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The Role of detection Algorithm in Tracking Techniques with the help of Deep Learning for an Enhanced user Experience

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Abstract: - The drum set is a prominent instrument in a variety of music genres including pop, rock, and jazz. However, it costs money and space to get from nothing to purchasing a kit. The objective of these studies is to enable drummers to hone their skills, at least blithely, without a full set of drums and to expedite the initiation of drummers to their drumming experiences without incurring any costs. Drums do not fit inside a single bag, making them more difficult to travel than other instruments. We propose a virtual drum prototype that enables air-drumming using just two sticks, a computer equipped with a camera, and readily available markers that resemble the drumstick tips, such colourful papers. The detection algorithm combines tracking techniques with deep learning technology for an enhanced user experience. This was done using the Python-based OpenCV, as well as the concept of color-based blob recognition was used to find the markers. The capacity to function as a USB controller and MIDI controllers as well as the possibility for further development as a released program have all been shown by this prototype. Results from experiments show how useful and successful this method is for producing a lifelike and immersive virtual drumming experience.

Keywords: OpenCV, YOLOv5, CNN, gesture recognition, object detection

I. INTRODUCTION

In the music business, the drums are presently the most often used percussion instrument. Learning to play a drum set is a common first step for beginners who aspire to become percussionists. A basic drum set is often costly, takes up a lot of room, and is challenging to transport, in contrast to other musical instruments like the guitar or piano. The purpose of this project is to develop a technology that will allow budding drummers to use computer vision to play as well as Play some drums. The purpose is to transform a video of an individual playing virtual drums in the case of real-time audio synthesis pertinent drum samples while taking into account genuine motions with an actual drum set Carl Timothy Tolentino et al. [1]. The project intends to provide an implementation which will enable anyone without money or practice equipment and acquire knowledge of the actual drums via a laptop's integrated web camera [30,31,32]. By optimizing a trained beforehand YOLOv5 neural network with the use of a specially created photo dataset of people pounding on the air and other surfaces, we build on these advancements. We employ a contour detection to follow the tip of the drumsticks since the image detection modules might not be entirely precise Sumathi. S et al. [2, 25, 26].

Drumming is an integral part of music production and performance. Virtual drum simulators offer an accessible and cost-effective solution, eliminating the need for physical drum kits. This paper presents an innovative approach that utilizes OpenCV, YOLOv5, and CNN to create a virtual drumming experience that accurately detects drumming gestures and produces realistic drum sounds K. He et al. [3].

II. LITERATURE REVIEW

A review study concluded that high accuracy of even 96.15% has to be verified whether the technology used is feasible or not [33, 34]. The technique used into the proposed work is OpenCV, Kalman filter and CV algorithms

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with 100% usability of the prototype. Main purpose is to play drums using computer vision [35, 36]. In this, orange markers were attached to the end of the drumsticks. Acceleration computation is used for the event detection and orange-colored papers as the markers are used for detection Carl Timothy Tolentino et al. [1].

The work proposed with a pre trained model of YOLOv5 neural network with the Dataset of 5000 images. Architecture structures such as SPPF, CSP-Darknet-53, PANet feature extractor and a Yolov3 head is used and found out the accuracy to 80%. Model was made very handy and portable, comparatively low accuracy Harel Yadid et al. [4].

The proposed work uses models like YCbCr color model, Virtual Musical Instruments (VMIs) and applications of a Gaussian filter. The techniques which are used are OpenCV, OpenCV 3.0, OpenCV music library instrument, Digital interface (MIDI) HSV with no such theoretic accuracy S. R. Fidellaga Bering [5]. Huairong CHEN et al. [6].

The model is made Hardware on FPGA implementation. Field Programmable Gate Arrays (FPGAs) are integrated circuits. They're referred to as 'field programmable' because they provide customers the ability to reconfigure the hardware to meet specific use case requirements after the manufacturing process. FPGA in a virtual drum simulator can provide several advantages, including low-latency signal processing and real-time responsiveness. Model is made on FPGA embedded systems drum simulator S. R. F. Bering et al. [7].

YUSEG: Yolo and Unet is all you need for cell instance segmentation is used as the basic architecture in this with the collaboration of YOLOv5. Data is trained and tested using algorithms where it is found of that 80% of accuracy came when the data is tested, and overall accuracy is found out to be 81.2%. The major specifications are Mosaic Data augmentation, Adaptive image scaling and filling loss function, weighted boxes fusion Bizhe Bai et al. [8,24].

The mentioned work contains algorithms such as MEMS 3D, support vector machines (SVM), K-Nearest Neighbors(KNN) and got the accuracy of 88.29 % Liguo Zhou et al. [9].

The visual recognition of object is done by deep convolution networks and convolution neural networks, where CNN is used with spatial pyramid pooling for the real time object detection, SPP-net for image classification F. A. Fiolana et al. [10].

YOLOv5 is a real-time object detection algorithm that gained popularity in the computer vision and machine learning communities. While YOLOv5 is a powerful and efficient algorithm, it may not necessarily be considered the "best" for creating a virtual drum simulator. The choice of algorithm for such a task depends on various factors, including the specific requirements and constraints of the simulator S. R. F. Bering et al. [7].

However, can highlight some general advantages and features of YOLOv5: High Accuracy, Efficient Architecture, Open Source, Pre-trained Models. However, it's important to note that a virtual drum simulator is a complex application that involves not only object detection but also audio synthesis, gesture recognition, and real-time interaction. YOLOv5 may be a component of such a system for tracking drumsticks or other objects, but it would not be the sole algorithm responsible for creating the entire simulator. That's why we are using OpenCV with YOLOv5 G. Jocher et al. [11].

The "best" algorithm or approach for a virtual drum simulator would depend on various factors, including the specific goals of the simulator. YOLOv5 has less complexity, high performance and had better used cases. So, YOLOv5 is preferred J. Redmon et al. [12]. C. Y. Wang et al. [13].

Attachable sensors were employed by certain portable drum system approaches to monitor the direction as well as velocity of the sticks. These sensors have the advantage of being more responsive to changes in velocity and requiring fewer setup steps than a camera. However, due to cost considerations, these sensors may stay inaccessible to the general population. Free drum, which costs roughly $235 for a whole kit, is an example of this in a commercial context Carl Timothy Tolentino et al. [1].

There are further works that use a OpenCV method to implement virtual drums. These devices have the advantage of being equipped with a camera right away. However, the methods could be tough to utilize in real time.

“Virtual Drumming” by VirtualDrumming.com, Virtual Drumming is an online platform that offers a virtual drumming experience. It provides a virtual drum kit realistic sound and allows users to play along with pre-recorded songs or create their own drums tracks C. T. Tolentino et al. [14].

III. SYSTEM ARCHITECTURE

The proposed virtual drum simulator system consists of multiple components. This section describes the overall architecture, including the video input module, the object detection module based on YOLOv5, the gesture recognition module using CNN, and the audio synthesis module. The interaction between these components ensures real-time detection of drumming gestures and the generation of corresponding drum sounds.

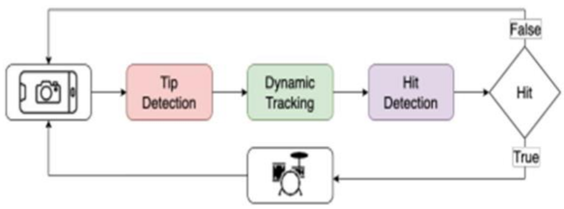


Figure.1. The algorithm for real-time detection and tracking

IV. METHODOLOGY

Because the YOLOv5 network had already been pre-trained to identify objects on common photos, we applied learning transfer techniques to adapt it to our particular task. The prototype of the virtual drum system was created with OpenCV version 2 or higher and Python 3.10

The methodology is separated into four major steps:

1. Tips Detection

2. Tip Tracking and Estimation

3. Hit detection algorithm

4. Drum Sound Synthesis.

4.1 Tip Detection:

Firstly, the preprocessing of the frame is done using the OpenCV algorithm. OpenCV detect objects based on their color and draw rectangles and circles on the video frame. This includes resizing of frame, converting it into RGB color space using HSV color space. The code coverts RGB color space of video feed into the HSV, which is a more intuitive way to represent colors. The HSV color model has three channels: Saturation, hue, and value, and the code uses this representation to filter out objects based on their color Xin Wang et al. [15].

We are using YOLO v5 algorithm to detect drumsticks in a frame. The algorithm should output the bounding boxes of the drumsticks.

We compute the three's location R[n], velocity M[n], and acceleration O[n]. key points.

the following equations are used to calculate the dynamics. Carl Timothy Tolentino et al. [1]

$$R(n) = \begin{bmatrix} a(n) \\ b(n) \end{bmatrix} \quad (1)$$

$$M(n) = \frac{\|R(n) - R(n-1)\|}{\Delta x} \quad \Delta x \text{ is the time step} \quad (2)$$

$$O(n) = \frac{M(n) - M(n-1)}{\Delta x} \quad (3)$$

$$\hat{}p(n) = C(n) \,.\, R(n) + (1 - C(n)) \,.\hat{}R(n-1) \quad (4)$$

where C(n) is the Kalman gain at time n

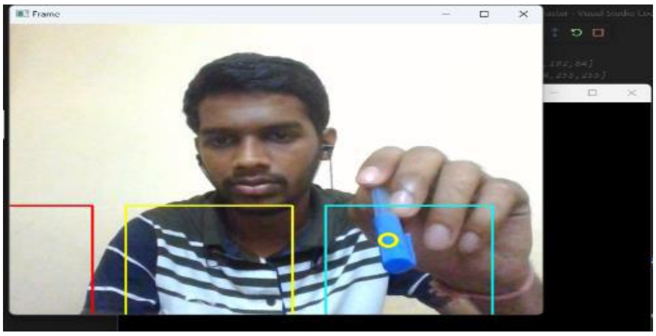


Figure.2. Real-time tip detection in difficult situations

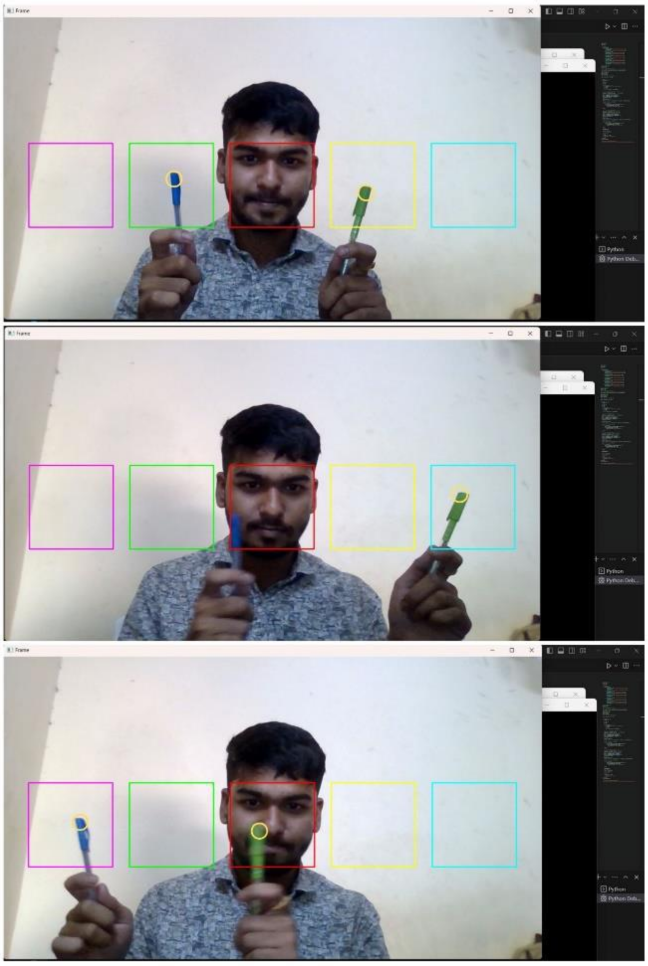


Figure .3. An example Display seen by a user when using our virtual drum system's initial mode

4.2 Estimation and Tip Tracking:

Although the precision of YOLO is superior than other computer vision techniques, it does have two limitations. As with any other type of object detection technology, YOLO is not perfect. In other cases, either none of the drumstick ends are recognized or only one of them is. Second, YOLO only tells where the points are situated inside a specific frame. As a result, anything that occurs between frames will entirely evade the detection system M. Tan et al. [16].

To do this, we use the well-known Kalman filter and consider the issue as a tracking with fading targets. As a result, the filter may be able to approximate the location of the intended target even in the absence of a position measurement. To increase contrast and accentuate the tip area, use thresholding methods on the area around the tip. This can be done using techniques like adaptive thresholding. Analyzing the thresholded tip region to find the coordinates of the tip. The techniques like contour detection or edge detection are used to identify the tip region accurately. Once the region is detected, the centroid or the highest point within the region is extracted to obtain the coordinates of the tip S. Liu et al. [17].

where p(t) denotes position, ω(t) N (0; ω) denotes driving noise, and v(t) N(0; v) denotes measurement noise. were thought to be static white sounds. Discretized time systems, the driving force input is ωk, and the measurement noise is vk.

$$\frac{d^2}{dt^2}P(t) = \omega(t) \quad \Rightarrow \quad x_{k+1} = Ax_k + G\omega_k \qquad (5)$$

$$y(t) = P(t) + v(t) \qquad y_k = cx_k + v_k$$

$$A = \begin{bmatrix} 1 & T \\ 0 & 1 \end{bmatrix} \;; \qquad G = \begin{bmatrix} \frac{T^2}{2} \\ T \end{bmatrix}; \qquad (6)$$

$$c = [10\ 0\ 0]; \qquad Q = \begin{bmatrix} \frac{T^4}{4} & \frac{T^3}{2} \\ \frac{T^4}{2} & T^2 \end{bmatrix} \sigma_\omega$$

4.3 Algorithm for detecting hits:

The detection of hits system assesses if a hit took place inside a drum's zone. The circular area around the drumstick is displayed. When an updated location estimate is received, the normal distance between the tip and each of the sticks is computed, and the estimate is associated with the nearest tip. Then, for each queue, there is a zero-crossing algorithm used to identify a change in the movement of the tip in one direction. Because estimations A detection threshold may be noisy. was added to filter out unwanted zero-crossings, such as drumstick remaining static or inadvertent erratic movement. In the event of a hit, a suitable sound is produced. Depending on the last frame zone, as well as the volume of the sound proportional to the speed of the tip is measured [4,18,22].

4.4 Drum Sound Synthesis:

Our virtual drum set includes eight drum components (1) Ride Cymbal, (2) Hi-hat, (4) Left Tom, (5) Right Tom, (6) Snare, (7) Bass, and (8) Floor Tom. Figure 4 depicts the location of these components. When a drum pad is touched, the appropriate drum sound is created depending on the hit's calculated position given the predetermined bounding boxes. Python modules called Pygame are created specifically for creating video games. The code uses the pygame library to play the sound effects when the sticks hit the virtual drums on the screen S. R. F. Bering et al. [7]. M. F. Kholid et al. [19]

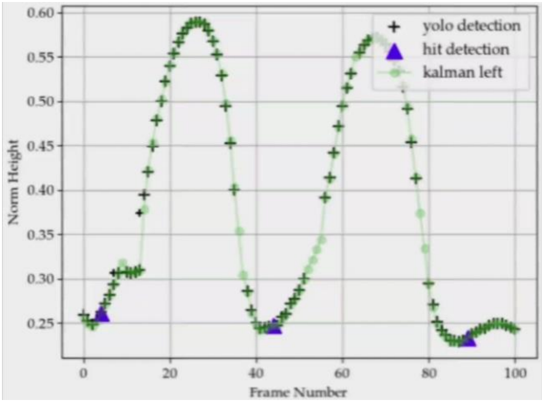
V. EMPIRICAL RESULTS

Our application is being evaluated in two ways. The first part is technical in nature, with the goal of evaluating the system's qualitative performance in relation to the design criteria and objectives. For example, network detection performance, tracking and estimate skills, and so on. The second part is the system's user experience, such as interaction with the system, perceptible delays, and so on. The laptop was used for all the research stage's experiments, consisting of a standard AMD Ryzen 5500U processor with Radeon Graphic card, 2100 MHz, 6 cores(s), 12 Logical Processors(s)

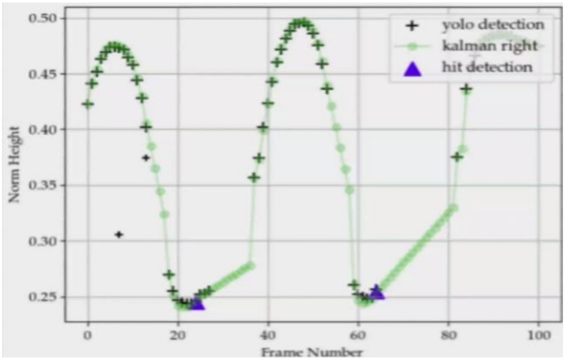
5.1 Performance Results:

The first evaluation compared the total system's real-time detection performance versus detection just by the detection network. The goal of this assessment is to evaluate the system's resistance against occlusions and miss detection, as well as to examine the system's estimating skills. Dark crosses indicate that the tip was identified by the detecting network, effective detection for the frames. The red triangle denotes a hit detection, while the light circles show how the Kalman filter evaluated the position of the tip. The camera collection rates and the time step of the Kalman filter were in sync in this instance. The time step associated with the Kalman filter, however, can often be multiples of its acquisition rate K. Simonyan et al. [20].

Additionally, we established a pair of metrics. The amount of hits that really happened but were overlooked by the algorithm is counted under false positive hits (FP). The second, known as false negative hit (FN), keeps track of how many hits the algorithm mistakenly categorized as false positives (no real hit). The effectiveness of these two measurements was evaluated against a variety of beats per minute (BPM). The percentage that represents the value of the measurement is calculated for each test after the user has continuously thumped for five minutes A. Krizhevsky et al. [21].



Left Hand



Right Hand

Figure. 4. Over 100 frames of drumstick movement along the y-axis (up and down). The frames were captured from a detection of a drumstick striking three times with each hand, three times in a row, at 80

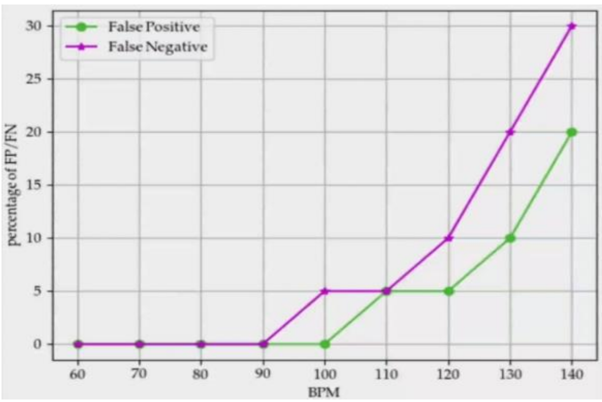


Figure 5. FP and FN detections at tempos ranging from 60 to 140 BPM.

5.2 User Survey:

We undertake a qualitative evaluation of our system using a survey of ten respondents. Freshmen who weren't familiar with playing the drums earlier, intermediates who have tried their hand a few times, and experienced players who play for enjoyment make up the three groups of responders. Each participant was asked to react to the following questions after the five minutes had passed:

1) How often have you observed a lag?

2) How frequently has the system been unable to find a hit?

3) What number of times has the system inaccurately sounded?

4) How will you evaluate your whole experience?

In our study, 40% of respondents were new to the game, 40% were intermediate, and 20% were advanced. The responses reveal that as user knowledge increases, so does sensitivity to delays and misses. As a result, overall system fulfillment suffers. The outcomes demonstrate that the objective of developing a system appropriate for leisure activities with regard to high pleasure, particularly for novice to advanced users, was accomplished. Furthermore, with an overall rating of 87%, The system is sufficient for even advanced users Harel Yadid et al. [4].

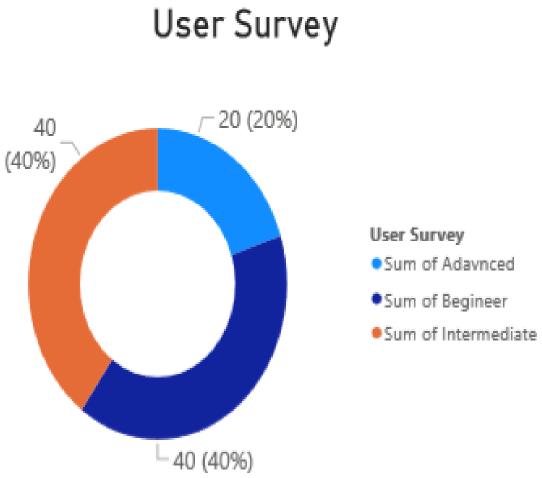


Figure 6. Result of User Survey

Question\Level	Beginner	Intermediate	Advanced
Q1	10%	20%	35%
Q2	10%	15%	25%
Q3	10%	20%	25%
Q4	95%	90%	80%

Table 1. Results of User Survey Questionnaire

5.3 Results and Discussion:

The experimental results demonstrate the efficacy of the virtual drum simulator using OpenCV, YOLOv5, and CNN. This section presents and discusses the results obtained from the performance evaluation. It also addresses potential challenges and areas for improvement in terms of accuracy, latency, and system responsiveness.

5.4 Future Directions:

The future development of virtual drum simulators holds great potential for further innovation and improvement. AR/VR technology integration, real-time collaboration tools, and improved AI capabilities are a few potential future developments that are highlighted in this section. It also discusses the importance of continued research and development to address the current limitations and challenges

VI. CONCLUSION

The proposed virtual drum simulator offers a novel approach to drumming experience by leveraging computer vision techniques, object detection using YOLOv5, and CNN-based gesture recognition. This research paper has outlined the system architecture, data collection, model training, and performance evaluation. The outcomes of the experiment show how this strategy has the potential to produce a lifelike and engaging virtual drumming experience. Future research directions include further refinement of the system, user interface enhancements, and exploring the integration of additional technologies for an enhanced drumming experience. As technology continues to advance, virtual drum simulators have the potential to revolutionize drumming education and performance, opening new opportunities for drummers and music enthusiasts alike.

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