RAPPORT DE PROJET DE FIN D'ETUDES

Development of a Semi-Automatic Mobile Application for Handball Shot Speed Analysis

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1. Problematic :

1.1. Context of the Study :

Handball is one of the most popular collective sports in the world, particularly in Europe and North Africa, where it is played at both professional and amateur levels. Over the last few decades, the game has evolved considerably, with athletes becoming faster, stronger, and more technically skilled. Consequently, the demands placed on coaches to develop efficient training methods and tools have increased significantly.

Among the key determinants of performance in handball, the shot plays a central role. A team's success often depends on its ability to generate fast, precise, and well-placed shots that can surpass the opposing goalkeeper. The evaluation of shots is therefore a fundamental aspect of player training. Two criteria are particularly important in this evaluation:

- **Velocity**: the speed at which the ball travels after being released by the player. A higher velocity generally reduces the goalkeeper's reaction time and increases the chances of scoring.
- **Precision**: the accuracy of the shot relative to the intended target, which determines the effectiveness of offensive play.

Traditionally, the evaluation of these parameters has been conducted through subjective observation by coaches or, in more advanced settings, through the use of specialized equipment such as radar guns, video analysis systems, or motion tracking sensors.

1.2. Limitations of Existing Methods :

Although several tools currently exist to measure the velocity of a handball shot, they are often associated with important limitations that hinder their practical adoption. Radar guns, for example, while precise, are expensive and require specific positioning and calibration, making them difficult to use in ordinary training contexts. Other methods, such as manual stopwatch measurements or simple video timing, are both imprecise and highly dependent on human reflexes, which significantly reduces their reliability. Even when computer-based solutions are used, they often lack flexibility, being tied to specific hardware configurations or requiring technical expertise that many coaches do not possess. Moreover, most of the existing solutions focus exclusively on the instantaneous measurement of a single shot without providing the possibility of storing results or analyzing long-term trends. This absence of integrated data storage and performance evolution analysis prevents coaches from tracking improvements, comparing players objectively, or identifying recurring weaknesses that could guide training strategies. Consequently, current methods fail to combine affordability, accuracy, usability, and long-term monitoring in a single coherent system, which highlights the need for developing a more practical and effective semi-automatic solution.

systems, or advanced video tracking platforms offer more objective measurements, but they come with substantial financial costs that are prohibitive for many clubs. Moreover, these technologies are often complex to operate, requiring specific technical expertise, additional personnel, or lengthy setups that are impractical in regular training environments. Consequently, their use is largely confined to elite-level teams with the necessary resources. For the vast majority of local and semi-professional clubs, there remains a lack of accessible and reliable solutions to evaluate performance with accuracy. This creates a considerable gap between what is available at the professional level and what grassroots coaches can realistically implement, leaving many athletes without the benefit of objective performance feedback.

1.3. The Need for an Accessible and Automated Solution :

The emergence of artificial intelligence and computer vision has opened up new possibilities to overcome these challenges by offering innovative approaches to performance analysis. With the proliferation of smartphones and affordable cameras, it has become feasible to design applications capable of tracking the trajectory of a ball, measuring its speed, and analyzing its precision without relying on costly specialized equipment. Such solutions would represent a major advantage for coaches, as they could objectively measure the velocity of shots, determine their accuracy relative to the target, and track progress over time with reliable data. In addition, the automation of the evaluation process would allow immediate feedback to players, thereby enhancing motivation, encouraging self-correction, and supporting continuous improvement. More importantly, these tools would democratize access to performance analysis, making advanced evaluation methods available not only to professional teams but also to local clubs, schools, and individual athletes who previously lacked the means to use such technologies. By bridging this gap, an intelligent and accessible application has the potential to transform handball training practices and contribute to raising the overall level of the sport.

1.4. Problem Statement

Given the importance of evaluating shot quality in handball and the limitations of existing methods, it becomes necessary to ask the following question:

How can we design and implement an intelligent, accessible, and automated application that enables coaches to evaluate their players' shots in terms of velocity and precision, while remaining practical, affordable, and adapted to real training conditions?

How to store shots and analyze the performance of players ?

This problematic lies at the intersection of sports science, computer vision, and digital innovation. The resolution of this challenge requires not only technical expertise in image processing and AI but also an understanding of the practical constraints faced by coaches during training sessions.

2. Semi-automatic Solution :

2.1 Principle of the Semi-automatic Approach :

The evaluation of handball shots through digital tools requires translating the physical motion of the ball into measurable data such as distance traveled, time elapsed, and resulting velocity. A fully automatic system would detect and track the ball without any user intervention. However, such a system is highly complex, requiring sophisticated machine learning models, high-quality training data, and robust hardware. In this project, as an intermediate step, a semi-automatic approach has been developed. The principle of this solution is to involve both the computer and the human operator (the coach or analyst) in the process of measurement, thereby simplifying the technological requirements while still ensuring accurate and reliable results.

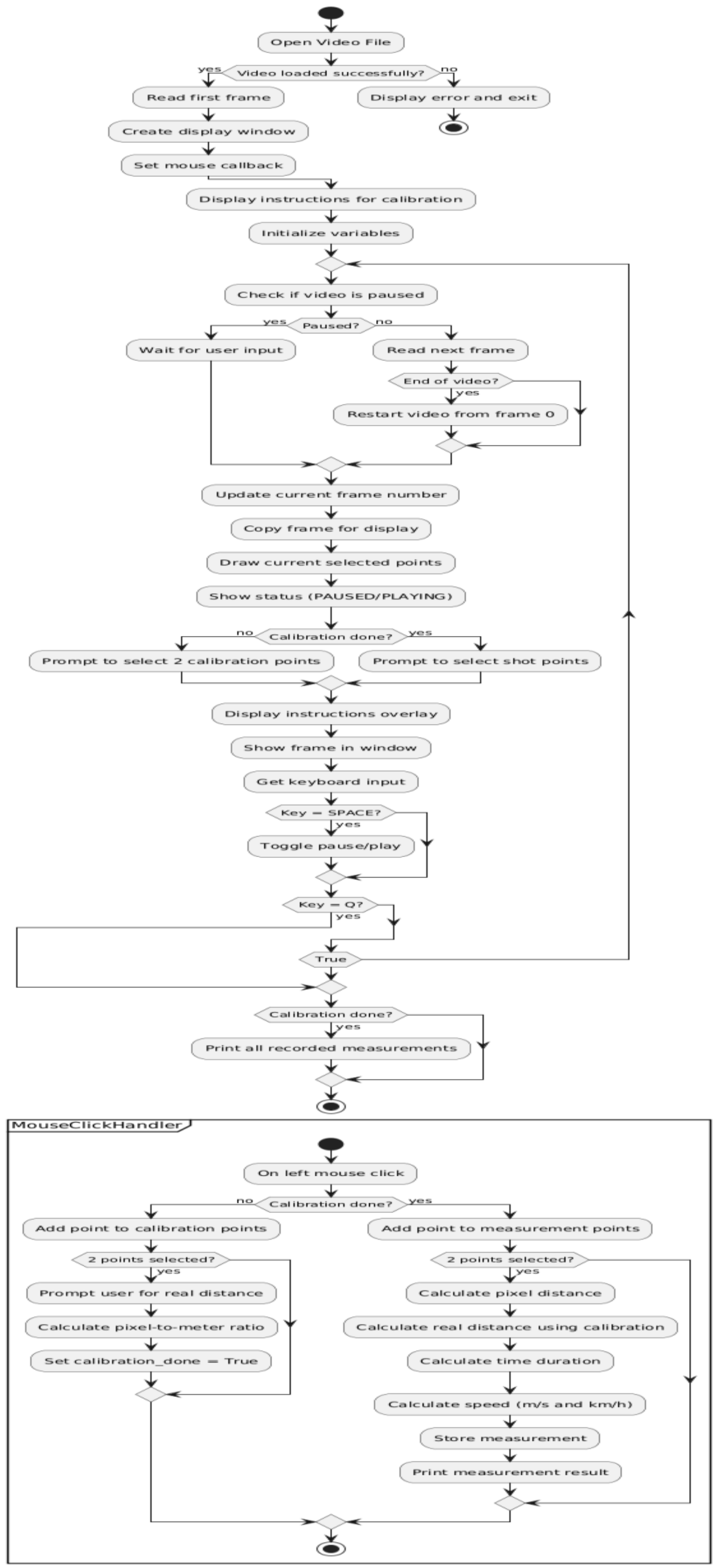
In this approach, the video of a player's shot is first loaded into the system. The video serves as the main source of information, and it provides the frames that will be used to determine the trajectory of the ball. The user interacts with the system by selecting reference points directly on the video using mouse clicks. The first step is a calibration phase, where the user clicks on two points in the frame that correspond to a known real-world distance (for example, the width of the goal or a marked line on the floor). This information is then used to establish a conversion ratio between pixels (as measured in the video) and real-world distances in meters. This ratio is fundamental, as it allows the software to transform pixel measurements into meaningful physical distances.

Once the calibration is completed, the user can select two points representing the position of the ball at different times in the video. The software retrieves the frame number for each point and calculates the time interval based on the frame rate (frames per second) of the video. It then measures the pixel distance between the two selected ball positions and converts it into meters using the previously established calibration ratio. By dividing the distance traveled by the elapsed time, the system determines the ball's velocity in meters per second and also converts it into kilometers per hour for easier interpretation.

This principle makes the solution **semi-automatic**, the measurement of speed relies on human input for selecting the ball positions, while the calculations are handled automatically by the software. This balances accessibility with precision, allowing a coach to obtain objective performance data without requiring complex tracking algorithms or expensive radar devices. The process is also highly flexible, as it can be applied to any video recording of training or matches, provided the frame rate is known and at least one reference distance is available in the field of view.

2.2 Conception of the Semi-automatic Solution :

The conception of this system required combining several essential elements: video processing, user interaction, calibration, and mathematical computation. Each component plays a key role in transforming a simple video into an interactive measurement tool for coaches.


Open Video File
Video loaded successfully?
yes
no
Read first frame
Display error and exit
Create display window
Set mouse callback
Display instructions for calibration
Initialize variables
Check if video is paused
Paused?
yes
no
Wait for user input
Read next frame
End of video?
yes
Restart video from frame 0
Update current frame number
Copy frame for display
Draw current selected points
Show status (PAUSED/PLAYING)
Calibration done?
no
yes
Prompt to select 2 calibration points
Prompt to select shot points
Display instructions overlay
Show frame in window
Get keyboard input
Key = SPACE?
yes
Toggle pause/play
Key = Q?
yes
True
Calibration done?
yes
Print all recorded measurements
MouseClickHandler
On left mouse click
Calibration done?
no
yes
Add point to calibration points
Add point to measurement points
2 points selected?
yes
Prompt user for real distance
Calculate pixel-to-meter ratio
Set calibration_done = True
2 points selected?
yes
Calculate pixel distance
Calculate real distance using calibration
Calculate time duration
Calculate speed (m/s and km/h)
Store measurement
Print measurement result

The first component is **video processing**, implemented using the OpenCV library. The software opens the video file, extracts its frames, and displays them in a graphical window. This display is continuously updated to simulate video playback, and the frame rate (fps) of the video is automatically detected or approximated. Accurate knowledge of the frame rate is critical, as it allows precise calculation of the time elapsed between two selected frames.

The second component is **user interaction**, which is managed through mouse clicks. The program uses a callback function that listens for left mouse button clicks on the displayed video. Depending on the stage of the process, these clicks have different purposes. During the calibration stage, two clicks correspond to the selection of two points whose real-world distance is known. During the measurement stage, two clicks represent the ball's position at two different times. The software records not only the coordinates of the selected points but also the frame numbers, which ensures that both spatial and temporal data are captured.

The third component is **calibration**, which establishes the relationship between pixel distance and real-world distance. When the user provides the actual distance between the two calibration points, the program computes a ratio in pixels per meter. This ratio is then stored and used for all subsequent calculations. Calibration ensures that the results are not dependent on the camera's position or zoom level, making measurements adaptable to different environments and videos.

The fourth component is **mathematical computation**, which transforms the input data into useful results. The program calculates the Euclidean distance in pixels between the two selected ball positions and converts this distance into meters using the calibration ratio. The frame numbers are compared to determine the number of frames between the two points, and dividing by the frame rate yields the elapsed time in seconds. Finally, the program computes velocity by dividing distance by time, expresses it in meters per second, and converts it into kilometers per hour. These values are displayed directly to the user and stored in memory for later review.

The final design of the system includes a **graphical overlay** to improve usability. Circles and labels are drawn on the selected points to visually confirm the chosen positions. Status information such as whether the video is paused or playing, the current frame number, and the next expected action is displayed directly on the video window. Instructional text guides the user during the calibration process, ensuring that even non-technical users can operate the software with ease. The controls are minimal, requiring only a few keyboard inputs (such as the space bar to pause or resume playback and the “Q” key to quit), which makes the system practical in a training environment.

From a conceptual point of view, this semi-automatic solution represents a compromise between full automation and manual measurement. While it does not automatically detect the ball, it leverages human visual recognition, which is extremely reliable for identifying the ball in a video. By combining this human input with automated mathematical calculations, the system provides accurate, objective, and reproducible results. It is also designed with flexibility in mind, as it can be adapted to different videos, distances, and training conditions.

2.3 Advantages and Limitations of the Semi-automatic Approach :

The semi-automatic solution offers several advantages. It is significantly less expensive than radar-based systems and requires no specialized hardware beyond a computer and a camera. It is flexible and adaptable to various training contexts, as any video can be used for analysis. It is also relatively easy to use, requiring only a few mouse clicks and simple calibration. Most importantly, it provides objective measurements of shot velocity, which can greatly support coaches in evaluating and improving their players’ performance.

However, the approach also has limitations. It relies on the accuracy of the user’s clicks, which introduces the possibility of human error, especially when the ball is moving quickly or appears blurred in the frame. The precision of the measurements also depends on the quality and frame rate of the video. Low-resolution or low-fps videos may reduce the reliability of the results. Additionally, the need for manual intervention prevents the system from being used in real time during competitive matches, limiting its application primarily to training sessions.

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2.4 Conclusion :

The semi-automatic solution represents an important step toward democratizing access to performance analysis tools in handball. By combining video processing with user interaction and automated calculations, the system offers a practical and accessible method for measuring shot velocity. While it is not yet fully automated, it significantly reduces the reliance on subjective evaluation and provides coaches with meaningful, data-driven insights. This solution serves as a foundation upon which more advanced, fully automated systems can later be developed, bridging the gap between costly professional tools and the needs of everyday training.

3.3 Mobile Application :

3.1 Introduction :

Following the successful development of the semi-automatic desktop solution for calculating handball shot speed, the next step was to extend this functionality to mobile devices. The desktop application demonstrated that with limited user interaction, it was possible to obtain reliable velocity measurements using video frames, calibration distances, and manual selection of points. However, its usability was limited in real training sessions and matches because a laptop was required on the field. Coaches and players often rely on their smartphones during practice, making the development of a mobile application both natural and necessary. The mobile version aims to replicate the semi-automatic workflow on portable devices, providing greater flexibility and accessibility while maintaining the accuracy and structure of the original system.

3.2 Objectives of the Mobile Application :

The primary objective of the mobile application is to bring the same semi-automatic workflow of the desktop tool to a smartphone environment. Users should be able to capture a video or load pre-recorded footage directly from the mobile device, pause at specific frames, and interact with the image by touching the screen to select calibration points or the ball's position. By doing so, the mobile app eliminates the need for a computer, enabling on-field usage. It is not intended to replace user interaction with full automation, but rather to make the manual steps easier and more intuitive on a touch screen. The application also aims to store measurements, calculate distances, and estimate velocities in real time, making it a practical assistant for coaches during training sessions.

3.3 System Architecture :

The mobile system is designed as a standalone application running directly on Android and iOS devices. Unlike the AI-based client–server approach, the semi-automatic mobile version does not require an external backend. Instead, all calculations are performed locally using Python logic adapted to mobile frameworks. The architecture consists of three main layers: video acquisition, user interaction, and computation. The video acquisition module allows the user to either record a sequence during practice or load an existing file. The interaction module provides tools to pause the video and manually mark points with simple touches, such as the calibration distance or the ball position across frames. Finally, the computation module applies the same mathematical models as the desktop version, using distances and frame indices to calculate velocities. This lightweight architecture ensures independence from network connectivity and preserves the semi-automatic spirit of the solution.

3.4 Design and Development :

The development of the mobile application required rethinking the user interface to adapt to touch interactions. On desktop, the workflow relied on mouse clicks and keyboard shortcuts to mark points and control playback. On mobile devices, these actions are replaced by intuitive gestures: tapping the screen to place a marker, dragging to adjust it, and using play and pause buttons overlaid on the video. The computational part reuses the algorithms written in Python, translated to mobile-compatible frameworks through libraries such as Kivy or BeeWare. These frameworks allow packaging the Python code into a mobile application that can be installed and executed natively on smartphones. The internal logic remains consistent with the desktop version: once the user selects calibration points and identifies ball positions in consecutive frames, the application computes the traveled distance and divides it by the elapsed time to obtain velocity. The development effort focused mainly on user interface adaptation and on ensuring smooth playback of videos on devices with limited resources.

3.5 User Interface :

The interface of the mobile application is minimal and focused on the user's interaction with the video. The main screen displays the video in full view with simple controls for play, pause, and frame navigation. When paused, the user can tap directly on the video frame to select points, which are displayed as colored markers. A toolbar provides options for resetting points, saving measurements, and confirming calibration. Once points are marked across frames, the calculated velocity is displayed at the bottom of the screen in both meters per second and kilometers per hour. The design emphasizes simplicity and clarity, ensuring that the application remains practical for quick use during training sessions without distracting the coach or player from the main task.

3.6 Deployment and Testing :

The mobile application was first tested in an emulator environment to validate its functionality before being deployed to physical devices. During testing, various types of handball shooting videos were used to ensure that playback, point selection, and calculations behaved as expected. Once stable, the application was installed on Android smartphones for real-world testing. The results confirmed that the mobile adaptation offered the same accuracy as the desktop version, provided the user correctly marked calibration distances and ball positions. Minor adjustments were required to optimize frame navigation and ensure smooth video handling on devices with lower hardware capabilities.

Overall, the deployment demonstrated that the semi-automatic methodology could be effectively transferred to mobile platforms.

3.7 Advantages of the Hybrid Approach :

Translating the semi-automatic desktop solution into a mobile application provides several practical advantages. The most significant benefit is portability, as users can now perform velocity analysis directly on the field without additional equipment. Touch-based interaction simplifies the workflow, making it faster and more intuitive to mark points compared to mouse and keyboard operations. The standalone architecture avoids reliance on network connectivity, allowing the application to be used even in environments where internet access is limited. Furthermore, because the logic of the system remains unchanged from the desktop version, there is no loss in accuracy, ensuring that the results remain trustworthy. The mobile adaptation therefore enhances accessibility and usability while preserving the reliability of the original tool.

3.8 Conclusion :

The development of a mobile application for the semi-automatic solution represents a natural and necessary evolution of the project. By migrating the desktop prototype to smartphones, the system becomes more practical, user-friendly, and accessible in real training contexts. The mobile application preserves the semi-automatic nature of the solution, requiring user interaction for calibration and ball tracking, while streamlining the process through an intuitive touch interface. The results of testing confirm that the methodology remains effective and accurate in its mobile form. This chapter demonstrates how combining lightweight algorithms with mobile-friendly design can transform a desktop prototype into a portable tool that directly benefits athletes and coaches on the field, bridging the gap between technological research and real-world application.

4. Conclusion and Perspectives

4.1 Conclusion :

The project set out with the ambition of developing a reliable tool for measuring the velocity of handball shots, a parameter of great interest in performance analysis and training. At the beginning, a semi-automatic solution was implemented on a desktop platform, combining user interaction with computer vision techniques. This approach demonstrated that, by integrating calibration steps and manual point selection, it was possible to obtain accurate measurements of shot speed without requiring complex or fully automated artificial intelligence models. The desktop prototype validated the methodology, highlighting the feasibility and accuracy of the approach in controlled environments.

The limitations of the desktop implementation were primarily related to its lack of portability. Coaches and athletes could not easily bring a laptop to every training session or game, which restricted the system's use in real-world practice. To address this, the project evolved toward a mobile application that adapted the same semi-automatic workflow to smartphones. This migration was a major milestone, as it not only preserved the scientific validity of the methodology but also extended its accessibility to on-field usage. The mobile application successfully demonstrated that velocity estimation can be carried out directly on portable devices, with the same logic, accuracy, and structure as the desktop version. Through this adaptation, the system became more practical, user-friendly, and versatile, responding to the real needs of practitioners.

The project illustrates how a practical need in sports can be addressed through the careful combination of computer vision, human interaction, and mobile technology. Starting with a desktop prototype and extending to a mobile application, the system shows a complete evolution from proof of concept to practical usability. The perspectives outlined highlight that this is not the end of the journey but the beginning of further exploration into semi-automatic and hybrid solutions for sports analytics. By continuing to refine, extend, and integrate such tools, it is possible to contribute significantly to the modernization of training practices, offering athletes and coaches new ways to understand and improve performance.

In summary, the combination of a solid semi-automatic desktop prototype and a functional mobile application confirms the relevance of the project and its contribution to the intersection of sports science, computer vision, and mobile technology. The tools developed provide both theoretical validation and practical usability, positioning this work as a promising step toward the integration of technology in sports performance analysis.

4.2 Perspectives :

While the results of the project are encouraging, several perspectives open the way for future improvements and research. One important avenue concerns the further automation of the workflow. The current semi-automatic method requires user intervention for calibration and for selecting ball positions across frames. In future iterations, computer vision models or lightweight machine learning algorithms could be incorporated to automatically track the ball while still allowing the user to intervene when necessary. Such a hybrid system would reduce the workload on the user and increase the efficiency of the measurements without completely sacrificing accuracy.

Another perspective relates to the scalability and optimization of the mobile application. Although the current mobile prototype ensures portability and ease of use, further improvements could include advanced video navigation tools, integration of cloud storage for saving and sharing measurements, and compatibility with wearable devices that provide complementary performance data. Expanding the application to both Android and iOS ecosystems with optimized performance across different devices is also an essential step for broader deployment.

From a methodological point of view, the system could be extended to include not only the velocity of handball shots but also additional performance metrics such as trajectory analysis, impact point detection, and correlations with player movement. This would transform the tool into a comprehensive performance analysis suite rather than a single-purpose application.

Finally, in terms of adoption, collaboration with sports clubs, academies, and federations would allow large-scale testing, validation, and iterative improvement of the application in real competitive contexts. Such partnerships would ensure that the tool does not remain a prototype but evolves into a widely accepted technological solution for training and performance monitoring.