RoboSoccer Analysis

Part II: Communication Methods and Strategies

Introduction:

An integral and necessary part of anything that needs a team needs to have effective communication amongst its members and this philosophy transcendents into robotics as well, where any project with more than one robot needs an effective way of communication and hence a proper communication protocol.

Communication, or rather ways to communicate, would result in nothing if it is unknown what is the objective of communication and what is it that is to be communicated. That is to say that without a proper and common goal in the mind, any perfect team might not be able to demonstrate its true capabilities and that is where Strategies play an important role.

This report shall try to cover all the different types of Communication Protocols, Technologies, and Strategies, that are applicable in the field of RoboSoccer, of varying complexities and applications along with the different methods of handling and their difficulties.

Wired Communication Protocols:

There exist a plethora of communication protocols that need a physical medium such as a wire to send and receive data in their defined formats such as industry standardized EtherNet, ControlNet, MODBus, etc. but are not feasible for application in the field of wireless and autonomous moving robots and therefore would not be discussed further in this report.

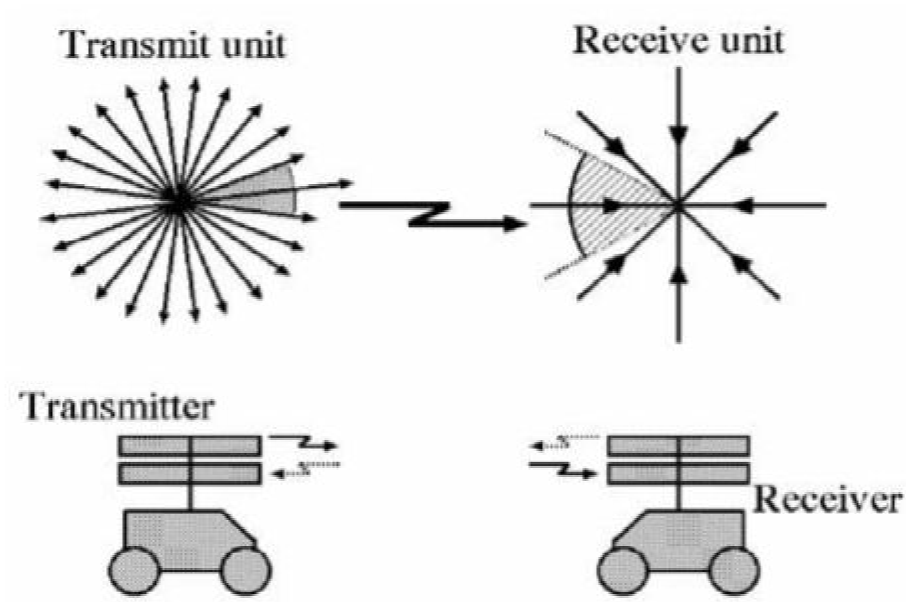


Fig: Inter - Robot Communication

Wireless Communication Protocols and Technologies:

As for robots that have fixed and specified tasks designated to them, and in order for their proper function, needs to communicate either amongst other robots or with a central control unit, there are many suitable and reliable methods of communication that are often used in conjunction with one another to get the desired results.

Machine Learning Assisted Object Detection

A simple yet effective way of communicating a robot's current location and distance to another bot is through object detection. The basics of Object detection consists of Representation, how to represent an object, and Recognition, to recognize the represented object.
Object detection is usually done using video sequence by the process of detecting the moving objects in frame sequence using digital image processing techniques.

This process can be highly optimized and improved with the assistance of machine learning and introducing a learning step in between Representation and Recognition.
A simple example is to use the Gabor filter for the target robot features representation alongside a supervised learning method of support vector machine (SVM) that is used for classification and recognition of the target robot.

Note: In image processing, a Gabor filter, named after Dennis Gabor, is a linear filter used for object detection. In the spatial domain, a 2D Gabor filter is a Gaussian kernel function modulated by a sinusoidal plane wave. The Gabor filters are self-similar: all filters can be generated from one mother wavelet by dilation and rotation. A set of Gabor filters with different frequencies and orientations may be helpful for extracting useful features from an image

Support Vector Machine
A support vector machine (SVM) is a concept in computer science for a set of related supervised learning methods that analyze data and recognize patterns, used for classification and regression analysis. The standard SVM takes a set of input data and predicts, for each given input, which of two possible classes. The input is a member of, which makes the SVM a non-probabilistic binary linear classifier.

ZigBee

ZigBee is a rather new wireless technology that looks to have applications in a variety of fields. ZigBee is a technological standard based on the IEEE 802.15.4 specification for low data rates in the industrial, scientific, and medical radio bands. The technology allows for devices to communicate with one another with very low power consumption and enables them to run on simple batteries for several years.

The vision from a bot can be processed on board as well as remotely on a control unit. The data from the bot as well as the instructions to the bot use ZigBee as its communication medium. ZigBee also allows for inter robot communication which results in faster instruction processing.

ZigBee is the only standards-based wireless technology
designed to address the unique needs of low-cost, low-power, long battery life capability, robust security, and high data reliability for wireless sensor and control networks. ZigBee also connects the widest variety of devices into easy-to-use networks, giving unprecedented control of the used devices.

Dedicated Short Range Communication (DSRC)

DSRC is based on the 802.11 family of Carrier Sense Multiple Access with Collision Avoidance (CSMA-CA) protocol. In this protocol, the device listens to the channel before sending a packet, and any packet is sent only if the channel is clear.
Originally, DSRC was designed for autonomous automotive but due to its capabilities in the short-range, it can be easily used for scaled-down models and robots.

WiFi

WiFi is one of the most popular wireless communication technologies in the industry which are compliant to IEEE 802.11 standards.

It can be easily added to a bot with the help of a wireless module, usually 2.4GHz, which is compliant to WiFi standards and helps convert the radio signals to digital data.
An additional feature of WiFi is that it can not only be controlled remotely in the local area network but can also send and receive data over the internet.
WiFi also reduces the complexity of the overall project as most devices would already be equipped with WiFi compliant modules.

InfraRed Sensor System

Another simple technology is the InfraRed Sensor System. It is easy to understand and implement. A transmitter in your controller transmits IR light (or pulses) and an IR receiver on your robot receives the signal, which is decoded with the help of a microcontroller. IR requires a line of sight control and best suited for applications that require a shorter control range. However, care must be taken while designing IR transceivers, because the sunlight, or any heat-generating objects gives out infrared light.

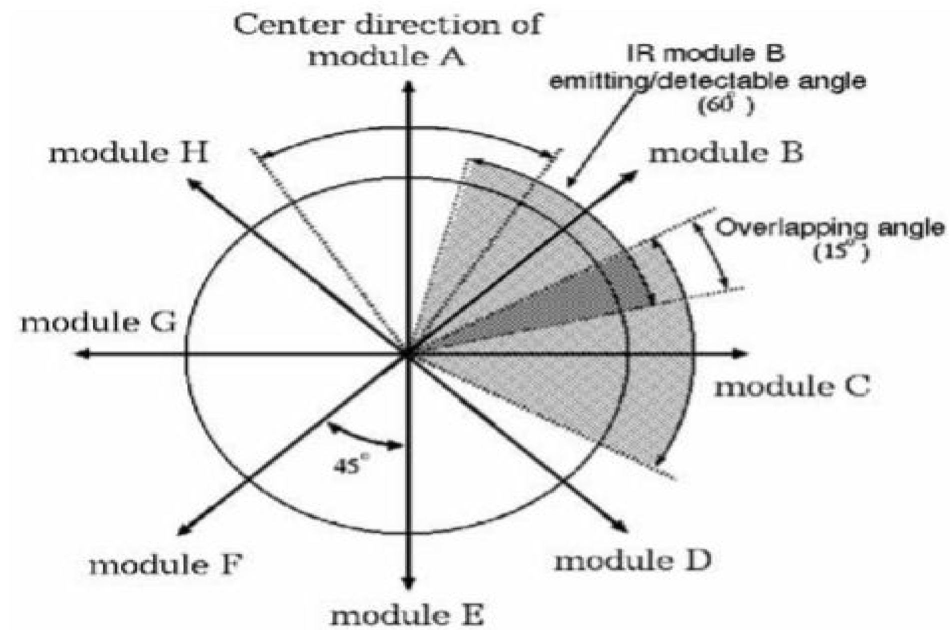


Fig: Arrangements of the Transceivers

The IR system can be just utilized for sending and receiving data amongst the bots or can be developed to improve localization of other bots as well. This can be done using a space-division optical wireless inter-robot communication system for multiple mobile robots. Infrared optical wireless communication is suitable for mobile robots, because of its low level of interference in multiple directions. However, optical wireless communication is lost when either of the robots runs and/or rotates due to the nature of infrared rays. The proposed communication system has a set of infrared transceivers, which face all directions. The system can maintain circuit connections by exchanging transceivers. Furthermore, it can communicate at the same time with more than one robot in different positions by using different transceivers.

Additional Assisting Components:

Additionally, a few more components can be added to the robot for better localization and communication of the bot such as a Compass System.

An electronic compass TDCM3 is placed on the top center of the robot to obtain the terrestrial magnetism data. The terrestrial magnetism data is invisible in nature. Based on the obtained compass data, the direction of the soccer field and the main direction of the robot are determined. In the self-localization design, the environmental information about the field obtained from the compass system and the vision system are considered simultaneously so that the strategy design is more flexible.

Various RoboSoccer Strategies

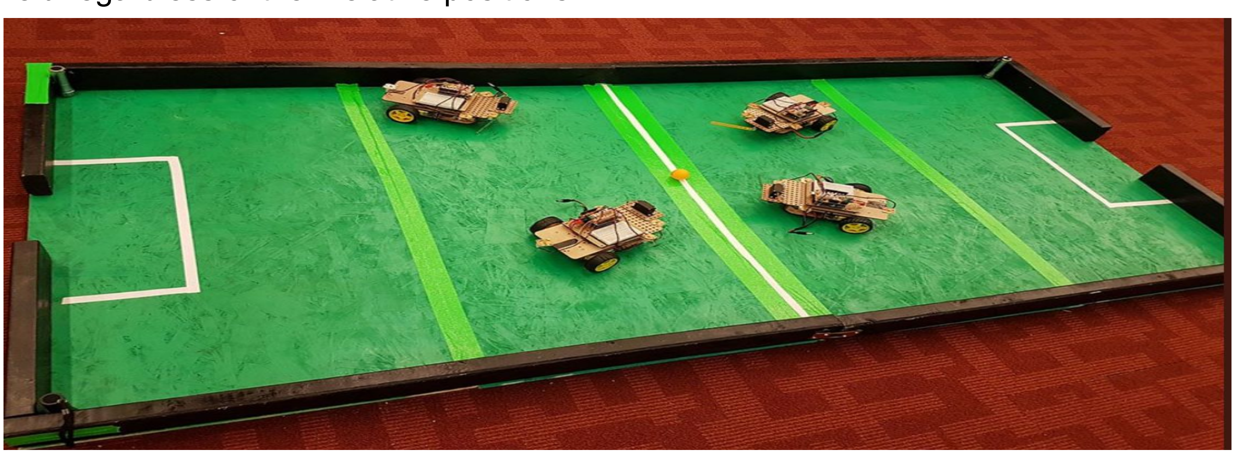
In recent years RoboSoccer, as a field of robotics and sports, has seen a lot of growth. This has resulted in an outburst of enthusiasts who want to compete and test their abilities against the world, which transformed into numerous ideas and innovations, from fairly simple, all the way to humanoid level complexities, diversifying and improving as they progress.
Most of the strategies can be implemented with or without remote processing. Some of the basic strategies that are widely used in the field are as follows:

Score the Goal

This very basic strategy is to just obtain the ball and push it towards the Goal. This kind of strategy requires a minimalistic bot without any inter-robot communication method, with just basic detection techniques to capture the ball.

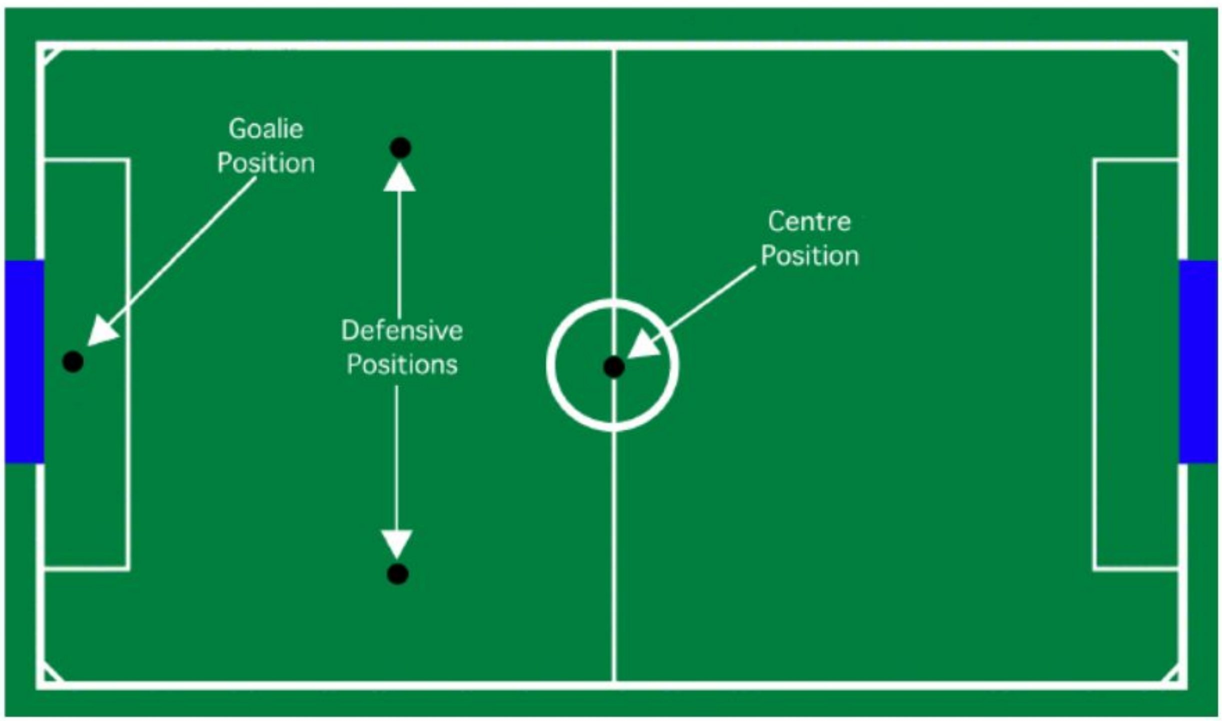
Nearest Target

This strategy improves upon the previous one by adding inter-robot communication in its arsenal.
It optimises the ball-obtaining task by instructing the robot that is nearest to the ball, avoiding unnecessary collision of teammates.
When the ball is in possession, it can process whether a teammate is closer or the goal and pass the ball accordingly.
The inter-robot communication can be implemented using any of the previously stated technologies like ZigBee and the process of the visual data can be done remotely or onboard using various microcontrollers like NSP or Raspberry Pi.
This type of arrangement assumes that each of the bots is having a common role in the field regardless of their relative positions.



Knowledge-Based Role Allocation - KOBRA

Increasing the complexity of Nearest Target, this strategy inherits the roles of players from real-life soccer and integrates positional roles to the robots.
The addition of various roles restricts the number of operations a bot might perform in a particular situation and hence drastically optimizing their processing speed.
Roles may have variations depending on the bot to run as well as compatibility, objectives, and their own algorithms. The prospective roles are Cover, Ball Attack, Defender, Barrier, Defensive Penalty, and Offensive Penalty.

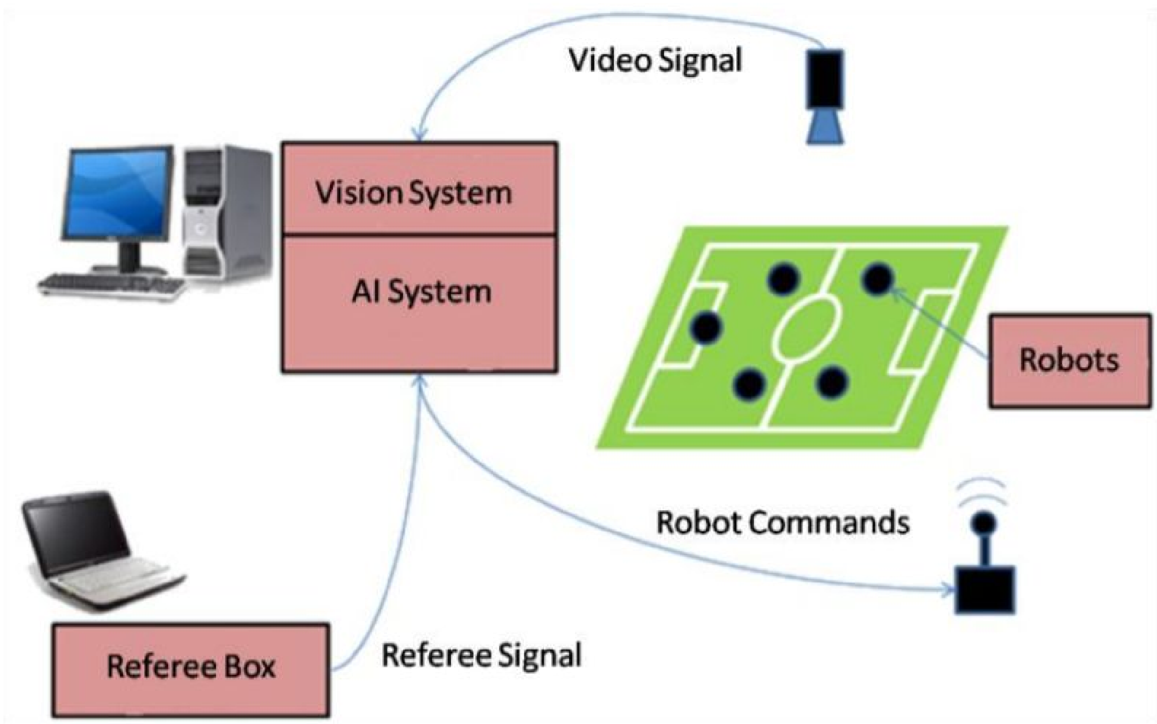


An illustration of the positions used by the KOBRA system roles on the robot soccer playing field.

One feature of KOBRA is that by changing the roles assigned to the robots and the priority of those roles, KOBRA can be used to implement different strategies.
These strategies can be used to make the team perform differently in its entirety based on the state of the game and improve the performance of the team
The defensive strategy is designed to protect the goal at all costs and try to force the ball back over to the other side of the field. The offensive strategy is designed to take more risks and to attack the enemy's goal more aggressively. The offensive strategy also keeps some robots back to defend the goal should the attack on the opponent's goal be unsuccessful.
KOBRA decides which strategy to use by analysing the positions of the robots in relation to the ball and the goals and determines threat values for each robot.

Introducing Artificial Intelligence

Along with using machine learning to improve object detection, Artificial Intelligence is also implemented to further improve the gameplay of the team.
Most of the strategies that come under the umbrella of using assisted computation, need the help of an extra remote control unit, to handle the processing while still remaining autonomous.



The advantage of using AI is the ability to predict the movement of the ball and the opposing team based on past experience.

Furthermore, it improves the detection and avoidance of obstacles using the study of the path.
This study is to determine if the path that will take the agent is positioned by one or more robots and how far is the agent.
Within the algorithm there are several cases:
Case 1: The agent has one or more obstacles but is located a long distance.
In this case, there are obstacles in the path of the agent, but they are not coming, then the agent follows its normal path, hoping that the obstacle will disappear or be closer to take evasive action.
Case 2: The agent has one or more nearby obstacles.
In this case, the obstacles satisfy the condition of closeness and need to avoid them.
To evade two points are generated perpendicular to the path equidistant from obstacle position. This creates a change of a target position of agent that is generated by a point closest to the target. This position is held until the agent stops detecting the obstacle, to reallocate the original target position.

These kinds of strategies can be implemented via additional hardware that is probably supported in the field to provide extra visual information.

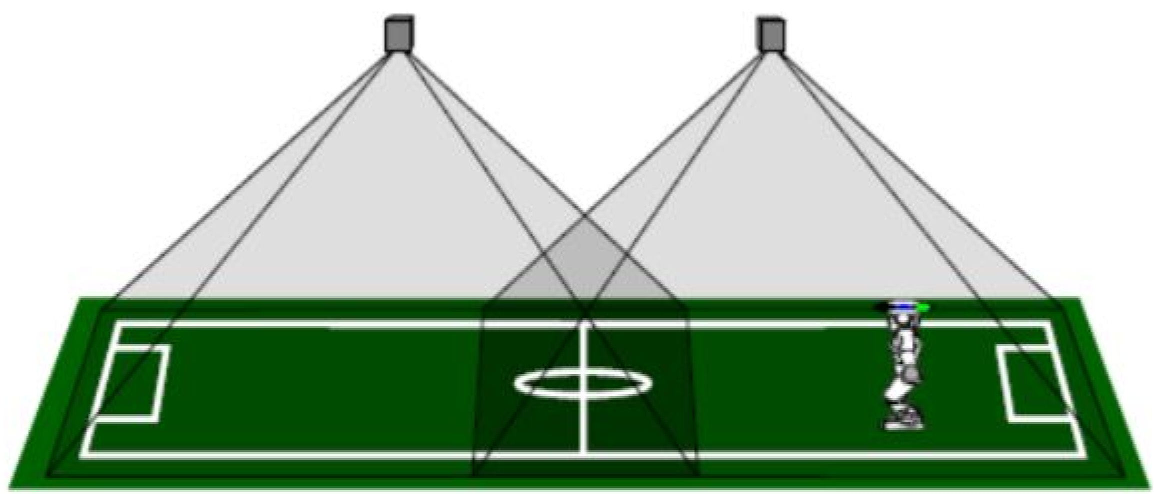


Figure 1: Illustration of how the camera should be placed. In real situation both camera are placed over the goal line.