# A cutting-edge system for managing a professional team in real-time, akin to a virtual coach

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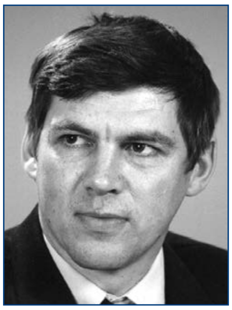

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**Abstract**

**Objective of the study** was to creating a dynamic game management system that operates in real-time for a professional team («Computer Coach»).

**Methods and structure of the study.** In the experimental phase of the research, a comparative evaluation of the efficiency of computer vision algorithms employed to analyze video footage of basketball games in the ASB Division championship in the Sverdlovsk region was conducted. The data obtained were used to assess the precision and performance of mathematical models designed to address the challenges of the control system.

**Results and conclusions.** The objectives of calculating the three-dimensional coordinates of players with an accuracy of 0.4 meters, identifying players, the ball, tracking players, categorizing teams of players, and recognizing numbers on jerseys were achieved. Without the use of neural networks, it was possible to identify 30 types of technical and tactical martial arts (TTA), a method for generating voice commands in real-time, and elements of communication with players were implemented. We estimate the potential impact of the implementation at 22-28% of the additional points scored, however, due to a number of technical constraints, it is not yet possible to fully utilize the project's potential. The authors are eager to collaborate with professional clubs to complete the project.

***Keywords:*** *game management system, sports, coach, information technology, big data, machine learning, optimization, team effectiveness.*

**Introduction.** Computer vision is actively used in sports to engage viewers, analyze performance, identify movements, improve technique during visual control, adjust the accuracy of decisions, and create heat maps with data on team strategy. Computer vision has long been involved in refereeing matches at the level of recording the ball going out of bounds or crossing the finish line. For example, algorithms can track body position and provide feedback on the correctness of the exercises, as is done with YOLOv8. In addition, systems such as Hawk-Eye are used to improve the accuracy of refereeing decisions in tennis and football. Computer vision is used to create interactive elements in broadcasts, such as augmented reality, which provides viewers with live statistics and heat maps of players directly on the screen. However, for mass development, it is necessary to resolve issues of cost, economics, and data rights. Companies have emerged that are capable of implementing such solutions for the customer (ultralytics.com). This work is a continuation of the previously published work [1] on the «Computer Coach» project in basketball. We have managed to integrate computer vision into game management, but a number of technical difficulties are holding back the completion of the project.

In sports, computer vision is implemented in the SAP Sports One and Oracle Sports Cloud systems. They provide information about the movement of players on the field during a competition using GPS sensors, recording games and training from several angles. During the game, these records can be viewed by coaches to make immediate tactical adjustments and give instructions to players. After the game, coaches can use them for more detailed analysis, identify errors and develop new strategies.

TTA recognition presented in the SAP Sports One Match Intelligence, Oracle Sports Cloud Premier, IBM Watson Sports Analytics systems do not participate in the formation of a game management strategy, but only provide information to coaches for further decisions.

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**Results of the study and discussion.** A mathematical model of dynamic management of competitive activity in real time has been developed, providing high accuracy of results (more than 93%), prompt analysis of relevant information reflecting the dynamics of situational changes. The model includes a computer vision algorithm for calculating the coordinates of players, calculating three-dimensional coordinates of the ball, detecting players, the ball, tracking players, classifying teams of players, recognizing numbers on T-shirts. Ball detection at sports competitions is implemented using a neural network with the YOLOv8m architecture trained on a custom data set. As a result of training the model on this data set, it was possible to obtain metrics of completeness – 73% and accuracy – 93% (see table). The detection results are visualized in Figure 1.

*Results of the trained segmentation network model based on the original dataset*

| Network architecture | Number of images | Box_Precision | Box_Recall | Mask_Precision | Mask_Recall |
|---|---|---|---|---|---|
| yolov8n-seg.pt | 349 | 0,92 | 0,6 | 0,79 | 0,52 |
| yolov8s-seg.pt | 349 | 0,9 | 0,7 | 0,8 | 0,58 |
| yolov8m-seg.pt | 349 | 0,93 | 0,73 | 0,78 | 0,63 |

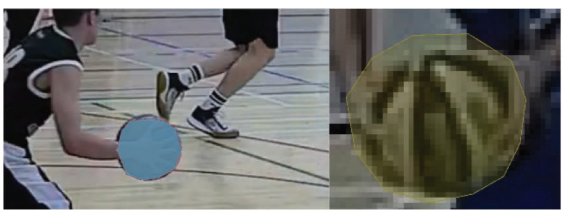

*Figure 1. Segmentation mask of the found ball*

The segmentation mask of the ball is then fed to the input of the 3D coordinate calculation module, based on the principles of projective geometry using camera parameters and multiple viewpoints of the ball, thus ensuring high reliability in case of occlusions, which are frequent and serious in team sports such as basketball or American football. The algorithm was upgraded to work in real time: instead of the computationally intensive operation of synchronizing frames from several cameras, a reference value was added - the diameter of the ball, which made it possible to use a single camera with a total accuracy of up to 40 cm. The algorithm was also expanded by a method for calculating the basic coordinate system based on the field markings and a spatial filter to exclude detections that go beyond the playing field. To identify and track athletes throughout the competition, a tracking system based on the ByteTrack algorithm was developed. Each player was assigned a unique identifier, which allows tracking their movements in real time. The ByteTrack algorithm, adapted for low frame rate sports videos (8 and 12 FPS), matches the current position of a player with his predicted location calculated using the Kalman filter. To evaluate the effectiveness of the proposed approach, a comparative study of the Deep Oc Sort, Oc Sort, Bot Sort and Strong Sort algorithms was conducted, applied together with various pre-trained models (Os Net, ResNet, Mobilenet) on standard datasets (MSMT17, Market1501, Duke). The experimental results presented in Figure 2 demonstrate that the Byte Track algorithm provides the highest accuracy of tracking athletes in real sports competition conditions.

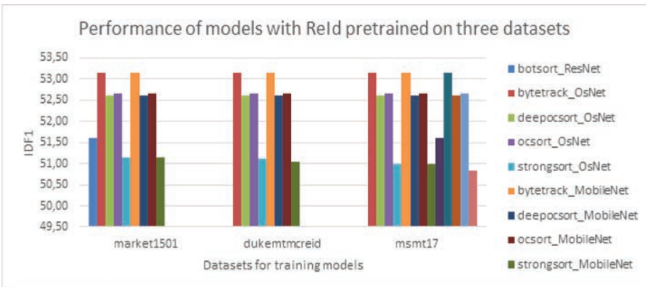


*Figure 2. Quality of tracking methods*

To identify the TTA, a list of indicators was developed: attack direction, attacking team number, index, ball possession, distance between players, exchange, speed of movement, ball position relative to the player, height and width of the box, defender position on the line between the ball and the ring, change in direction of movement. This list allowed us to solve the problem of identifying the TTA without using artificial intelligence.

The PIRS technology [2] was used as a basic model for the decision-making system. The team and player ratings are used to evaluate the results of interaction between players and the team. The state of the system depending on the control actions at time t can be written as follows:

S=Si(t, PIRS)={(x, y) 0/i,(x, y) k/i, T(TTE),(N1, N2); ti}

Based on the model calculations, the system selects the best combination of actions from the database (300-1000 options). The optimal replacement, position on the field, and optimal number of single combats are selected individually at each moment in time.

The system uses headphones for audio prompts that are sent to all players simultaneously. There is no direct ban on headphones, so this will not interfere with its further operation.

To simultaneously broadcast prompts to several headphones, the VAC control panel, Audio repeater system was used, capable of transmitting sound from a computer to all headphones connected to it.

The necessary information sent to the players was pre-structured into the following groups of actions: substitutions; defensive exchanges; the most deviating indicator from the required one; attack combination. The most difficult aspect turned out to be the formation of prompts for attack combinations. The dataset contains over 500 combinations, which can have an individual name. To advance in this matter, it was decided to call the exchange and type of TTA. The work is shown using basketball as an example, but is applicable to all team sports.

**Conclusions.** 1. A mathematical model for managing a professional team game has been developed using a complex of neural networks, including computer vision algorithms based on video recording. The following tasks were solved: calculating the coordinates of players, calculating the three-dimensional coordinates of the ball, detecting players, the ball, tracking players, classifying teams of players, recognizing numbers on T-shirts. A method for calculating the coordinates of players using spatial transformation methods using reference points, which were the field markings, was also developed, which made it possible to estimate the coordinates of players with an error of 40 cm. A mathematical algorithm for recognizing the ball using a segmentation mask based on the Yolo architecture was created, with an accuracy of 94%. An algorithm for determining the location of the ball in the coordinate system of the playing space was also developed, using a segmentation neural network, coordinates of contour points in the image and transformation methods that allow obtaining 3D coordinates with an error of 10 cm. A comparative analysis of player tracking algorithms (DeepOcSort, OcSort, BotSort) was performed, among which ByteTrack showed the best result using the pre-trained OsNet model.

2. To identify TTA, the following indicators were used: attack direction, attacking team number, index, ball possession, distance between players, exchange, speed of movement, position of the ball relative to the player, height and width of the box, location of the defender on the line between the ball and the ring, change in direction of movement. An algorithm for their determination was created. A specialized recognition model was developed for each type of TTA. The PIRS mathematical model was used as a basic model for the decision-making system, using a system of mutual ratings of players and teams based on won single combats.

3. To develop the practice-oriented technology «Computer Coach» in basketball, an algorithm of its operation was created, technical problems were solved (camera parameters, voice communication, etc.), a method for generating voice commands in real time, elements of communication with players were implemented, the «Computer Coach» project was tested using the example of games of student teams, an excess of results by 9 points was obtained, which indicates the advantage of the automated system over expert coaching assessment.

The selected methods of computer vision and algorithms for determining TTA allowed us to implement the computer trainer project as an automatic system for managing the game of professional teams in real time.

**References**

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