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Mechatronics System Design

Feasibility Study on Data Collection Technologies

Eindhoven, March 2023

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1. Introduction

1.0.1 The need for feasibility check

Feasibility checks are an essential step in the design process because they help ensure that the design is realistic and achievable. Before beginning the actual design work, it is crucial to assess whether the design is feasible from various perspectives, such as technical, economic, legal, environmental, and social.

Here are some reasons why a feasibility check is necessary before designing:

Identifying potential roadblocks:
Conducting a feasibility check can help identify potential roadblocks or challenges that may arise during the design process. For example, it can identify technical constraints that may limit the design's functionality, legal requirements that must be met, or environmental considerations that must be addressed.

Saving time and resources:
A feasibility check can save time and resources by identifying potential issues that may require redesigning or abandoning the project altogether. It is better to identify these issues early on in the process, rather than after significant time and resources have been invested in the design.

Ensuring cost-effectiveness:
A feasibility check can help ensure that the design is cost-effective by identifying potential cost implications and finding ways to reduce costs.

Meeting stakeholder expectations:
A feasibility check can help ensure that the design meets stakeholder expectations, including clients, users, and investors. By identifying potential issues early on, designers can incorporate feedback and suggestions from stakeholders to ensure that the design meets their expectations.

Feasibility checks are an essential step in the design process because they help ensure that the design is realistic and achievable. Before beginning the actual design work, it is crucial to assess whether the design is feasible from various perspectives, such as technical, economic, legal, environmental, and social.

1.0.2 Object

There are various technologies to be used for visualizing the stadium from a fixed perspective. These technologies provide different types of data with different levels of accuracy, cost, and reliability. Take video streams from five stationary cameras and apply an image processing algorithm to obtain information about the game (such as the position and speed of the soccer ball or robots, etc.). Use the collected information as an assistant referee. For the feasibility analysis, only one camera will be considered. This will restrict information gathering to a limited area of the field. Thereare lots of criteria which needs to be considered:

Determine the type of sensor:
Referees need to determine the type of sensor that will be used to monitor the soccer robots. There are various types of sensors which will be discussed in detail in next chapter.

Select the location:
Referees need to select the ideal location to mount the sensor. They need to consider factors such as the angle of view, the distance from the soccer robots, and any potential obstructions that may interfere with the sensor's view.

Mount the sensor:
Once the sensors' location has been determined, referees need to mount them securely. They can use mounting brackets or stands to attach the sensors to a stable surface. They should ensure that the sensors are level and have a clear view of the soccer field.

Connect the sensors to a monitoring system:
Referees need to connect the sensors to a monitoring system that will enable them to view the footage in real-time. They can use a computer or a mobile device to monitor the footage.

Test the sensors:
Before the match, referees need to test the sensors to ensure that they are working correctly. They should check the footage to verify that the sensors are capturing clear images and that there are no issues with the connection.

2. Feasibility check of sound sensor

2.0.1 Advantages

Cost:
Sound sensors are generally less expensive than laser sensors, which can make them a more affordable option.

Directional:
Sound sensors can be directional, which means they can be used to detect the direction of a sound source, such as the ball or another robot.

range:
Good range of distance with good margin of error

Accuracy
The measurement accuracy is independent of lighting conditions. Not effected by color or transparency.

2.0.2 Disdvantages

Accuracy:
Sound sensors may not be as accurate as laser sensors, especially over longer distances, which can affect the precision of object detection and localization.

Interference:
Sound sensors can be affected by background noise, such as the noise of the crowd or other robots, which can reduce their effectiveness in certain environments.

Limited range:
Sound sensors generally have a shorter range than laser sensors, which can limit their ability to detect objects from a distance.

Obstacles:
Other obstacle in the way may affect the sound result. Moreover, the angel of the surface of the obstacle is crucial for the sensor.

Delay:
Signal sending delay/ signal receiving delay (caused by operating system).

Position:
Position of the sensor is important, because if its far from the needed point we might lose some amplitude (intensity).

Temperature:
Temperature affects the progration of sound waves over long distance (it will affect the density of the air. Which influence the speed of the sound).

3. Feasibility check of temperature sensor

Temperature sensors are designed to measure the temperature of their environment and are not capable of detecting robots or balls directly. However, depending on the material of the robot or ball, it is possible that they may emit or absorb heat differently than their surroundings, which could potentially be detected by a sensitive temperature sensor.

For example, if a robot or ball is made of metal or some other material with a high thermal conductivity, it may conduct heat differently than the air or other objects around it, leading to a detectable temperature difference. Similarly, if the robot or ball is powered by batteries or motors, it may generate heat that could also be detected by a temperature sensor.

However, it's important to note that detecting objects based on temperature differences can be difficult and is not a reliable method for identifying robots or balls in most cases. Other sensors, such as cameras or sonar, are generally better suited for this purpose.

3.0.1 Advantages

Non-Contact Detection:
Temperature cameras don't require physical contact with the objects being detected, which can be beneficial in situations where physical contact might interfere with the game.

Functionality in Different Light Conditions:
Temperature cameras can function in low-light conditions, which can be helpful in outdoor settings where lighting conditions can vary.

3.0.2 Disadvantages

Limited Range:
Temperature cameras have a limited range compared to other types of cameras. This can limit their usefulness in large outdoor settings, where a wider range may be required.

Limited Object Types:
Temperature cameras are most effective at detecting objects with a temperature different from their surroundings. As such, they may not be as effective at detecting certain objects that have a similar temperature as their surroundings.

Cost:
Temperature cameras can be more expensive than other types of cameras, which may limit their accessibility to some teams or organizations.

Limited Resolution:
Temperature cameras may have limited resolution compared to other types of cameras, which can limit their effectiveness in detecting small objects or objects at a distance.

Inconsistency:
These sensors are highly dependent on the material of the object. Thermal conductivity is required for all objects.

4. Feasibility check of laser

4.0.1 Advantages

Accuracy:
Laser sensors are highly accurate and can provide precise measurements of the distance and position of objects, which is important for soccer robots to navigate the playing field and avoid obstacles.

Speed:
Laser sensors can provide real-time measurements, which is critical for soccer robots to react quickly to changes in the environment, such as the movement of other robots or the ball.

Range:
Laser sensors have a longer range than many other types of sensors, which allows detection of objects from a greater distance.

Adaptability:
Can work very accurately even in relatively poor lighting conditions (lighting condition has no effect.)

Reliability:
It is safe and reliable

4.0.2 Disadvantages

Cost:
Laser sensors can be more expensive than other types of sensors, which can increase the overall cost of building a soccer robot.

Complexity:
Laser sensors can be more complex to integrate into a soccer robot's control system than other types of sensors, which may require additional programming and testing.

Laser sensors can be affected by interference from other sources of light, such as the sun or bright stadium lights, which can reduce their effectiveness in certain environments.

Reflection:
Reflective surface when measuring the distance from reflective surfaces, the values might be inaccurate. The bright light might alert the beam a little and disturb the measuring.

5. Feasibility check of stadium cameras

Choose one rule such as corner kick procedure, not real-time for our scope, additional computational solutions may be needed

5.0.1 Advantages of Using Stadium Cameras

- Trustable and reliable data source
- Accessible
- Comprehensive data (Full view of the field)
- Easy to record and re-use
- Could be built upon in the future generations
- Multi-functioning: Use as an assistant referee and can be further developed
- Availability off the shelf

5.0.2 Disadvantages of Using Stadium Cameras

- Processing time for decision making
- Processing work
- Fusion of more than one camera for a better field understanding
- Calibration

6. Feasibility check of lidar

Lidar (Light Detection and Ranging) is a remote sensing technology that uses laser beams to measure distances and create high-resolution 3D maps of an environment. It can be used for object detection and tracking in robotics, including in soccer robots. Here are some pros and cons of using lidar for detecting balls and players in soccer robots:

6.0.1 Advantages

Accurate:
Lidar sensors can provide accurate 3D measurements of objects and their positions in real-time. This can help the robot accurately detect and track the position of the ball and players on the field.

Fast:
Lidar sensors can operate at high speeds, allowing the robot to detect and respond to objects in real-time.

Robust:
Lidar sensors can work in various lighting conditions, including low light and bright sunlight, and can operate in dusty or dirty environments.

6.0.2 Disadvantages

Cost:
Lidar sensors can be expensive, which can make them less accessible for some robot developers or soccer teams.

Limited range:
The range of lidar sensors can be limited, which means that they may not be able to detect objects at very far distances.

Vulnerability to interference:
Lidar sensors can be susceptible to interference from other sensors, particularly in environments with multiple robots or other sources of laser emissions.

Limited view angle:
Lidar sensors have a limited view angle, which means that they may not be able to detect objects that are outside of their field of view.

In summary, while lidar can provide accurate and fast object detection and tracking in soccer robots, it may also be limited by cost, range, vulnerability to interference, and a limited field of view. Therefore, it may be useful to combine lidar with other sensors, such as cameras or ultrasonic sensors, to improve the overall performance of the robot.

7. Feasibility check of radar

7.0.1 Advantages

Non-visual:
Radar can work in low-light conditions, through smoke and fog, and without the need for line of sight. This can be useful in soccer robots that may operate in outdoor or indoor environments with changing lighting conditions or obstacles.

Fast and Accurate:
Radar can provide precise measurements of distance and speed, making it useful for tracking the movement of the ball and players in real-time. It can also provide data for advanced analytics to improve the performance of the robot.

Robust:
Radar is less susceptible to interference from other devices or signals than other sensors such as cameras or lidars, making it more reliable in certain situations.

7.0.2 Disadvantages

Limited Resolution:
The accuracy of radar may be limited when it comes to detecting small objects such as a ball or distinguishing between closely spaced objects such as players standing next to each other.

Cost:
Compared to other sensors such as cameras or lidars, radar technology can be more expensive.

Complexity: Radar systems can be complex to integrate and configure, requiring specialized expertise and knowledge. It may also require more power and computing resources than other sensors.

8. Feasibility check of camera plus lidar

8.0.1 Advantages

High Resolution:
The combination of camera and lidar sensors can provide a high level of accuracy and resolution when detecting objects, including small objects such as a soccer ball.

3D Perception:
Lidar can provide accurate depth information, enabling the robot to better perceive the environment and detect obstacles and players.

Versatile: Cameras can provide color information, while lidar can operate in low-light conditions, making this combination useful in a variety of environments and lighting conditions.

8.0.2 Disadvantages

Cost:
Combining camera and lidar sensors can be more expensive than using a single sensor type.

Limited Robustness:
Cameras and lidars can be more susceptible to interference from other devices or signals, which can affect their performance and reliability.

Data Processing:
Combining camera and lidar sensors can produce a large amount of data that requires significant processing power, which can affect the speed and efficiency of the robot's performance.

9. Feasibility check of camera plus radar

9.0.1 Advantages

Robust:
The combination of camera and radar sensors can provide a more robust system, as they are less susceptible to interference from other devices or signals.

Non-visual:
Radar can work in low-light conditions, through smoke and fog, and without the need for line of sight, while cameras can provide high-resolution visual information, making this combination useful in a variety of environments and lighting conditions.

Fast and Accurate:
Radar can provide precise measurements of distance and speed, making it useful for tracking the movement of the ball and players in real-time. Cameras can provide high-resolution visual information, enabling the robot to detect objects with greater accuracy.

9.0.2 Disadvantages

Limited Resolution:
The accuracy of radar may be limited when it comes to detecting small objects such as a ball or distinguishing between closely spaced objects such as players standing next to each other. Cameras can provide higher resolution, but they may be affected by lighting conditions.

Cost:
Combining camera and radar sensors can be more expensive than using a single sensor type.

Complexity:
The integration of camera and radar sensors can be complex, requiring specialized expertise and knowledge. It may also require more power and computing resources than other sensor combinations.

10. Feasibility check of camera mounted on robots

10.0.1 Types of sensors

There are several types of sensors that can be mounted on robots to help the referee make correct decisions in a soccer robots league. The choice of sensor will depend on the specific rules and regulations of the game and the type of violation being detected. A combination of sensors may be necessary to provide accurate and reliable detection of rule violations. Additionally, it is important to consider the cost, complexity, and feasibility of implementing sensor technology in the game. Here are some options:

RGB cameras
RGB cameras capture full-color images and are commonly used in robotics and computer vision applications. They can be mounted on robots to provide a high-resolution view of the game, which can be used to track the position of the ball and the robots on the field.

Depth cameras
Depth cameras use infrared sensors to measure the distance between the camera and objects in the scene. They can be mounted on robots to provide a three-dimensional view of the game, which can be used to accurately track the position of the ball and the robots on the field.

Thermal cameras
Thermal cameras detect heat signatures and can be used to track the movement of the ball and the robots on the field. They can be particularly useful in situations where the ball or robots are difficult to see with a traditional RGB camera, such as in low-light conditions or when there is glare on the field.

Panoramic cameras
Panoramic cameras capture a wide-angle view of the scene and can be used to provide a comprehensive view of the game. They can be mounted on robots to capture a full 360-degree view of the field, which can be useful for tracking the movement of the ball and the robots.

Pressure sensors
These sensors can be mounted on the robot's feet and used to detect when the robot is in contact with the ball or another player, which can be used to detect fouls and other rule violations.

Ultrasonic sensors
These sensors can be used to detect the distance between the robot and the ball, which can be used to determine if the robot is in an offside position.

Magnetic sensors
These sensors can be used to detect the magnetic field of the ball, which can be used to track its movement and detect whether it has gone out of bounds or crossed the goal line.

Inertial measurement units (IMUs)
These sensors can measure the acceleration and rotation of the robot, which can be used to detect collisions and other rule violations.

Infrared sensors
These sensors can be used to detect the presence of the ball and the players, which can be used to determine the location of the ball and the players' positions.

10.0.2 Advantages

The use of special sensors mounted by the referee on robots has the potential to significantly enhance the fairness, accuracy, and overall experience of soccer games. However, it is important to carefully consider the implementation and use of such technology to ensure that it does not detract from the essence and spirit of the game.

Trustable and reliable data source:
Robots cannot change the data provided by these sensors as these sensors will be mounted on robots before starting the match by the referee and only the referee has access to these sensors.

Comprehensive view of field:
Different sensor data can be merged to provide us with a comprehensive view of the soccer field.

Works exactly same as TechUnited data:
These sensors provide us the data exactly the same as Robot sensors but the difference is that these sensors can be just used by referee so the data comming from these sensors are trustable.

Available cameras:
There are lots of available cameras that can be used based on the budget available for the project.

Easy to record and re-use:
The game can be easily recorded and rechecked by Referee and teams

Could be built upon in the future generations
Next MSD trainees can improve this method by using different types of cameras

Contribution of other teams:
Different teams can have contribution in the improvement of this method.

Improved accuracy:
Sensors can provide a more accurate and objective way of detecting rule violations, reducing the risk of human error and bias in decision-making.

Faster detection:
Sensors can detect rule violations in real-time, allowing referees to make quick and informed decisions.

Consistency:
Sensors can provide consistent and uniform detection of rule violations throughout the game, reducing the potential for discrepancies between different referees or instances of inconsistency within a single game.

Improved fairness:
Sensors can help ensure that the game is played fairly and that all players are held to the same standard of behavior.

Enhanced game experience:
Sensors can add a new dimension to the game, providing additional information and insights into player behavior and game strategy.

Reduced controversy:
Sensors can reduce controversy and disputes over referee decisions, improving the overall perception and enjoyment of the game for players and spectators alike.

10.0.3 Disadvantages

There are several disadvantages of using special sensors mounted by referees on robots for detecting rule violations in competitions or games.

Design a mounting device for the camera:
Designing a mounted device that can be used by all robots without making any problem in their software and hardware is challenging.

Cost:
Mounting special sensors on robots can be expensive, especially if they require custom design and fabrication. This can limit the availability of such technology to only the most well-funded teams, creating an unfair advantage.

Might involve additional regulation on players:
Due to the hardware constraint or in some cases software, it may involve in some additional regulations on players.

Processing time for decision making:
Based on the type of sensor, the processing time might be different.

Data Fusion:
Fusion of data coming from different sensors mounted on robots for improving accuracy and to have a complete view of the field.

Increased complexity:
Adding special sensors to robots increases their complexity, making them more prone to malfunction or failure. This can lead to inaccurate readings or false alarms, which can unfairly penalize or advantage teams.

Time-consuming:
The installation and calibration of special sensors can be time-consuming, requiring extra preparation time before competitions. This can delay the start of events or disrupt the flow of the game.

Limited scope:
Special sensors may only detect a limited set of rule violations, leaving other potential violations unnoticed. This can create an incomplete view of the game and lead to inconsistent enforcement of rules.

Unintentional Contact:
Robots are likely to make contact with each other during gameplay, which could trigger the sensors and lead to false positives. This could unfairly penalize players and disrupt the flow of the game.

Privacy:
The use of sensors could raise concerns about privacy, as they would be monitoring the actions and movements of the players.

Reliability:
Sensors can be sensitive to environmental factors, such as temperature or humidity, which could affect their accuracy. A malfunctioning sensor could lead to incorrect calls and undermine the integrity of the game.

Interference:
If multiple robots are in close proximity, the sensors could interfere with each other's signals, leading to false positives or false negatives.

11. Conclusion

This is made evident by fact that, technically there are different methodologies which can be consider as a solution to client's need. In other to choose the best solution, we minimized our focused on different domains such as cost, time, accuracy, reliability, technical boundaries, complexity, safety, adaptability to previous groups, human resource and etc. Adding all these concerns together, we choose stadium camera as a solution. It is because of this reason, this solution is the only one where can fulfill all the requirements up to the desired expectations based on having short time and limited human resources.