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Empowering Blind Tennis via Music

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ABSTRACT
Lawn Tennis is one of the most popular sports all around the world. Especially, during last few years, a great deal of high-end technology is being used to follow every point of every match of the Tennis Tournaments. Unfortunately, visually challenged players cannot take the pleasure of following and playing this sport completely as they face the challenge of determining the position of the ball accurately on the court which increases their stress and anxiety levels and hence numerous players eventually give up. The training period is difficult not only for the visually-impaired players but also the coaches because the players have to be trained rigorously to determine how the ball is being hit, from where it is currently, and where the ball will land on the court. So, there is a high need for a system that makes the sport more enjoyable and less stressful for the visually-impaired people. Moreover, the existing system to play the sport of Blind Tennis makes use of sound balls, special balls that rattle when they bounce. This paper presents a comprehensive survey of Blind Tennis, the existing technologies that analyze the game and propose a system that would enable the visually-impaired people to not only play the sport but also follow the sport with enthusiasm just like general public by following every point of the match closely.

General Terms
Object Recognition, Object Detection, Blind Tennis

Keywords
Blind Tennis, Object Detection and Tracking, Sound Generation, Computer Vision.

1. INTRODUCTION
The World Health Organization estimates that 285 million people are visually impaired worldwide: 39 million are blind and 246 have low vision. Out of these, 12 million are from India, which makes India home to one-third of the world's blind population [41]. To cater to the entertainment needs of these people, blind tennis was created in Japan, in Kawagoe in 1984 by Miyoshi Takei. He was a blind student who wanted to play tennis, and along with his physical education teacher, they tried to adapt to this sport. After working several years developing the ball and the rules, as more and more people started to lay the first tournament took place in Japan in October 1990. Blind tennis features a smaller court, lower net and junior tennis rackets with bigger heads and shorter handles. The string is taped to the floor so players can feel the boundaries with their feet. Players use a foam ball filled with metal beads that rattle on impact, allowing them to locate the ball when it hits the ground or racket. Once served, they have to return the ball before it bounces three times. But blind or visually impaired people have a considerable disadvantage as they lack information for bypassing obstacles and have relatively little information about landmarks, heading, and self-velocity. Visual information is the basis for most navigational tasks, so visually impaired sports-persons are especially at a disadvantage because necessary information about the surrounding environment during competitions is not available.

Assistive technology enables people with disabilities to accomplish daily tasks and aids them in communication, education, work and recreational activities. In general, it helps them to achieve greater independence and enhance their overall quality of life. From the different assistive technologies available, a special focus was put on those that enhance the mobility of blind or visually impaired people.

With the recent advances in inclusive technology, it is possible to extend the support given to players with visual impairment during their mobility. In this paper, we propose a system, whose objective is to give blind sportsperson the ability to move around in an unfamiliar environment, through the medium of sound and its scope. There are three key steps in developing the blind tennis system:

1. Recognition of target objects, primarily ball, used during the match.
2. Tracking of such objects from frame to frame.
3. Production of apt sound tones according to the spatial location of the ball in real-time.

2. REVIEW OF EXISTING SYSTEMS
The authors in [2] have proposed a trajectory based algorithm to detect and track the ball in broadcast tennis video (BTV). The algorithm is used to decide whether the trajectory is a ball trajectory and is able to locate the ball locations for most frames in BTV.

The authors in [3] have proposed an interactive object annotation method that incrementally trains an object detector while the user provides annotations. The authors have focused on minimizing human annotation time rather than pure algorithm learning performance. The method proposed by the authors is suitable for both still images and videos.

The authors in [4] present an algorithm, which offers the possibility to control remote software with information extracted from the digital image of a human hand. The paper primarily focuses on human hands, whereas it should have tested the same for other body parts or other obstacles as well.

The authors in [5] consider a method for improving the runtime of general-purpose object-detection algorithms. The method proposed by the authors is based on a model of visual search in humans, which schedules eye fixations to maximize the long-term information accrued about the location of the target of interest. The approach can be used to drive robot cameras that physically scan scenes or to improve the scanning speed for very large high-resolution images. They have evaluated the approach using the OpenCV version of the Viola-Jones face detector.

The authors in [6] consider the problem of object detection. A short description of the implementation of the object detection system with a discriminatively trained part based model and a gradient boosting trees algorithm is given. The algorithm is successful but it is based on the research part more (machine learning). The research is basically more inclined towards the machine learning part which makes the scope of this research concise.

The work in [7] deals with multi moving object detection and tracking under moving camera. Moving objects are detected by homograph-based motion detection. After moving objects are detected, we apply online-boosting trackers to track moving objects.

The authors in [8] introduce OpenCV software as an important tool in the field of Computer Vision. The paper explores various built-in algorithms for detecting static and moving objects using the software.

The authors in [9] have proposed to track and detect real-time images using high tech cameras and OpenCV based on image processing.

The authors in [9] have developed and implemented object detection and tracking system operational in an unknown background, using real-time video processing and a single camera.

The authors in [10] introduce a technique for automating the methodology of detecting and tracking objects utilizing color feature and motion. Video Tracking is the methodology of finding a moving object over the long distance using a camera. The main aim of video tracking is to relate target objects in consecutive video frames.

The author in [12] has proposed a system that uses ultrasonic sensors capable of detecting obstacles a maximum of two to three feet away from the user and signal it to the user to notify about any object ahead.

The author in [13] explores the inadequate designs of current sound generation systems. The paper also provides new techniques to generate sound using High Pitch Bat technology and Sound Overloading.

The authors in [14] focus on the spatial audio technique implemented for 3D multimedia content including spatial audio and video. The spatial audio rendering method based on wave field synthesis is particularly useful for applications where multiple listeners experience a true spatial sound while being free to move around without losing spatial sound properties.

The authors in [15] discuss some famous and basic algorithms of object detection and tracking and also give their general applications and results.

The authors in [16] start with the introduction to human face detection and tracking, followed by an apprehension of the Vila Jones algorithm and then discussing the implementation in real video applications.

3. METHODOLOGY

The proposed system uses cameras and computer vision for object detection and tracking. When the ball hits the ground, appropriate sound is generated and transmitted to the blind player according to its position. Block Diagram of proposed system –

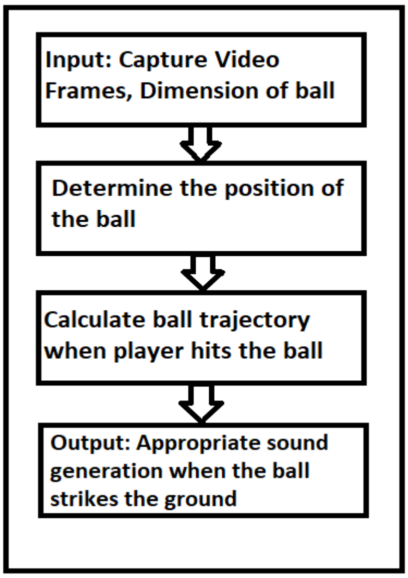

Fig 1. Overview of our proposed system

Locating an object in successive frames of a video is called tracking. The definition sounds straightforward but in computer vision and machine learning, tracking is a very broad term that encompasses conceptually similar but technically different ideas. OpenCV is a library of programming functions mainly aimed at real-time computer vision. The high-definition cameras detect the field, player, and ball. After detection, OpenCV will be used for tracking the detected objects. The input of our system is a frame captured using a camera. In the first frame, we mark the objects that we intend to track. Using OpenCV the marked objects are continuously tracked. The position of the ball and player is being detected and the continuously changing position of the ball is determined. As soon as the player hits the ball trajectory of the ball is calculated using different algorithms. The calculated trajectory will produce sound and the output in the form of sound conveys the position of the ball to the headset of visually-impaired player.

Table 1. Summary of work on Object Detection & Tracking and Sound Generation

Work Cited	Parameter	Features	Additional Features	Dataset	Evaluation Measure
5	Object Detection & Tracking	Object Detection & Tracking, Hitting Detection, Ball Trajectory, Ball location computation	---	Total frames with ball detected-2644 Total frames-2754	Accuracy- 96%
[3]	OpenCV	Creation of Mask of Tracked Object, Mask Segmentation, Thumb Identification and Naming of Fingers, Designed Graphical Interface	---	---	---
[4]	Optimal Scanning	Digital Fovea, Object Detection	Multinomial Distribution	3,500 images of faces	1/5th were < 10% of the image major axis, and 1/5th each were 10-20%, 20-30%, 30-40% and 40%+ of the image major axis
[5]	OpenCV	Pattern Recognition, Image Analysis	Gradient Boosting	---	---
[6]	Object Detection &Tracking	Homograph, Online Boosting	---	---	---
[7]	OpenCV	3D reconstruction, Visual Tracking, Image Registration	---	---	---
[8]	OpenCV	Video Stabilization, Object Detection	Panorama Stitching	---	---
[9]	Object Detection & Tracking	Color Segmentation, Edge Tracking, Real-time Object Tracking, Recognition	Contrast Stretching, Histogram Equalization	---	---
[9]	Object Detection & Tracking	Object Detection, Real-time Tracking, Background Subtraction, Motion Detection	Morphologica l Filtering	---	---
[10]	3D Sound	3D ETA Jacket, 3D ETA Glove, 3D ETA Stick	---	---	---
[12]	Obstacle Signaling	Sensory Substitution, ETA	---	---	---
[13]	3D Sound	WFS, Convolution, FFT	---	---	---
[14]	Object Detection & Tracking	Real-time Object Tracking, Object Detection, Object Segmentation,	SIFT, Camshift	---	---
[15]	Human Face Detection & Tracking	Adaboost, Real-time Object Tracking	---	---	Adjustment of the threshold can be done to detect 100% of the faces with a false positive rate of 40%
[16]	Object Detection	SIFT, SURF, Object Detection, Visual Substitution	PCASIFT	---	---

4. CONCLUSION

This paper brings altogether a new system, representations, and insights which are generic and may well have broader application in supporting visually impaired sports. There exist algorithms which contain object detection and tracking and sound generation but isolated, our proposed system a both the algorithms merged together. Finally, this paper presents a set of detailed experiments on sound generation, ball and player detection and tracking the ball which has been widely studied. This includes a wide range of conditions including; real-time ball tracking and detection, ball trajectory, sound generation and camera variation. Nevertheless, the system is flexible enough to adjust according to the changing conditions. The proposed system makes the sport of blind tennis easier to grasp, play and follow for the visually-impaired people.

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