis, Mel-Frequency Cepstral Coefficients (MFCC) spectrograms are derived. These spectrograms are considered as distinctive signatures that encapsulate the essence of the audio environment.

Through a meticulous labelling process, frames of the MFCC spectrograms are classified into two categories: fighting environment and normal environment. This labelled dataset is then harnessed to train a Support Vector Machine (SVM) model. SVM's proficiency in binary classification aids in predicting whether a given audio segment corresponds to a violent environment or a non-violent one. The trained SVM model thus serves as a powerful tool for identifying auditory cues indicative of aggressive behaviours among prisoners.

In the final phase of the methodology, the outputs of both the computer vision and audio processing models are combined. The predictions from the individual models are analyzed to determine whether they concur in identifying a given scenario as a violent or normal environment. The holistic evaluation of both visual and auditory cues enhances the accuracy of the detection system, minimizing false positives and negatives.

B) Track and detect abnormal events and activities

The methodology employed for the "Track and Detect Abnormal Events and Activities" component involves a comprehensive approach to ensure the safety and security of prisons. This component comprises several sub-objectives, each addressing a specific aspect of abnormal event detection.

The first sub-objective is to analyze real-time behaviors of prisoners. This involves continuously monitoring prisoner activities using surveillance cameras and collecting video footage for analysis. The collected data is then processed using computer vision techniques to extract relevant features and detect abnormalities.

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The second sub-objective is to analyze the footage and identify prisoners with abnormal behaviors. Computer vision algorithms, such as YOLOv5 object detection, are employed to detect and track individuals within the video frames. By analyzing the movements, postures, and interactions of prisoners, abnormal behaviors can be identified and distinguished from normal activities.

The third sub-objective focuses on identifying people in restricted areas. This involves designing algorithms that can detect and classify individuals entering or lingering in areas that are off-limits or restricted within the prison premises. By leveraging computer vision and machine learning techniques, unauthorized access can be identified, and alerts can be generated to notify prison staff.

The fourth sub-objective is to identify camera-covered areas. This involves analyzing the video footage to detect instances where cameras are obstructed or covered intentionally. By detecting such incidents, security staff can be alerted to potential security breaches or attempts to hide illegal activities.

The fifth sub-objective aims to notify prison staff about abnormal behaviors and provide them with detailed information about the prisoners involved, along with the exact location of the event. Real-time alerts are generated and sent to the appropriate personnel, enabling swift response and intervention.

Lastly, incident details are stored for future identification and reference. The collected data, including video footage, identified prisoners, and event information, is stored in a secure database for analysis, investigations, and potential evidence in the future.

This combines computer vision, machine learning, and real-time monitoring techniques to detect and track abnormal events and activities in prisons. By leveraging advanced technologies, the goal is to enhance prison security and safety by promptly identifying and responding to security threats or deviations from normal behavior patterns.

C) Suspicious behavior detection when prisoners interact with visitors

The methodology for identifying suspicious behavior during prisoner-visitor interactions involves key steps that bolster system effectiveness. This article elaborates on these steps, highlighting their importance within the research context.

One critical aspect is capturing and analyzing video data using stable cameras. These cameras record interactions, particularly focusing on facial expressions as indicators of suspicious behavior. Employing computer vision, the system extracts emotions from the footage, aiding in the identification of abnormal actions or expressions. This forms the basis of visual analysis for detecting suspicious behavior.

Simultaneously, audio data is gathered through microphones, recording conversations. The system scrutinizes these recordings, specifically targeting hate speech as a suspicious behavior indicator. Utilizing audio processing and natural language techniques, the system detects potentially alarming speech patterns. This adds to the audio analysis aspect of the overall system.

The integration of video and audio analysis is the subsequent step. Merging facial emotions from video with identified hate speech from audio, the system gains a more comprehensive view of interactions. This fusion enhances accuracy, capturing information from multiple sources to understand potential threats.

Upon identifying suspicious behavior, the system generates alerts, notifying authorities for prompt intervention. Real-time alerts ensure timely response to detected behavior, boosting overall prison security.

Lastly, the system stores incident details for future analysis. Archiving footage, audio, and metadata aids post-event investigations and system improvement. This comprehensive approach informs better detection algorithms and strategies.

Incorporating these steps, the research aims to develop a robust system for identifying suspicious behavior during prisoner-visitor interactions. Utilizing stable cameras and microphones, along with facial emotion and hate speech analysis, the system generates real-time alerts and stores incident data. Adhering to legal and ethical considerations is vital, ensuring privacy and consent of all parties involved.

D) Unauthorized equipment detection

For improving safety and security in correctional facilities, consider using the Unauthorized Equipment Detection Module. This module tackles the significant problem of identifying unauthorized equipment existing on jail premises by utilizing a variety of cutting-edge methods.

The module's primary focus is on employing security cameras to analyze prisoners' behavior in real-time. These cameras provide continuous, real-time surveillance of inmate activity, allowing for the extraction of major behavioral patterns using highly developed computer vision algorithms. The system looks for any abnormalities from normal activity

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that would point to the existence of unauthorized equipment, with a focus on knives and other weapons in particular. This real-time analysis enables rapid detection of possible security issues, enabling prison administrators to take immediate action.

The system's capacity to recognize illicit equipment, especially weapons and knives, is a crucial feature. This calls for the application of specialized computer vision algorithms, most notably the YOLOv5 object detection approach. The technology can discover and categorize illegal goods with great accuracy thanks to highly optimized algorithms. The module strengthens security measures and stops prisoners from having access to harmful materials by quickly recognizing the presence of such things.

The module's capabilities are further increased with the use of facial recognition technology. With the use of this technology, it is possible to accurately identify specific convicts who are connected to unauthorized equipment, facilitating their quick capture. The technology compares faces to the listed forbidden objects in real time using cutting-edge facial recognition algorithms, allowing authorities at jails to respond quickly and precisely.

The module examines precisely where security breaches take place in order to guarantee total situational awareness. This is accomplished by using the camera's coverage area and range of view to identify the precise location of any unauthorized equipment. Prison personnel can react quickly and efficiently to the reported incidences by giving exact location information.

Additionally improved to provide thorough security notifications is the module's real-time alert system. The device immediately informs users whenever it spots knives or weapons in the real-time camera feed. These warnings include important information about the restricted items, the related prisoner, and their exact location on the prison premises. With this knowledge, security officers are better equipped to analyze the situation swiftly and take the appropriate steps to handle the security danger.

Additionally, the module keeps track of incident information, enhancing the real-time notifications. Security personnel have access to the information they need to make wise decisions and respond to security breaches thanks to this thorough data display.

Finally, the unauthorized Equipment detection Module integrates real-time behavior analysis, cutting-edge item identification, facial recognition, accurate position assessment, and comprehensive alarm systems to produce a reliable solution for locating illicit equipment in correctional facilities. The safety and security of these institutions are greatly enhanced by this multimodal approach.

IV. RESULT

This section presents the outcomes of our research on the Computerized Prison Monitoring Application based on Knowledge Engineering, with a specific focus on the four main components: Track and Detect Abnormal Events and Activities, Suspicious Behavior Detection when Prisoners Interact with Visitors, Unauthorized Equipment Detection, and Track and Detect Violent Behaviors between Prisoners. Through rigorous experimentation and analysis, our application has demonstrated its effectiveness in enhancing prison security and safety. The following subsections delve into the detailed results and findings obtained from each component, showcasing the practical impact of our innovative approach.

The Unauthorized Equipment Detection Module has excelled at boosting security inside of prisons. The module successfully detects unauthorized guns and knives on prison property by fusing real-time behavior analysis, cutting-edge object identification, facial recognition, and exact position evaluation. This comprehensive strategy ensures quick reaction to security breaches, enhancing general safety. The following examples show how the module may accurately find objects that are prohibited.

Figure 1: Unauthorized Equipment Detection

These examples demonstrate how the module enhanced security precautions and shielded correctional facilities from potential attacks.

The included image figure 2 illustrates the successful detection of abnormal activity within the prison environment. The image is divided into two panels for comparison. The left panel displays a person situated within a normal, authorized area of the prison facility. This scene serves as a baseline for typical prisoner movements and activities.

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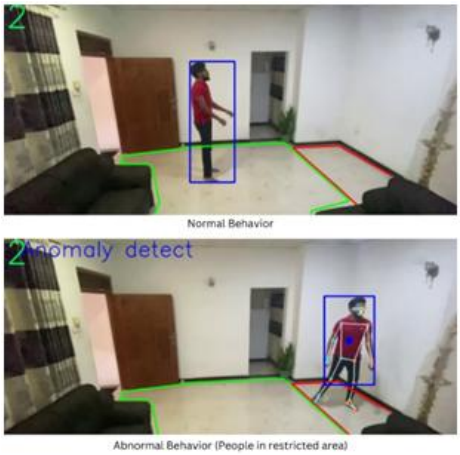

Figure 2: Abnormal Activity Detection - Anomaly Detected

In contrast, the right panel captures a person who has ventured into a restricted or unauthorized area within the prison. This breach of security triggers an immediate "Anomaly detected" alert. The image vividly showcases the application's ability to recognize deviations from standard prisoner behavior and promptly notify prison staff of potential security breaches.

The image demonstrates the effectiveness of the Computerized Prison Monitoring Application in identifying abnormal events and activities. The left panel represents a person in a normal area, while the right panel captures a person in a restricted area, resulting in the application's prompt detection and alert for further action. This visual representation highlights the application's crucial role in enhancing prison security.

Security in correctional facilities is significantly enhanced with the Violence Behavior Detection Module. The module efficiently recognizes and reacts to violent altercations and fights among convicts through real-time behavior analysis, sophisticated action identification, and exact location assessment. The examples below show how the module correctly detects this behavior:

Figure 3: Violence Behavior Detection

V. DISCUSSION

There are a number of positive outcomes that can result from the integration of a computerized prison monitoring application that is underpinned by knowledge engineering. To begin, the system is able to efficiently analyze and interpret real-time data from surveillance cameras since it makes use of knowledge engineering approaches. This paves the way for the detection of aberrant occurrences and actions that take place within the confines of the jail environment. The results of this study suggest that it is both possible and effective to use computer vision techniques, such as YOLOv5 object detection, for the purpose of accurately identifying convicts and diagnosing deviant behaviors.

In correctional facilities, the need of maintaining constant vigilance and watchfulness is brought to light by the research as well. The workers at the correctional facility can improve their ability to recognize unusual occurrences and react appropriately more quickly if they use a computerized application. The technology is able to create real-time notifications, which allow for prompt intervention. This helps to mitigate potential threats and ensures the safety of both staff members and inmates.

In addition, the research highlights how important it is to store data and do analysis when it comes to surveillance in prisons. The data that was taken from the incident, such as the video footage and the specifics of the occurrence, can be saved in a safe database for future research and reference. This information may be put to use for the purposes of conducting investigations, recognizing patterns, and possibly even serving as evidence in legal processes. The capacity to store and access incident data in an organized manner contributes to the overall strengthening of the security framework that is present within the correctional facility.

In addition, the study underlines the possibility of integrating the computerized prison monitoring program with the many security protocols and systems that are already in place. The program is able to supplement and improve the capabilities of the human-operated security infrastructure since it makes use of methodologies from the field of knowledge engineering. When combined, automated monitoring and human involvement have the potential to create a synergy that can result in increased situational awareness, enhanced decision-making, and more efficient reactions to anomalous situations.

The findings of the research are encouraging; nevertheless, there are several caveats to take into consideration. The success of the system is dependent on the caliber of the surveillance cameras and their breadth of coverage within the correctional institution. There could be a

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problem with the location of the cameras, or there could be a technical issue that prevents accurate detection and monitoring of individuals. In addition, the performance of the system may change depending on the lighting circumstances, when it is confronted with occlusion, or when it is presented with other demanding scenarios. It is recommended that these restrictions be addressed in subsequent iterations so that the application's overall dependability and efficiency can be significantly enhanced.

VI. CONCLUSION

Research on the Computerized Prison Monitoring Application based on Knowledge Engineering has shown that using advanced technologies to make prisons safer works and has a lot of promise. By combining computer vision algorithms, machine learning techniques, and real-time monitoring, the suggested application offers an automated and efficient way to track and find unusual events and activities in a prison setting.

The results of this study show that it is possible to set up a computerized system that can correctly identify prisoners, spot strange behavior, and send out alerts in real time so that help can be given right away. By using knowledge engineering techniques, the application creates a solid framework for analyzing and making sense of surveillance data. This helps jail staff be more aware of what's going on and better able to respond to it.

The study shows how important it is for prisons to have constant monitoring, data storage, and analysis. The ability to store information about incidents in a secure database makes it easier to investigate, find patterns, and improves the general security of the prison. Also, the possibility of integrating the computerized application with current security systems and protocols offers synergistic benefits by combining automated tracking with human-operated intervention.

Even though the study results look good, there are some problems that need to be fixed. The success of the system depends on how well and where the surveillance cameras work inside the prison. Technical problems, such as lighting and occlusion, can make it harder to identify and track things accurately. Because of these problems, more study and development are needed to make the app more reliable and work better.

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