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Editorial Preface

Robots are becoming part of people's everyday social lives - and will increasingly become so. In future years, robots may become caretaking assistants for the elderly or academic tutors for our children, or medical assistants, day care assistants, or psychological counselors. Robots may become our co-workers in factories and offices, or maids in our homes. It is the second issue of volume first of International Journal of Robotics and Automation (IJRA). IJRA published six times in a year and it is being peer reviewed to very high International standards.

IJRA looks to the different aspects like sensors in robot, control systems, manipulators, power supplies and software. IJRA is aiming to push the frontier of robotics into a new dimension, in which motion and intelligence play equally important roles. IJRA scope includes systems, dynamics, control, simulation, automation engineering, robotics programming, software and hardware designing for robots, artificial intelligence in robotics and automation, industrial robots, automation, manufacturing, and social implications etc. IJRA cover the all aspect relating to the robots and automation.

The IJRA is a refereed journal aims in providing a platform to researchers, scientists, engineers and practitioners throughout the world to publish the latest achievement, future challenges and exciting applications of intelligent and autonomous robots. IJRA open access publications has greatly speeded the pace of development in the robotics and automation field. IJRA objective is to publish articles that are not only technically proficient but also contains state of the art ideas and problems for international readership.

In order to position IJRA as one of the top International journal in signal processing, a group of highly valuable and senior International scholars are serving its Editorial Board who ensures that each issue must publish qualitative research articles from International research communities relevant to signal processing fields.

IJRA editors understand that how much it is important for authors and researchers to have their work published with a minimum delay after submission of their papers. They also strongly believe that the direct communication between the editors and authors are important for the welfare, quality and wellbeing of the Journal and its readers. Therefore, all activities from paper submission to paper publication are controlled through electronic systems that include electronic submission, editorial panel and review system that ensures rapid decision with least delays in the publication processes.

To build its international reputation, we are disseminating the publication information through Google Books, Google Scholar, Directory of Open Access

Journals (DOAJ), Open J Gate, ScientificCommons, Docstoc and many more. Our International Editors are working on establishing ISI listing and a good impact factor for IJRA. We would like to remind you that the success of our journal depends directly on the number of quality articles submitted for review. Accordingly, we would like to request your participation by submitting quality manuscripts for review and encouraging your colleagues to submit quality manuscripts for review. One of the great benefits we can provide to our prospective authors is the mentoring nature of our review process. IJRA provides authors with high quality, helpful reviews that are shaped to assist authors in improving their manuscripts.

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Development a Real Time Cooperative Behavior Approach for Autonomous Soccer Robots Applied in Robocup- MSL

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Abstract

Robocup is an international competition for multi agent research and related subject like: Artificial intelligence, Image processing, machine learning, Robot path planning, control, and obstacle avoidance. In a soccer robot game, the environment is highly competitive and dynamic. In order to work in the dynamically changing environment, the decision making system of a soccer robot system should have the features of flexibility and real time adaptation. In this paper we will focus on the Middle Size Soccer Robot league (MSL) and new hierarchical hybrid fuzzy methods for decision making and action selection of a robot in Middle Size Soccer Robot league (MSL) are presented. First, the behaviors of an agent are introduced, implemented and classified in two layers, the Low_Level_Behaviors and the High_Level_Behaviors. In the second layer, a two phase mechanism for decision making is introduced. In phase one, some useful methods are implemented which check the robot's situation for performing required behaviors. In the next phase, the team strategy, team formation, robot's role and the robot's positioning system are introduced. A fuzzy logical approach is employed to recognize the team strategy and further more to tell the player the best position to move. We believe that a Dynamic role engine is necessary for a successful team. Dynamic role engine and formation control during offensive or defensive play, help us to prevent collision avoidance among own players when attacking the ball and obstacle avoidance of the opponents. At last, we comprised our implemented algorithm in the Robocup 2007 and 2008 and results showed the efficiency of the introduced methodology. The results are satisfactory which has already been successfully implemented in ADRO RoboCup team. This project is still in progress and some new interesting methods are described in the current report.

Keywords: Cooperative Multi-agent system, Decision Making, Decision Tree, Role Assignment, Robocup

1. INTRODUCTION

Robot soccer games had been popular with educational institutions around the world since the inauguration of the Robocup competition in 1997. This initiative provide a good platform for Machine Learning (ML) techniques and Multi Agent research, dealing with issues such as cooperation by distributed control, neural networks, genetic algorithms, decision tree, decision making, fuzzy logic and also many hybrid approaches as a combination of some aforementioned ones ML techniques. In order to work in the dynamically changing environment, the decision making system of a soccer robot system should have the features of flexibility and real time adaptation. The robots in middle-size league should only use local sensors and local vision. Each team can have a maximum number of six robots. They can communicate with each other through a central computer via a Wireless Network. The rules in the competition are the same as the international soccer rules as far as they are practical for robots. The image information of the entire soccer field is captured by robot CCD camera then analyzes the image information to determine the situation of the soccer field and sent to the corresponding host computer. The host computer then analyzes the information to determine the situation of the ball and robots position in the field [1][2]. According to the determined situation, the host computer decides a strategy and plans the motion modes and the corresponding velocity commands for every soccer robot of the same team. Each soccer robot of ADRO then receives a role command from the host computer. A decision tree has several nodes arranged in a hierarchical structure. It implements decisions in a simple, apparent, multistage manner. Furthermore, since each node of a decision tree uses only a simple splitting role and a small subset of all features, the entire decision process is fast and efficient. In this paper a new methodology for decision making in RoboCup soccer with all abovementioned problems consideration is introduced. .We present our work in Dynamic Role allocation for a soccer robot team to modify robots role and strategies and decide which strategy should be applied to the current situation. Dynamic Role allocation allows a team to divide its main objective in a couple of sub-objectives more specialized and adapted to the location of each of the teammates and the strategy of the team. Strategic game play involves role switching for teams with same robots and formation control during offensive or defensive play, collision avoidance among own players when attacking the ball and obstacle avoidance of the opponents [4].

2. ROBOT SOFTWARE

We have developed a software system to fully utilize the hardware abilities. In this paper introduces software parts contain: Robot Strategy, Role Specification, World Model Construction, Artificial Intelligence, Trajectory and Network from a viewpoint of software system [3][5]. Three actions are allotted to the robot: attack, support, and defense. The attack is realized through the following process: first, the robot acquires the ball. The robots continuously try to get the ball. Next, the robot face to ball and targeting to opponent goal then dribbles and shoots the ball into the opponent goal. During the dribble, the robot adjusts its direction toward the opponent goal and dribbles with the fastest possible speed. One of the advantages of our robot is a strong kicking device;

FIGURE 1: ADRO middle size Soccer team from Islamic Azad University- Khorasgan banch, Isfahan, Iran

therefore the robot can shoot a loop-ball into the opponent goal before the opponent defender comes close to the robot. The support robot takes a position behind and near to the robot with the ball. The support robot fetches the ball only when the ball is near to the support robot. The defence robot is located between the ball and own goal. The defence robot doesn’t actively approach when the ball is far. In our team strategy three states are allotted to the team robots: attack, defense, and intercept. The robots autonomously choose to activate each of the roles.

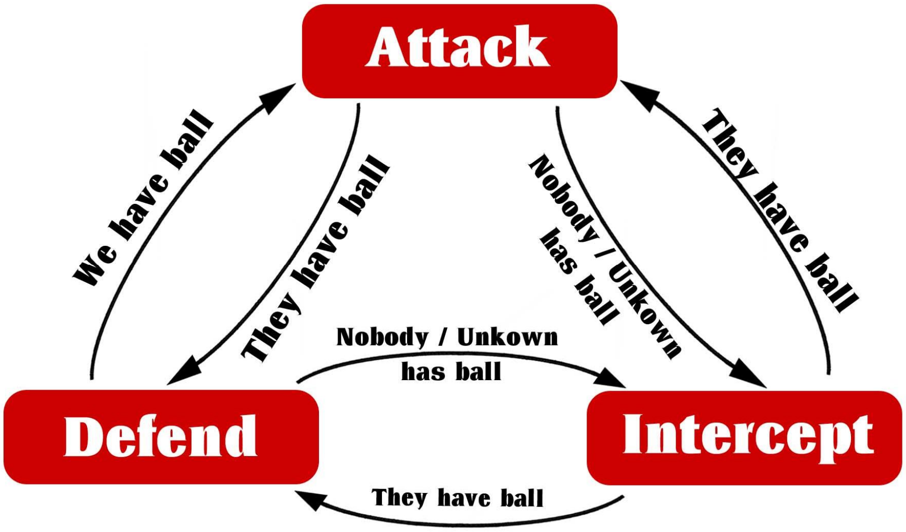

FIGURE 2: Finite state machine to determine the team strategy

3. ROBOT BEHAVIORS

In the proposed methodology some applicable skills are introduced and the decision making policy is developed by considering the features and limitations of this environment. The skills are classified in two layers, in the first layer there are the simple actions which are already implemented (Low_Level Behaviors) and in the second layer the actions are more complicated and sometimes a combination of basic skills are used (High_Level Behaviors). Besides, the decision making process has two steps; First step considers the robot's abilities of performing a high level skill according to his circumstances and the second step considers the robot positioning and choosing the best action regarding to the first step results. The Low Level Behaviors are defined as the actions, which are already implemented by ADRO RoboCup team; they can be employed by sending the proper commands to robot actuator, these commands are: Move(X,Y), Capture_Image(), Read_Ecoder() and etc. High Level Behaviors are those in which the world model information and the Low Level Behaviors are being applied. These skills consist of the actions with ball like: pass, shoot, dribble, etc. and actions without ball like: mark a robot or position, find objects in noisy frames. To actions with ball these actions, basically we need some information about the ball treats, when a force with a particular angle is applied, considering the environment parameters. A number of complicated mechanical formulas could help to predict the ball movements. Some of the most applicable skills with ball are as Shoot, Ball, Dribble (Move with ball), Clear Ball, and Actions without ball skills make robots to be arranged in positions so that they would have the most chance to create opportunities for team or to get the opponents opportunities.

4. STRATEGY

In robot soccer systems, images of objects on the field are processed by a vision system. Analysis of this primary data will yield information such as identification of objects including ball, line, player, and opponents. Other information such as object identity (identity of player), opponent, position, orientation and velocity can also be computed. Based on this information, each of the players carries out assigned roles including attacker, defender, supporter and goalkeeper. The simplest role selection strategy is to have a fixed role that does not change throughout the game. However, permanent role causes undesirable behavior such as a defensive player not going for the ball even though the ball is near but outside its defense zone or a forward player giving up its possession of ball when it incidentally enters a defense zone. The main objective in competitive environment is to score goals; and if a player is in a better position to secure a scoring chance, it must be given the opportunity. A cost function evaluates some parameters like the ball distance, localization, player's orientation towards the ball, etc. and obtains a value for each role. This parameters will be calculated periodically and roles will be assigned to robots according to the values obtained [7][12].

5. DECISION MAKING PHASE 1

In this phase, the robot ability of performing an action according to the environment situation (e.g. opponents' positions/speed, ball position/speed and their predicted states) is tested by Decision Makers (DM) to confirm if that action can be done by the robot in that condition. Some of these decision makers are explained below:

FIGURE 3: ADRO team formation control against MRL attacker robot

a) DM for shooting to a position:

To determine if a robot can shoot to a position or not, first the robot calculates the minimum degree, for shooting, if the degree could be found less than Max Kick Degree then tries to find an angle between min degree and Max Kick Degree and a force less than Max Kick Force. If the angle and a force found with these properties the DM returns true, otherwise it returns false.

b) DM for Shoot to goal

First, the agent quantizes the goal, to n discrete positions. For each position first checks the Shoot to position conditions, if the result is true then shoot the ball toward the goal otherwise check and select other behaviors according to environment situation.

c) DM for Dribble

To determine if it is safe enough for player to dribble, First, the player check the path is free with a potential field algorithm, Then he checks If there is no opponent with distance less than or equal with SecureDribbleDistanceinside; If the result is true then select Dribble behavior, otherwise check and select other behaviors according to environment situation.

6. DECISION MAKING PHASE 2

In The major issues we have addressed in this phase are the dynamic assignment of roles and team strategy. We adopted a formation/role system. Formation contains:

- Formation Name: Like real soccer team formations.
- Strategic area: The area in which the player is mostly supposed to be.
- Center of strategic area: also known as the home position

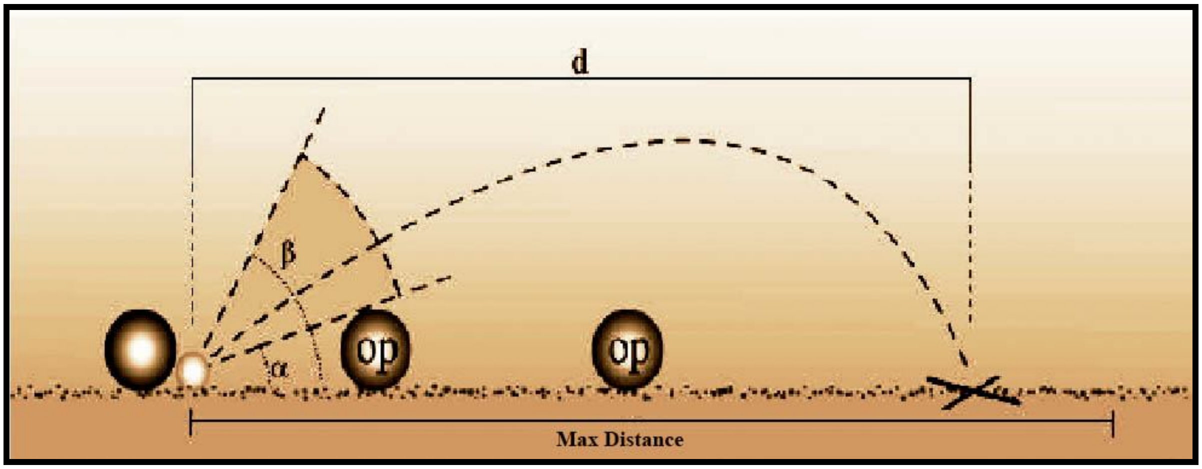

FIGURE 4: Shooting to a position requires minimum angle α to be less than (Max Kick Angle) and minimum distance d less than (Max Kick Distance)

- Player role: we introduced ٤ applicable roles for agents: goal keeper, defender, half backer and attacker.

In this methodology the player role and team strategy are dynamically assigned to the layers according to with different factors. The most important factor is the ball position. According to this changes in strategy the strategic area of the player, changes. To select the appropriate strategy we developed a fuzzy algorithm. In addition this algorithm helps a robot to find out the proper distance with ball according to his strategic area. Depending on the robot's team or the opponent's team owns the ball, the output variable strategy of fuzzy function may change. The last remaining condition is when the robot owns the ball, in this state agent uses the phase 1 decision making results to perform an appropriate operation.

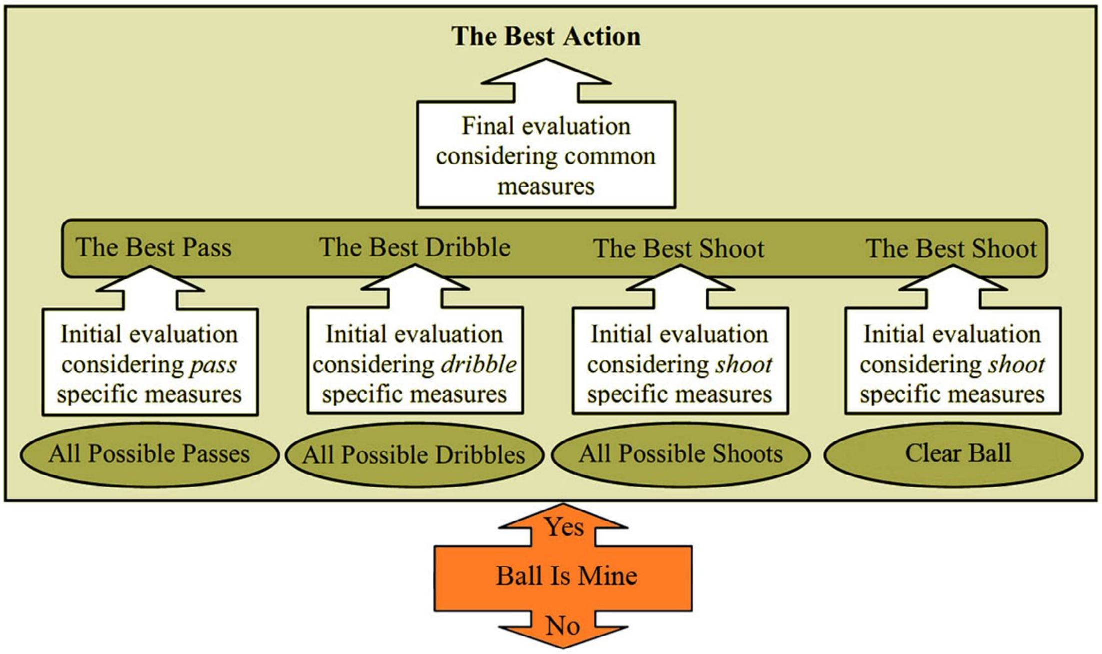

FIGURE 5: The diagram for action selection when players own the ball

7. ROLES SPECIFICATION

The roles can be assigned to each robot in a statically or in a dynamical way. Dynamic role allocation benefits for example, from opportunistic situations like fast ball changes along the field, or failures in some robot. We have considered six main roles in the Robocup domain: Goal-keeper, Attacker, Defender (Right Defense, Center Defense, Left Defense), and Supporter. Goal-keeper is the only role assigned statically. The main reason to have a single player to the Goal-keeper role is that the rules do not allow that players enter in its own goal area (like in the hand ball). The rest of roles can be exchanged among robots according to game conditions. Next, we are going to describe the objectives of each role and the advantages we have obtained using dynamic role allocation:

a) Goal-keeper: Its goal is to protect its own goal from shots by the other team players. Also, it should rest in its own area.

b) Attacker: It tries to get the ball and to carry it, or to kick it, towards the goal. When the other team has got the ball, it tries to recover it actively (going after the ball). None of the other roles are devoted to get the ball. This approach has one implicit advantage: It avoids collision among players of our team, which is explicitly penalized in the rules.

c) Defender: Its goal is to intercept the ball if an opponent kicks it to its goal. Furthermore, it should stand in the way of the opponent and should try to hide the goal preventing the opponent to kick the ball. Another implicit consequence of the Defender role is that one robot of the team always remains in a position near its own net. This fact is very useful taking into account that the ball quickly moves from side to side. We have always one robot covering its defending half of the field.

d) Supporter: The function of this role is to assist the Attacker in its path, and to cover the maximum amount of field in case the ball will be kicked in the wrong way. The main contributions of this role are to recover the ball if the kicks made by the striker do not go in the good direction, and also to maintain a good position for future passing kicks.

8. WORLD MODEL

The World Model is responsible to build a world model using sensorial data. From the sensory inputs and the static information about the game, the Word Model builds the game model, which consists of basic information, like ball position and player postures (Live or Dead), and advanced information such as cooperation decisions. The variables used to define the world model are stored in a Blackboard. The Blackboard is a data pool accessible by several components, used to share data and exchange messages among them. Traditional blackboards are implemented by shared memories and daemons that awake in response to events such as the update of some particular data slot, so as to inform the components requiring that data updated. In our implementation, the Blackboard consists, within each individual robot, of a shared memory among the different components, organized in data slots corresponding to relevant information (e.g. ball position, goal position), accessible through data-keys. Some variables of the blackboard are local, meaning that the associated information is only relevant for that robot, but others are global, so their updates must be broadcasted to the other teammates (e.g., the ball position) (Lima 2002). The cooperation is divided in a high-level cooperation and a low-level cooperation. The former one is stored in the Black-board, and consists of Group-Level and Team-Level Tactics, that can be viewed as analogues of the coach's directives in real soccer. The Group Level Tactics defines tactical parameters for the different player groups: defense, mid-field and attack. For instance, a good defensive tactic is to form a defensive line with the goalkeeper to block all paths to our goal. The Team-Level Tactics set general tactical conditions of the whole team. Parameters as basic formation, e.g. 2 defenders 1 attacker, if we are in a defensive play, or 1 defender 2 attackers, if we are in an offensive play. The low-level cooperation is outside the blackboard because it is a commitment between the robots that are involved in a cooperative action, e.g. when a robot tells another teammate to move to a certain position, in order to be able to receive a pass. It's necessary to have a communication method between all the robots, so they can exchange messages among them. We pretend to use an Agent Communication Language (ACL) (FIPA 2002), allowing us to use a standard and highly flexible message format. [6][9]

9. ARTIFICIAL INTELLIGENT

In this section the AI part of the software is briefly introduced. There are three distinct layers: AI Core, Role Engine and Behavior Engine [11]. AI Core receives the computed field data from world modeling unit and determines the play state according to the ball, opponents and our robots positions.

FIGURE 6: Defense strategy with two robots

Considering the current game strategy, determination of the play state is done by fuzzy decision-making to avoid undesirable and sudden changes of roles or behaviors. Then AI Core sends a set of roles to Role Engine to be assigned to the robots. Because there are instances in which the image-processing unit cannot see the ball, a memory is implemented in the AI Core for the position of ball that specifies which robot owns the ball. Since there is a relationship between new roles and old roles, roles are changed in a manner that robots never experiment sudden changes in roles (for example the role never changes from defense to attack in next cycle). Role Engine receives a set of roles from AI Core and provides the Behavior Engine with a set of behaviors for robots. Twin or triple roles are implemented so that the robots really cooperate with each other to do their roles. Behaviors are the building blocks of the robot's performance which includes simple actions like rotating, or getting the ball and etc. The Behavior Layer is the lowest layer in our architecture. This layer receives a sequence of behaviors along with some parameters from the upper layer (Role Engine) and executes the essential subroutines in order to accomplish a certain behavior. These subroutines use world model information and trajectory data in order to perform necessary movements.

10. Multi-COST FUNCTION FOR ROLE ASSIGNMENT

Role assignment used by many teams is usually computed in real time. Role assignment is necessary to avoid collision of players going for the ball or no player being assign such a role to attack the ball. At the Strategy Decider block has as inputs, amongst others, the score and the remaining time. Based on this information this block selects a fitting strategy that is to be applied, i.e. a combination of a formation (e.g. 1 keeper, 2 defenders, 3 attackers) and a tactic (e.g. center attack, tight defense). The Strategy Function has the following functionality:

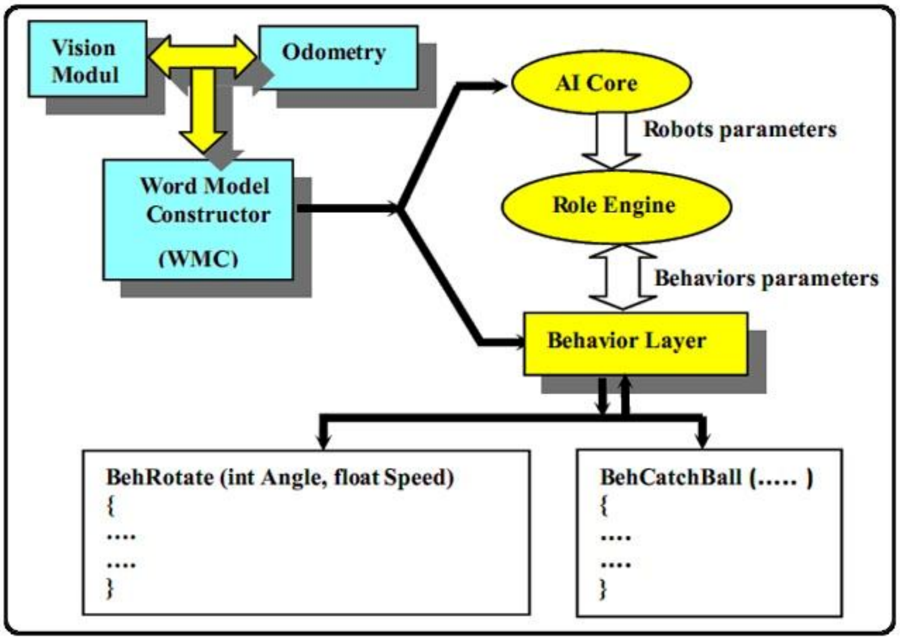

FIGURE 7: World model construction and artificial intelligent structure

(1) load formations and tactics before the game starts; (2) dynamically choose new formations and tactics during the game, based on the environment information; (3) send a list of ٦ unique role identifiers (6 Role IDs) to the Role Engine, based on the chosen formation and tactic. The Role Engine is the component in charge of determining the applicability of the roles with respect to the robots and assigning the most suitable role to each robot. In other words, the role engine determines robot a set of suitable roles for each robot and a rank for each role as a measure of its applicability. On the basis of these ranks, the Role Assigner assigns to each robot the most suitable role while avoiding conflicts with the assignment of this role to another robot. The ranking is based on information about the mechanical state of the robot, the positions of the robot and its team members, and the position of the ball. A general definition for parameters that use in fuzzy arbiter is "value to estimate the cost of executing an action". The parameters will be calculated periodically and roles will be assigned to robots automatically according to the values obtained. In our role assignment the parameters will be individually computed by each robot as inputs to the fuzzy arbiter factors are Distances to ball, goal, path obstacle and etc. These fuzzy variables are defined below:

a) Distance to ball: is the distance of the robot to the ball.
b) Distance to our goal: is the distance of the robot to our goal.
c) Distance to opponent goal: is the distance of the robot to the opponent goal.
d) Orientation: is the orientation of the robot with respect to the straight line path to the ball.
e) Path obstacle: is the angle bounded between the vector of the robot to the ball and the vector of the robot to the obstacle. To fuzzily the distance variable, the ratio of the minimum distance To Ball to the distance To Ball value is used, see equation 1. That is, the nearest robot to the ball will have a membership of value 1.0 for this variable.

$$U_{Dist.ancetoball} = \frac{Dist.ancetoball\_Min}{Dist.ancetoball} \qquad (1)$$

Equation2 describes the membership function for the Orientation variable. A single cosine function is used. The robot that is directly facing the ball will have an orientation angle of 0 degrees, and a membership value of 1.0 for Orientation.

$$\begin{aligned} U_{Orientation} &= Cos(Orientation) \qquad For \quad -90 \le Orientation \le 90 \\ U_{Orientation} &= 0.0 \qquad Otherwise \end{aligned} \qquad (2)$$

The 'or' operation used is the algebraic sum operation. All the fuzzy memberships are added together and the resultant is the membership value of the role Assigned. Next are the equations to select the appropriate robot for each role. In this paper we suppose that the order in roles assignment is Striker, Defender and Supporter.

$$\begin{aligned} &U_{Strike.r} = Min(U_{i,Strik.r}) && \forall i \in (1...n) \\ &U_{Defender} = Min(U_{i,Defender}) && \forall i \in (1...n) \quad \wedge \quad i \neq Robot_{striker} \\ &U_{Supporter} = Min(U_{i,Supporter}) && \forall i \in (1...n) \quad \wedge \quad i \neq Robot_{striker}, Robot_{Defender} \end{aligned} \tag{3}$$

The robot with the highest membership value is assigned the highest priority order among the robots to the role of "attack the ball". Every robot updates its utilities periodically, and broadcasts this information to its teammates. We will refer to this information as coordination information. Finally, the Behavior Executer block executes the behavior that belongs to the assigned role (Role ID). The behavior has to make decisions that are based on the environment at that time. For this purpose, it requires information from the World Model. The assigned role is constructed based on a decision tree (Behavior tree), which consists of the following three types of nodes: Selector, Sequence, and Action, see Fig. 7, 8, 9. The reason that we choose for a behavior tree over for instance a finite state machine is that behavior trees support a clear visual interpretation. The design uses weights for selecting a strategy and assigning the roles. These weights are a priori defined and during the match these weights cannot be changed. In the future, learning will be added to adjust the weights during a match such that a robot will make different decisions as the match develops. The information sent is its own location, and an estimation of its distance to the ball. Coordination information is sent at 5Hz. When one robot receives coordination information it updates data associated to the corresponding robot in its global model. This global model stores position of the teammates and, combined with the position of the ball is used to calculate utilities functions.

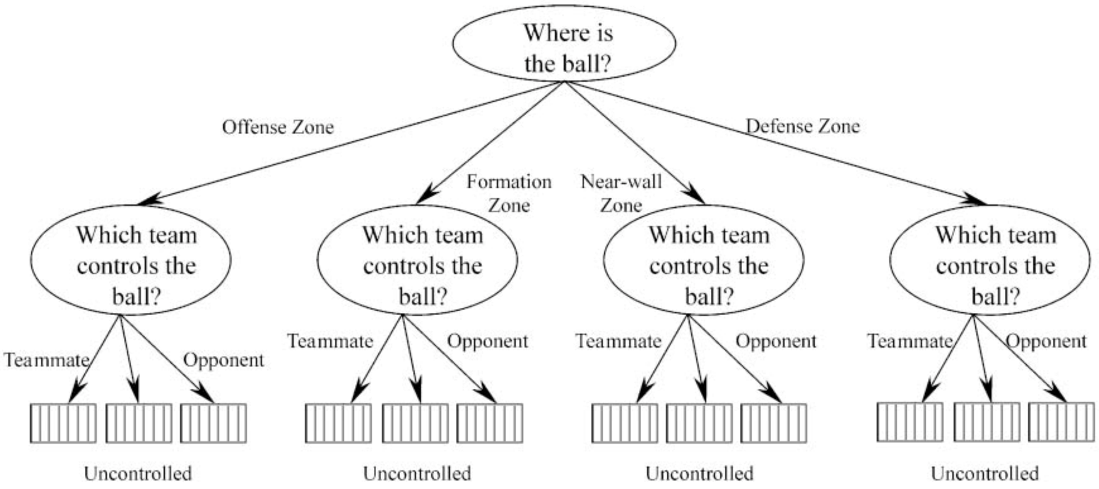

FIGURE 8: The decision tree which implements the strategy-based decision making system.

11. Trajectory

Since the motion trajectory of each robot is divided into several median points that the robot should reach them one by one in a sequence the output obtained after the execution of AI will be a set of position and velocity vectors. So the task of the trajectory will be to guide the robots through the opponents to reach the destination (Figure 11). The routine used for this purpose is the potential field method (also an alternative new method is in progress which models the robot motion through opponents same as the flowing of a bulk of water through obstacles) [7][8][9].

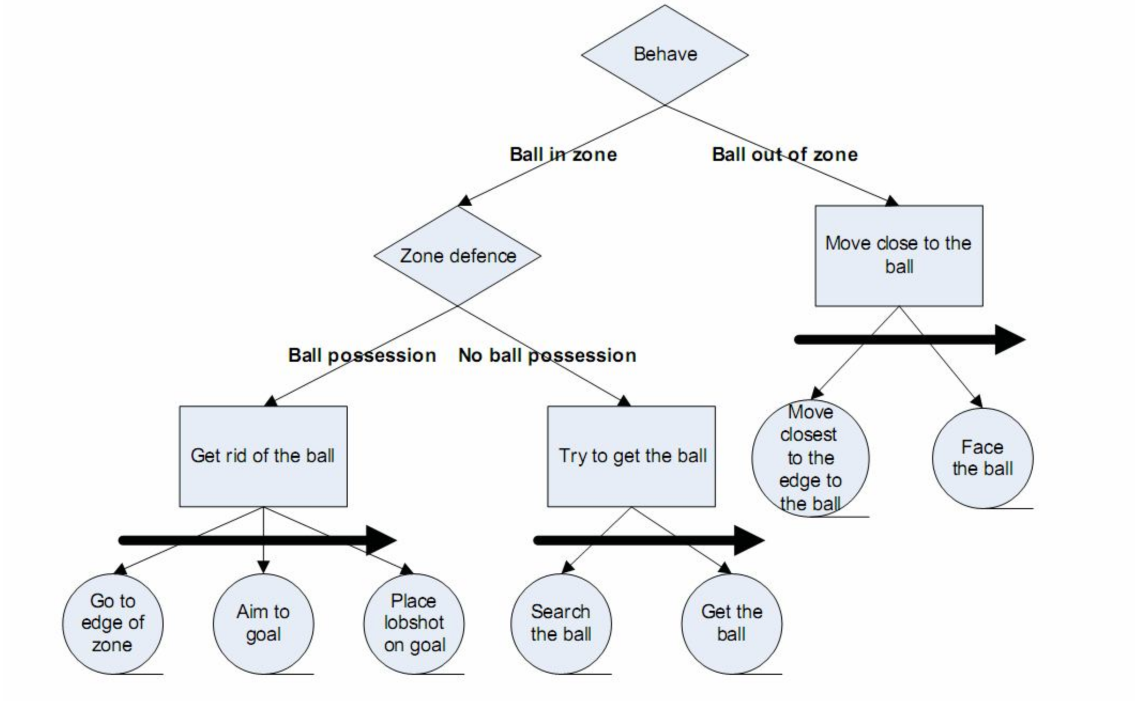

FIGURE 9: Example of a behavior tree: selector (diamond), sequence (rectangle), action (circle).

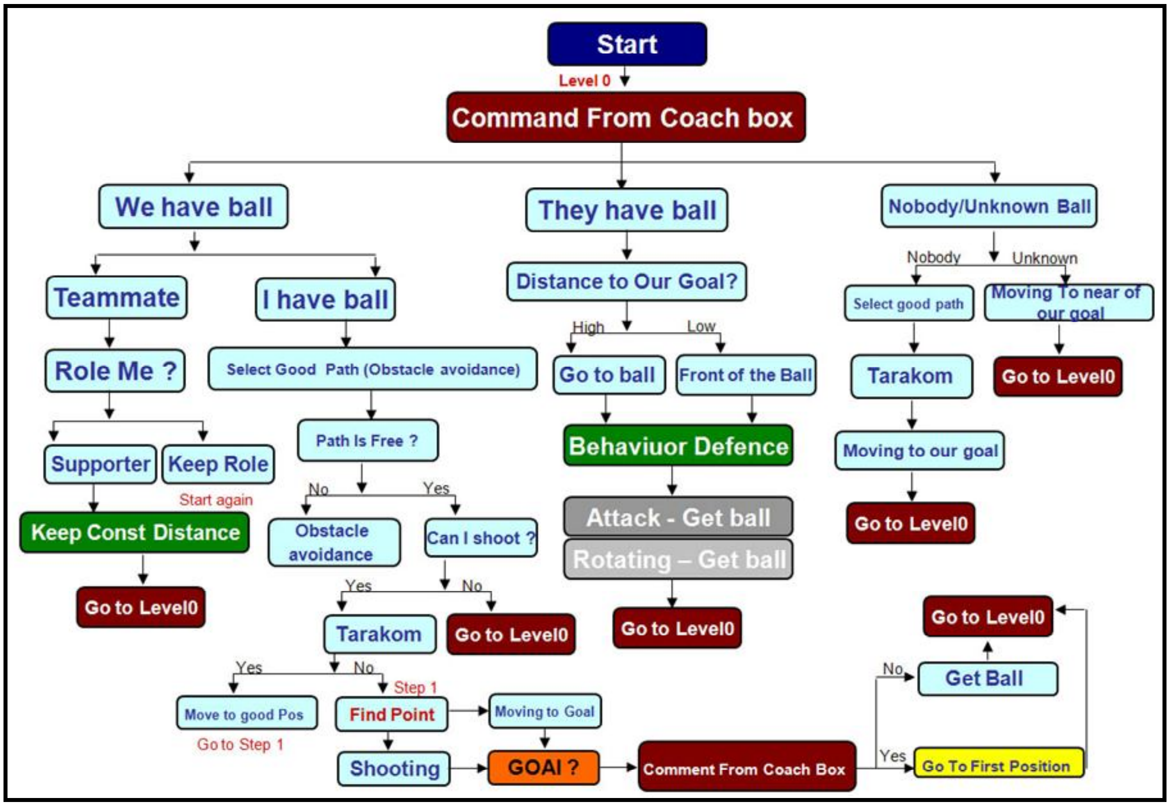

FIGURE 10: The decision tree which implements for soccer robot AI

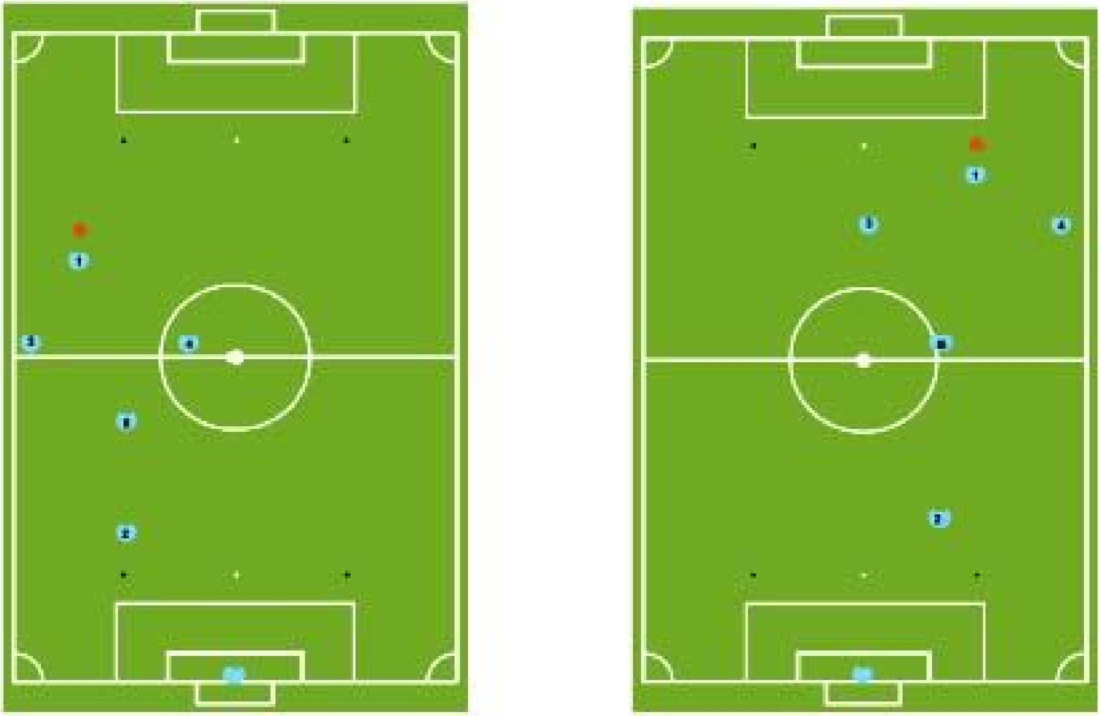

FIGURE 11: ADRO Robots in some different game situations.

In this method different electrical charges are assigned to our robots, opponents and the ball. Then by calculating the potential field of this system of charges a path will be suggested for the robot. At a higher level, predictions can be used to anticipate the position of the opponents and make better decisions in order to reach the desired vector. In our path planning algorithm, an artificial potential field is set up in the space; that is, each point in the space is assigned a scalar value. The value at the goal point is set to be 0 and the value of the potential at all other points is positive. The potential at each point has two contributions: a goal force that causes the potential to increase with path distance from the goal, and an obstacle force that increases in inverse proportion to the distance to the nearest obstacle boundary. In other words, the potential is lowest at the goal, large at points far from the goal, and large at points next to obstacles. If the potential is suitably defined, then if a robot starts at any point in the space and always moves in the direction of the steepest negative potential slope, then the robot will move towards the goal while avoiding obstacles. The numerical potential field path planner is guaranteed to produce a path even if the start or goal is placed in an obstacle. If there is no possible way to get from the start to the goal without passing through an obstacle then the path planner will generate a path through the obstacle, although if there is any alternative then the path will do that instead. For this reason it is important to make sure that there is some possible path, although there are ways around this restriction such as returning an error if the potential at the start point is too high. The path is found by moving to the neigh boring square with the lowest potential, starting at any point in the space and stopping when the goal is reached.

12. NETWORK

The network physical layer uses the ring topology. The UDP (User Datagram Protocol) network protocol is used for the software communication layer. The data flow of the network is as follows: A half field data (the data representing the position and status of the robots, opponents, goals and the ball) is transmitted to the server from each client computer of robots, the server combines them, constructs the complete global localization field then sends the appropriate data and commands (indicating which objects each robot should search for) back to the clients. When the data is completed it is passed to the AI unit for further processing and to decide the next behavior of the robots.

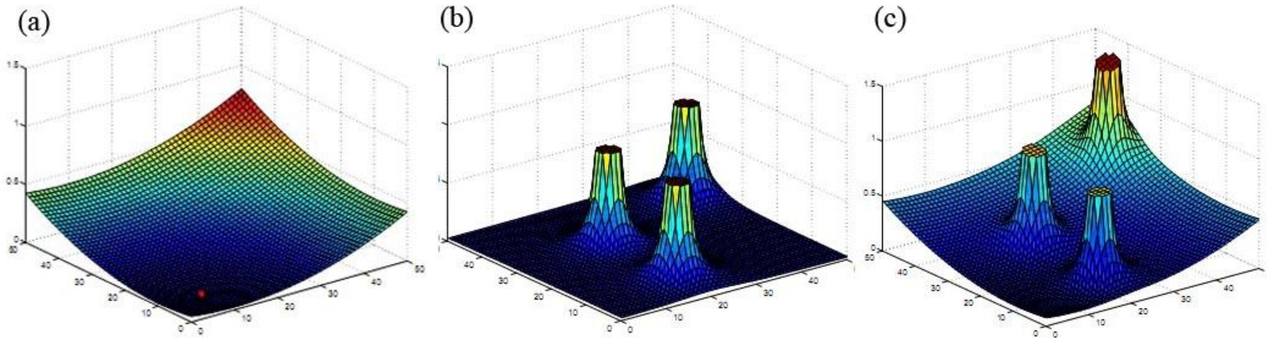

Figure 11. Potential at every point; it is highest in the obstacles and lowest at the goal. Elsewhere it is generally higher farther from the goal and near obstacles. [Image a describe the Goal force (Attractive potential to the goal) and image a describe the Obstacle force (Repulsive potential) and finally image c is Goal Force plus Obstacle force]

13. RESULT

We implemented this methodology on ADRO RoboCup Team. We compare ADRO team performance2008 with its previous version 2007 The results showed the success of this methodology; The team performance in coordination and collaboration highly improved; in fact the players switched their strategic area smoothly as the team strategy changed in a reasonable manner, the robots carried out the high level behaviors much more efficiently and at last the final results enhanced significantly. In 2007 we ranked 2nd place Middle Size Soccer Robot League in 2nd International Iran-Open RoboCup Competitions the Iran-Open is one of the, Asia’s major RoboCup event. At the China-Open RoboCup 2007 as well as at the Iran–Open RoboCup 2007 we ranked 2nd place Middle Size Soccer Robot League, in 2008 we achieved the First Place in the 3rd International Iran-Open Competitions. The basis for our success was the robust and reliable hardware design, well-structured software architecture and efficient algorithms for sensor fusion and behavior generation.

14. CONCLUSION & FUTURE WORK

In this paper, a new method for decision making in RoboCup Middle size soccer robot (MSL) has been proposed. First identification used to the RoboCup middle size soccer robot which led to mechanical formulas, then soccer skills were introduced and classified in different layers then a two phase mechanism for decision making is presented, We have developed a basic role engine and formation control mechanism among members of a multi robot team. Robot localization and local ball estimation are the elements shared. Combining periodically the information received with local information, each robot updates a global model of the environment. Using coordination we have also got a very good way to identify the rest of the team members. In the development of robot soccer where players are homogenous, role engine and formation control becomes a necessity to formulate an efficient strategy to achieve the goal of a successful game. Using a rule based approach allows the strategy for role selection to be naturally developed using domain expertise rather than the alternative of trying to find a suitable cost function that would provide the same performance. in this mechanism both fuzzy and non fuzzy algorithms are applied and finally the proposed methodology implemented on a ADRO RoboCup soccer team and the results. Further information's and video about our works are presented on our website *http://www.IranAdro.com*

15. ACKNOWLEDGMENT

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Advancement of Android and Contribution of Various Countries in the Research and Development of the Humanoid Platform

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Abstract

A human like autonomous robot which is capable to adapt itself with the changing of its environment and continue to reach its goal is considered as Humanoid Robot. These characteristics differs the Android from the other kind of robots. In recent years there has been much progress in the development of Humanoid and still there are a lot of scopes in this field. A number of research groups are interested in this area and trying to design and develop a various platforms of Humanoid based on mechanical and biological concept. Many researchers focus on the designing of lower torso to make the Robot navigating as like as a normal human being do. Designing the lower torso which includes west, hip, knee, ankle and toe, is the more complex and more challenging task. Upper torso design is another complex but interesting task that includes the design of arms and neck. Analysis of walking gait, optimal control of multiple motors or other actuators, controlling the Degree of Freedom (DOF), adaptability control and intelligence are also the challenging tasks to make a Humanoid to behave like a human. Basically research on this field combines a variety of disciplines which make it more thought-provoking area in Mechatronics Engineering. In this paper a various platforms for Humanoid Robot development are identified and described based on the evolutionary research on robotics. The paper also depicts a virtual map of humanoid platform development from the ancient time to present time. It is very important and effective to analyze the development phases of androids because of its Business, Educational and Research value. Basic comparisons between the different designs of Humanoid Structures are also analyzed in this paper.

Keywords: Humanoid Robot, Android, Biped Robot, Evolution of Humanoid Robot.

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1. INTRODUCTION

Nowadays robots become very powerful elements in industry because of its capability to perform many different tasks and operations precisely. Moreover it does not need the common safety and comfort like human. Besides these industrial robots, significant advances have been made in the development of biologically inspired robots or social robots. Bipedal robot especially humanoid robot is naturally enthused from the functional mobility of the human body. However, the complex nature of the skeletal structure as well as the human muscular system cannot be reproduced in this system. A bipedal robot therefore has fewer degrees of freedom (DOF) than a human body. It is very important to choose the number of DOF for each articulation where the selection approach consists of analyzing the structure of the robot from three main planes, sagittal, frontal and transversal planes.

Japanese have a predilection for humanoid robots. In 1952 a Japanese cartoonist, Osamu Tezuka created a human-like robot character, “Atom”, also known as “Astro-boy” in overseas, who became the favorite idol for Japanese children. One hundred fifty years ago Japan had a super-technology in a mechanical doll, a tea serving doll. If a tea cup was putted on a tray, the doll carried it to the guest, served the tea cup and then came back to the start position. Basically today’s humanoid robots are nothing but walking or dancing dolls and are not ready to serve our house hold works. Though humanoids are neither intelligent enough nor autonomous, they currently represented as one of the mankind’s greatest accomplishments. It is the single greatest attempt of mankind to produce an artificial, sentient being. In the recent years manufacturers are making various types and kinds of humanoid robots which are more attainable to the general public.

This paper describes the evolution of humanoid platform based on the earlier and present research work on various mechanical designs and control systems to make the humanoid more friendly and presentable to the world. Some female like androids and humanoid robot kits are also introduced in this paper that holds the values both for the economical and educational advancement.

2. EVOLUTION OF HUMANOID ROBOT PLATFORM

Early research on Humanoid system

Leonardo de Vinci who is considered as the first man, have drawn a humanoid mechanism in 1495 [11]. It was designed to sit up, wave arms, move head while opening and closing its jaw. The 18th century can be considered as the fertile period in the development of many autonomous which were able to reproduce some human movements. In 1773, Pierre and Henry Louis invented the first automation which was able to write [11]. The mechanical trumpeter was created by Fridrich Kaufmann in 1810 [11]. The trumpeter contained a notched drum which was used to activate some valves that helped to pass air through twelve tongues.

Construction and development period of humanoid begins in the 19th century when John Brainerd invented the Steam Man in 1865 [10]. It was moved by steam-engine and used to pull carts. In 1885 the Electric Man was built by Frank Reade Junior which was more-or-less an electric version of the Steam Man [10]. A prototype soldier called Boilerplate was built by Dr. Achibald Campion in 1893.

An evolutionary number of humanoid systems appear during 20th century. At the beginning of this century the Westinghouse society made a human like robot called ELEKTRO in 1938, which was capable to walk, talk and smoke [10]. During 1960s to 1990s a numerous types of legged robot platform started to appear in USA, Russia, France and especially in Japan. A great work on jumping robot was carried out at Massachusetts Institute of Technology (MIT) in 1980s [10]. The Biped Planar, Spring Flamingo, Spring Turkey, Uniroo and 3D Biped were built in MIT having remarkable performance on walking and running movements in a dynamic and stable gait. Figure 1 shows some recent and earlier development of humanoid system.

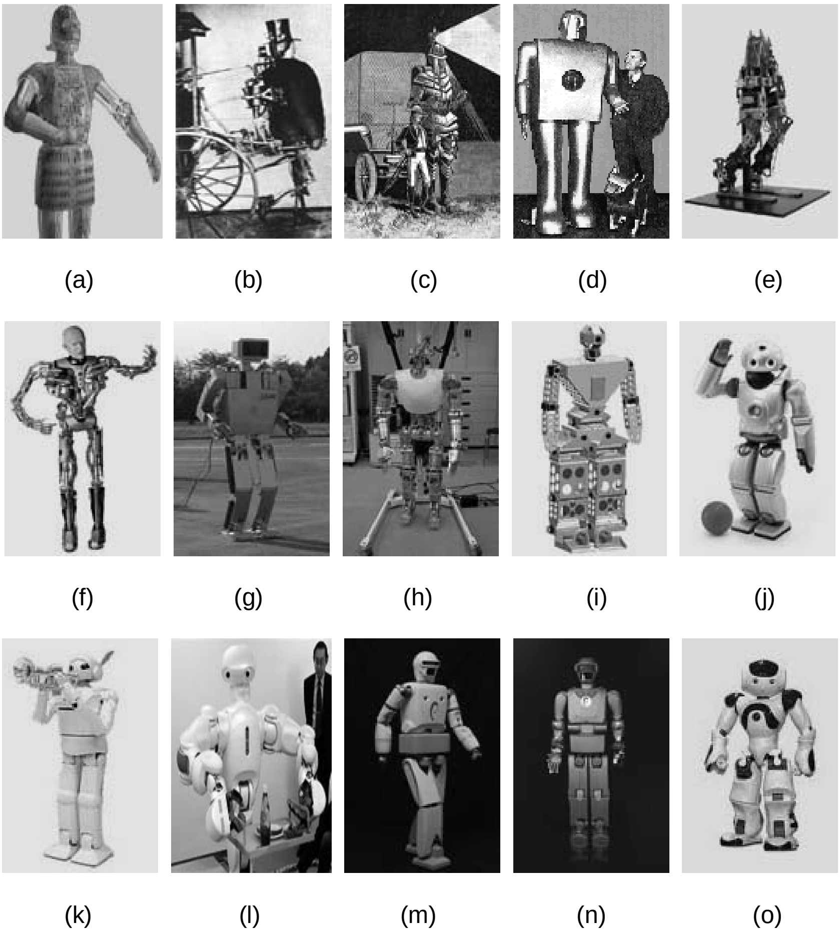


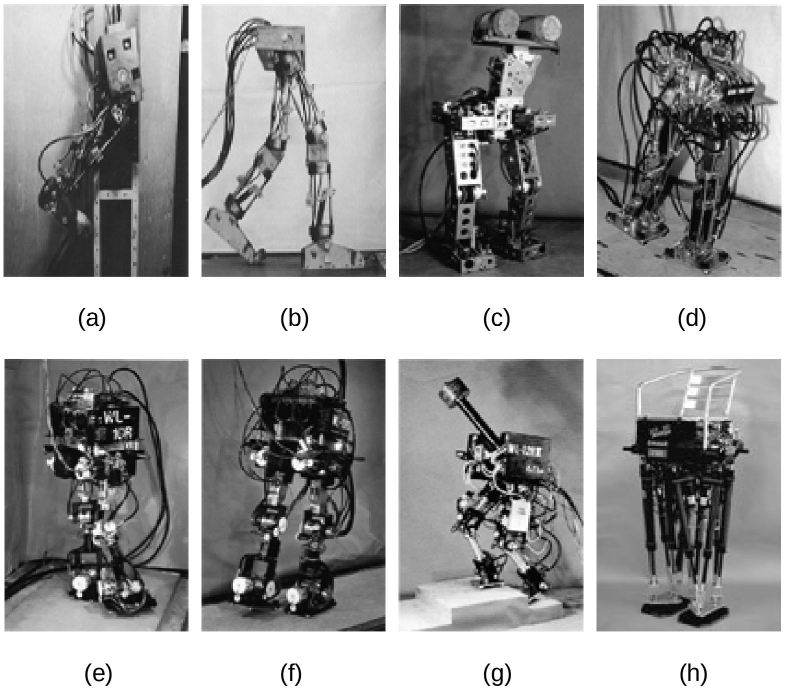
FIGURE 1: Some android platform from ancient time to present time.
(a) First humanoid by Leonardo in 1495, (b) Steam Man in 1865, (c) Electric man in 1885, (d) ELEKTRO in 1938, (e) BIPER-4 in 1984, (f) Tron-Xm developed in Australia in 1997, (g) H6 humanoid from Tokyo University in 2000, (h) Robot JACK in September 2000, (i) GuRoo in 2002, (j) QRIO from SONY on September 19, 2003, (k) Partnar Robot by Toyota Motor Company in 2004, (l) TwendyOne in November 27, 2007 from Wasida University, (m) REEM-A, chess player robot by UAE in 2007, (n) REEM-B by UAE and (o) NAO, in French 2008.

Japanese contribution in the development of humanoid system

Professor Kato's robotic team of Waseda University in Japan developed a whole family of Waseda Legged (WL) robots during 20th century. The fundamental function of bipedal locomotion was applied on the artificial lower-limb WL-1 which was constructed on 1967 [14] [16]. WL-3 was created on 1969 [14] [16] having electro hydraulic servo actuators. Master-slave method based control mechanism was constructed and it was able to manage human like movement in swing and stance phase. Automatic biped walking and the ability to change direction of walking were experimented and made possible using WL-5 in 1972 where a mini-computer was used as its main controller. WL-5 was experimented using the lower limbs of the WABOT-1 having laterally bendable body through which it could move its center of gravity on a frontal plane [14]. Instead of mini-computer, a 16-bit microcomputer was used in WL-9DR (1979 - 1980). In 1983 WL-10R was developed with one more degree of freedom at the yaw axis of the hip joint. Plane walking like walking laterally, turning, walking forward and backward were acquired in this humanoid system where rotary type servo actuator (RSA) was introduced. The latest development of these robots was WL-10RD which was developed in 1984 [10] [16]. It had 10 articulations motorized by electrical servomotors and the body parts made of plastic which were reinforced with carbon fibers. Figure 2 shows the bipedal system of WL family.

Artificial Muscle made of rubber was introduced in 1969 which was used as actuator in WAP-1. For WAP-2 the powerful pouch-type artificial muscles were used and automatic posture control was obtained by implanting pressure sensors under the soles. The three-dimensional automatic biped walking was achieved for the first time by Kato after the development of WAP-3 in 1971 [14]. It was capable to move its center of gravity on the frontal plane so that it could walk on a flat surface, descend and ascend stairs or slope and turn while walking. WL-5 was actually inspired by this mechanism. WAP bipedal robot family is shown in the figure 3.

To develop a personal robot the research on the anthropomorphic intelligent robot, WABOT (WAseda roBOT), was started in 1970s [15]. In 1973 the WABOT-1 was appear as the first fun-scale anthropomorphic robot developed in the world consisting of a limb-control system, a vision system and a conversation system. It was able to communicate with a person in Japanese and to measure distances and directions to the objects using external receptors, artificial ears and eyes, and an artificial mouth. It was able to walk with his lower limbs (WL-5 as its artificial legs) and also able to grip and transport objects with hands (WAM-4 as its artificial hands) that used tactile-sensors. It was estimated that the WABOT-1 has the mental faculty like a one and half years old child. The robot musician WABOT-2 was called as specialist robot in 1984 [15] because of its expertise to play a keyboard instrument with almost human-like intelligence and dexterity. The WABOT-2 was the first milestone in developing a personal robot that was able to converse with a person, read a normal musical score with its eye and play tunes of average difficulty on an electronic organ. It was also able of accompanying a person while listening to the person singing.

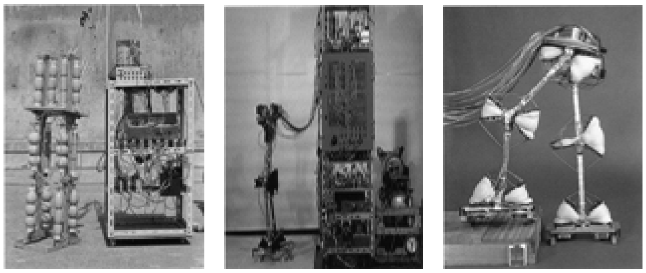

(a) (b) (c) (d)

(e) (f) (g) (h)

FIGURE 2: Evolution of Waseda Legged (WL) robot family.
(a) WL-1 in 1967, (b) WL-3 in 1969, (c) WL-5 in 1971, (d) WL-9DR in 1980, (e) WL-10R 1983, (f) WL-10RD 1984, (g) WL-12RIII in 1990 and (h) WL-16 appeared in 2004.

In 1984, WHL-11 robot was also developed by Waseda and Hitachi, which walked more than 85 km at Tsukuba Science Expo 1985 [16] [17]. During 1986 and 1990, a hydraulic biped robot, WL-12 family, having a trunk and a 2 DOF waist, was constructed to establish more human like motion. A balance control algorithm was developed to improve walking stability, which compensates for moments generated by the motion of the lower limbs. Using the control method, WL-12RIII robot, shown in figure 2 (g), performed complete dynamic walking on a stair with a height of 0.1m having a step speed of 2.6s per step and a step length of 0.3m. On a trapezoid floor with a slope of 10°, it achieved complete dynamic walking with a speed of 1.6 s per step. Also, dynamic walking was realized under an unknown external force of 100 N applied to its back (Takanishi et al. 1991). WL-12RVI, developed in 1992 [16], was able to maintain stable dynamic walking on unknown paths. A walk-learning method and an optimal path generator were created for this device. In 1995, WL-RVII performed dynamic walking on Tatami, Japanese traditional mattress, with a step speed of $1.28ms^{-1}$ and a step length of 0.3m [16]. A foot mechanism using elastic pads had been proposed to absorb impact and contact forces. To improve some problems such as rigidity, power, position errors, etc. of this conventional series, biped walking robots having a parallel mechanism (WL-15 and WL-16) was developed since 2002. The robots were designed for multipurpose use such as welfare and entertainment. An aluminum chair was mounted on the pelvis of WL-16. The humanoid system performed dynamic walking for the first time in the world while carrying a human weighing up to 60kg [16].

WABIAN, an adult-size robot, was created in 1996 using electric motors and achieved the same step speed as a human. It had 35 DOF, two 3 DOF legs, two 10 DOF arms, a 2 DOF neck, two 2 DOF eyes and a torso with a 3 DOF waist. It was able to dance with a human and carry goods [16]. In 1997, WABIAN-R having 43 DOF was developed for exploring robot environment interaction. In 1999, using WABIAN-RII, having 41 motorized joints [10], the emotional motion was presented, which was expressed by the parameterization of its body motion. Human-following walking control was proposed, which has a pattern switching technique based on the action criterion of human robot physical interaction. An impedance control method for WABIAN-RIII was created in 2004 to absorb the contact forces generated between the landing foot and the ground. The control method was able to adjust impedance like the relaxed and hardened motion of muscles of a human. An online locomotion pattern generation was developed for a biped humanoid robot having a trunk, which was based on visual and auditory sensors [16].



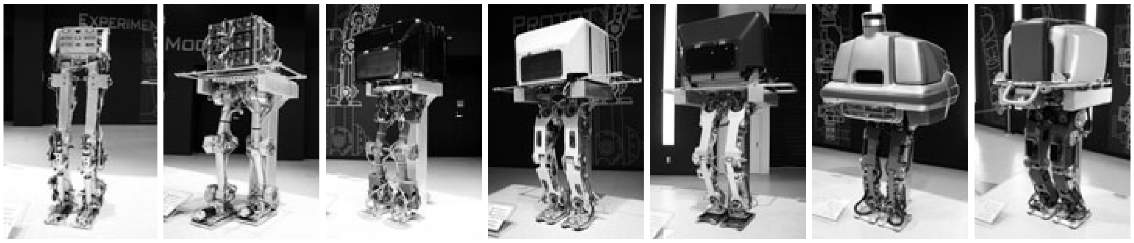
(a) (b) (c)

FIGURE 3: WAP bipedal family developed by Professor Kato's robotic team of Waseda University in Japan where artificial muscles were introduced.
WAP-1 invented in 1969, WAP-2 in 1970 and WAP-3 brought out in 1971.

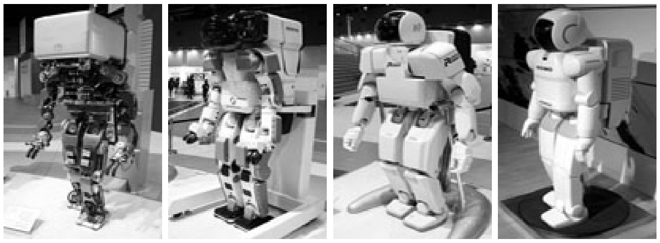
In 1980s, Miura and Shimoyama developed a bipedal robot family called BIPER which was statically unstable but dynamically stable in walking. BIPER-4 robot had non-motorized articulation at the ankles, very big feet and no articulation at the knee [10]. The analogy of an inverted pendulum's movement was used to define its gait. From 1984 to 1988, sano and Furusho's team worked on the BLR-G2 robot which had 9 DOF and was controlled by DC motors. The maximum speed of progression of the robot was $0.35ms^{-1}$. Kajita and Tani built the MELTRAN-II robot in the 1990s [10]. It had passive articulations at the ankles and one of the laws of control was a function that depended on the angle of the equivalent virtual leg. In Japan HONDA company built a whole range of bipedal robots from 1986, shown in figure 4. First there were E0 to E6, then humanoid robot called P1 to P3 and finally the most intelligent humanoid robot called ASIMO (Advanced Step in Innovative Mobility). First version of ASIMO was 1.2m high having 26 DOF and moved by electric motors. The latest version was developed in 2005 having 1.3m high and 34 DOF. Running in straight path as well as circling path was achieved in this latest humanoid robot. Basic specifications of Honda humanoid series are shown in table 1. The University of Tokyo, Japan, developed a humanoid system named SAIKO in 1997 which was low cost, light weight human size robot [3]. Another system called H6 was developed at the same university in the year 2000, as a platform for the research on perception-action integration in humanoid system [2]. Under the Ministry of Economics, Commerce and Industry, Japan, the Humanoid Robot Project (HRP) was started with the creation of a simulation platform, OpenHRP, and the creation a humanoid. The project continued for 5 years from 1998 to 2002 [1]. HRP-2 was a new humanoid robot platform, which was developed as the second version of HRP. It was 1.5m high, weighs was 58kg and had 30 DOF with the ability to move at a speed of 2.5kmh^{-1}. It had vision cameras; force and attitude sensors to control its own balance as well as making plan and control its tasks.

Series	Year	Weight (kg)	Height (cm)	DOF	Walking (Kmh^{-1})	Running (Kmh^{-1})
E0	1986	16.5	101.3	6	Very slow. 5 seconds between steps	No
E1	1987	72.0	128.8	12	0.25	
E2	1989	67.7	132.0	12	1.2	
E3	1991	86.0	136.3	12	3.0	
E4	1991	150.0	159.5	12	4.7	
E5	1992	150.0	170.0	12	Slow	
E6	1993	150.0	174.3	12	Slow	
P1	1993	175.0	191.5	30	Slow	
P2	1996	210.0	182.0	30	2.0	
P3	1997	130.0	160.0	28	2.0	
ASIMO	2000	52.0	120.0	26	1.6	
	2005	54.0	130.0	34	2.7	6.0 (straight path) 5.0 (circling path)

TABLE 1: Specification of Honda Android series.



(a) E0 (b) E1 (c) E2 (d) E3 (e) E4 (f) E5 (g) E6



(h) P1 (i) P2 (j) P3 (k) ASIMO

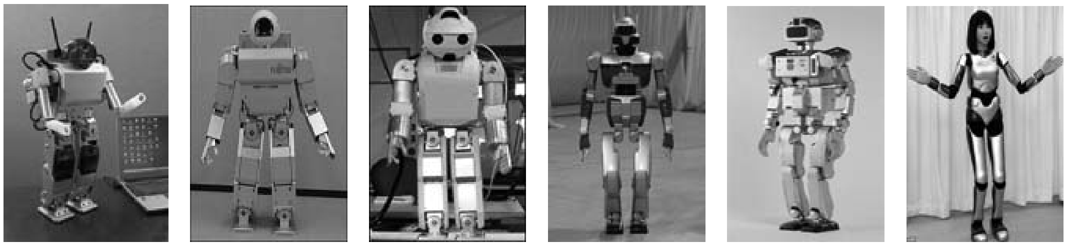
FIGURE 4: Evolution of HONDA Humanoid Robot.
E0 in 1986, E1 in 1987, E2 in 1989, E3 in 1991, E4 in 1991, E5 in 1992, E6 in 1993, P1 in 1993, P2 in 1996, P3 in 1997 and ASIMO started from 2000.

Research on humanoid system in France

The first bipedal robot having only legs and feet was studied and invented in 1993, at Strasbourg University LSIT laboratory, France [10]. 3D bipedal robot BIP2000 was designed and constructed jointly by the INRIA Rhone-Alpes and LMS Poitiers [10]. It was 1.8 meter high and weight was 105kg. Locomotive system of the robot had 12 basic mobilities which enabled it to perform walking gaits similar to that of a human. A pelvis-trunk also mounted on it having three DOF. Statically stable trajectories were obtained in this system to walk at the speed of 0.36kmh^{-1} (0.1 ms^{-s}). With the aiming to establish walking and running gait, the RABBIT project was started in 1998 with CNRS Grenoble, the Frence bipedal robot community [10]. The system had a few DOF and each of the gearboxes of the motors was capable to produce a maximum torque of 150 Nm which was necessary for running gaits. The LIRIS Laboratory at the University of Versailles made an experimental anthropomorphic biped named ROBIAN in 2004 [10]. It had a three-dimensional kinematic architecture with 16 DOF motorized freedom. The 1.30m high robot weighs was 29kg and its foot was made up of an articulated forefoot along a transversal axis moved with a compliant link. The mechanism of the trunk having three mobile mass were used to transfer weight in three dimensions.

Research on humanoid robot in Germany, Korea, Australia, Italy and other countries

Research activities in the field of human robotics are expanding rapidly. Since the advent of Honda's ASIMO and Sony's AIBO, robot fever has broken out in the general public of Japan. Serious basic research for humanoid robots is going on which may have an impact on the future of robotics. In 2002, a small but relatively fast walking autonomous humanoid robot was invented having 17 DOF at Technical University Berlin, Germany [5]. An autonomous humanoid robot was designed in University of Queensland, Australia [6]. Mechanical design of an anthropomorphic bipedal robot was carried out at the National University of Singapore in 2003. The University of Genova, Italy, designed and developed two years old child like humanoid robot called iCub in 2006 [7]. Science the year 2000, a series of KAIST Humanoid Robot (KHR) was developed in Korea. KHR-0 which was developed in 2001 had 2 legs without upper body. KHR-1 was developed on the purpose of research about biped walking which had 21 DOF with no hands and head. The objective of KHR-2, 41 DOF humanoid system, was to develop the humanoid which could walk on the living-floor with human-like appearance and movement. KHR-3 also known as HUBO shown in figure 7 (f), had more human-like features, movements and human-friendly characters. HUBO became familiar from the year 2005 [4]. The HOAP3 humanoid robot platform supplemented the one that was installed at the LAAS CNRS, Toulouse, France in June, 2006 [18]. From 28-31 March 2002 ROBODEX2002 (www.robodex.org) was held in Yokohama where a total of 28 exhibitors, including 13 companies, ten universities and three groups were showed up with a number of humanoid robots platform [19]. ASIMO (Honda), Robovie II, Robovie III (ATR), Guardrobo C3, C4 (Sogo Keibi Hosho), SDR-4X (Sony), Dream Force 01 (Takara), PINO (Tsukuda Original), QC-SR, Tmsuk04 (Tmsuk Co. Ltd), BN-7, BN-8 (Bandai), HOAP (Jujitsu Automation), Posy (SGI Japan & Flower Robotics), Morph (Japan Science and Technology Corp. Kitano Symbolic Systems Project), HRP-1S, HRP-2P (Manufacturing Science and Technology Center), The Shadow (The Shadow Robot Company, UK) were some of them. In addition, universities were showing up with their humanoid related accomplishments with YANBO III (Tokyo Institute of Technology, Hirose Laboratory), SAYA (Science University of Tokyo. Kobayashi Laboratory), KARFE (Nippon Engineering College of Engineering), Mecharobo (Nippon Bunri University, Hirakoso Laboratory), Easy Going Daddy-1 (Hosei University, Takashima Laboratory), High Bar Gymnastic Robot, Saxophone-performing Robot, MARI-1, MARI -2 (Yokohama National University, Kawamura Laboratory), WAMOEBA-2Ri, I SHA, WE-4 (Waseda University, Humanoid Laboratory) and Magdan (Kyoto University, Takahashi Laboratory).



(a) HOAP 1 (b) HOAP 2 (c) HOAP 3 (d) HRP 2P (e) HRP 3P (f) HRP 4C

FIGURE 5: HOAP (Jujitsu Automation, Japan) and HRP (Manufacturing Science and Technology Center) family of humanoid robot platform.
HOAP 1, 2 and 3 are introduced in 2001, 2004 and 2006 respectively. HRP-2P is brought out in 2002, HRP-3P in 2005 and HRP-4C in 16 March, 2009.

Project Romeo is an ambitious to develop a functional prototype of a humanoid robot by the end of 2011. The project is undertaking by a coalition of companies and national labs in France with the aim to develop a humanoid system that will be able to assist the elderly and visually-challenged people at home. The robot will be 1.2 to 1.5 meter high bipedal intelligent machine that humans could communicate with voice and gesture. The system also could help a person to get up in case of a fall. The idea of the Project was enlightened in March 2008 and started in January 2009 [12]. The organizing company in this project is Aldebaran Robotics, which develops and sells the smaller and intelligent humanoid robot NAO, shown in figure 1 (o).

In Malaysia a small size humanoid, Malaysia Boleh, was developed with the collaboration between Universiti Teknologi Malaysia (UTM) and Cytron Technologies Sdn. Bhd. [22]. It was able to balance itself while walking and standing on inclined floor. Turning, dancing, push up was achieved in this robot. IRobo was a human like robot developed in International Islamic University Chittagong (IIUC), Bangladesh, which was capable to pick up objects, mopping floors and perform other simple tasks. Siddiky's IRobo, developed in 2007, had some special intelligence to respond some voice commands [23] [24].

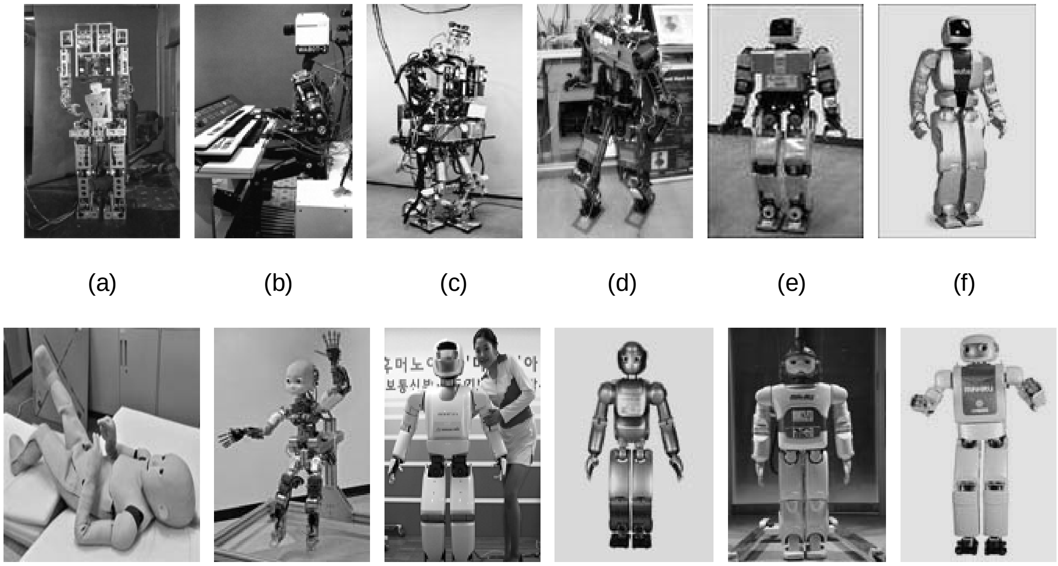
Female androids and other recent humanoid projects

There are also many other greatest android projects both in male and female like structure. The National Institute of Advanced Industrial Science and Technology (AIST) of Japan in conjunction with Kawada Industries has released the HRP-4C humanoid, looks like a young lady with 30 DOF, stands 1.58 meters tall and weighs 43kg (95 pounds). Fashion model cat walk is achieved in this female model like robot and can walk slowly. The price of this robot is about 20 million Yen or USD 200,000. HRP-4C is shown in the figure 5 (f). Kokoro and Osaka University have developed a new life-like android called Actroid DER2 [13]. This android also looks like human lady that can talk and move its head, arms, hands, and body. This android is available for rental at the rate of USD 3,500 for 5 days. China has introduced a singing android called DION. It is a life-sized standing android with a very womanly shape but not so advanced. Another Korean group at KITECH had produced an android called EveR-1 in 2006, which was very much like Repliee-Q1, by Osaka University & Kokoro Inc. Japan. It was about 1.6m tall and weighs about 50kg. Other female androids are AIKO, a very anthropomorphic humanoid built by Le Trung (Brampton, Canada), ACTROID, a VERY realistic and sitting female android announced by Kokoro Dreams and Osaka University in 2003, small size (1 meter) android, Repliee-R1, with 9 DOF by Osaka University and RONG CHENG was introduced by the Institute of Automation of the Chinese Academy of Science in Beijing on August 7, 2006 [20]. Figure 6 shows some of the female like robotic platform.

(a) (b) (c)

(d) (e) (f) (g)

FIGURE 6: Human lady like robotic platform.
(a) and (b) DER-2 project in Kokoro and Osaka University, (c) DION, a singing android from china, (d) and (e) RONG CHENG from Institute of Automation, China, (f) and (g) Repliee-R1, small size android from Osaka University.



(a) (b) (c) (d) (e) (f)

(g) (h) (i) (j) (k) (l)

FIGURE 7: Some bipedal robot family from different institutes.
(a) WABOT-1 in 1973, (b) WABOT-2 in 1984, (c) WABIAN-R IV in 2000, (d) KHR-1 from Korea in 2002, (e) KHR-2 in 2003, (f) KHR-3 also known as HUBO, introduced in 2005 (g) Japanese Child Robot with Biomatric Body or CB2 in 2007, (h) iCub in 2007, (i) MAHRU-II from KIST in 2006, (j) MAHRU-III in 2007, (k) MAHRU-R in 2008, and (l) MAHRU-Z in 2010.

The JST ERATO Asada project and Osaka University have built a child-sized android called CB2 (Child robot with biometric body) shown in figure 7 (g). It is 130cm tall, weighs 33kg, and has 56 DOF. It has cameras for eyes and microphones for ears. It also has 197 tactile sensors embedded in the silicone skin. KAIST has introduced Mahru-M in 2008, Mahru-R in 2009 and Mahru-Z in 2010. E-nuvo is a 1.26m tall humanoid built by Nippon Institute of Technology [20]. Its weigh 15kg., and has a total of 21 DOF. ATOM-7xp is a new humanoid appeared in January 2010 and developed by Dan Mathias at FutureBots over the last 8 years. It is 1.58m tall, weighs 73kg, and has 49 DOF. Pal Technology of the UAE (United Arab Emirates) has announced a very sophisticated new humanoid called REEM-A. It stands 1.45m tall, weighs 41kg. and has 30 DOF [20]. Kawada has released the HRP-3P humanoid. This robot stands 1.60m tall and weighs 65kg. It has a total of 36 degrees of freedom. Tmsuk of Japan has produced a new Samurai warrior robot called KIYOMORI.

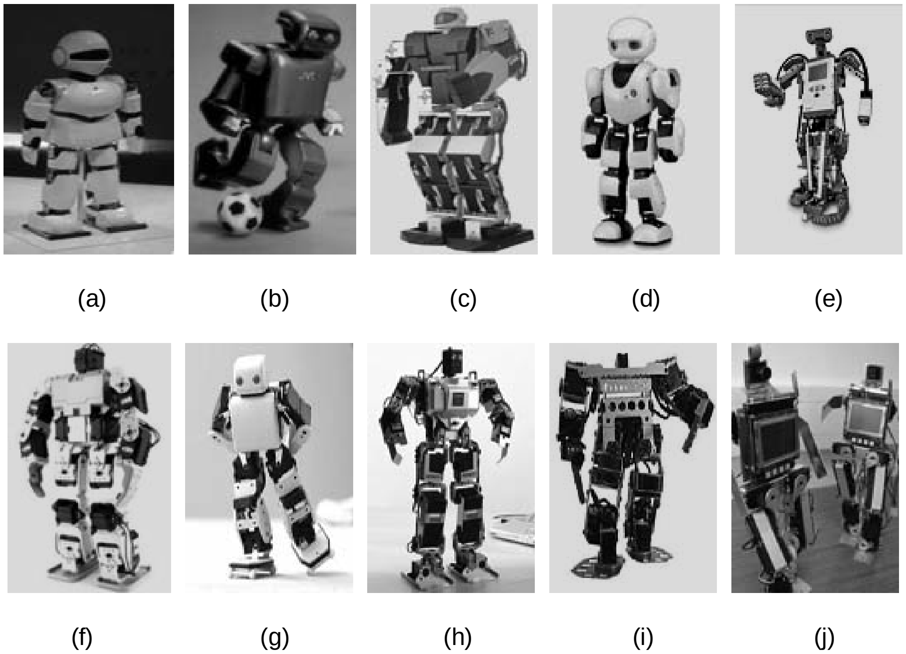


FIGURE 8: Some biped robot kits in humanoid form.
(a) ZMP INC. released PINO humanoid in 2001, (b) Japan Victor (JVC) released J4 robot in 2004, (c) Hitec-Robonova 1 released in 2005, (d) Kyosho-Manoi AT01 in 2006, (e) LEGO MINDSTORMS NXT is a robotics toolset released in 2006, (f) BIOLOID kit released from Robotics in 2006, (g) AkaZawa Plen in March, 2006, (h) KHR-2, bipedal humanoid robot kit in 2006, (i) Robovie-M version 3 released also in 2006 and (j) Flip and Flop robot kit developed in Imperial college London.

Fesco, the pneumatics experts in Australia, had built a huge android called TRON X in 1997 which was about 2.8m tall and weighs about 300kg. It was operated by over 200 pneumatic cylinders of all different sizes [20]. September 10, 2001 Fujitsu Laboratories Inc announced their toy android called HOAP-1, a 0.4572m (18 inch) tall and 5.91kg (13 pound) android with 20 degrees of freedom. The cost was USD 41,000 or 4.8 million Yen [20]. On September 19, 2003 Sony introduced a small size humanoid called QRIO. It was quite similar to the SDR-4X which could walk better and also could recover from a falls [20]. Two new humanoids called ARNE and ARNEA were announced in August 5, 2003 in Russia. These robots were built by St. Petersburg Company called New Era. These humanoids stand 1.23m tall and weigh 61kg having 28 DOF. Beijing Institute of Technology had a big humanoid project called BHR-1 on 2002. This android was 1.58m tall and weighs 76Kg having 32 DOF. It could walk with 33cm steps at a speed of 1kmh^{-1}. Hiroaki Kitano of Kitano Symbiotic Systems (Tokyo, Japan) which was a subsidiary of Japan Science and Technology Corp, succeeded to build an android baby called PINO on April

18, 2002 [20]. The PINO had 29 motors and stands about 75cm tall and weighs 8kg. This android was one of the most popular open source platforms to develop humanoid robot. Another project called TWENDYONE from the Sugano Lab at Waseda University in Tokyo was appeared in 2007 [20]. The big advance in this humanoid was its very sophisticated hands with fingers which had tactile sensors. The humanoid had 47 DOF and stands 1.47m tall and weighs 111kg. Imperial College London had two humanoid projects which had an upper half of a humanoid similar to COG - called LUDWIG. They also had other two small humanoids called FLIP and FLOP which stand about 0.3556m (14 inch) tall [20]. MITs M2 leg project, Fukuda Lab at Nagoya University project called the Biological Inspired Robot System (BIRS), Iranian android called FIRATELLOID (First Iranian Intelligent Humanoid) are some of the recent projects in the field of humanoid robot research. Figure 8 shows some biped robot kit in humanoid form.

Android	**Year**	**Weight (kg)**	**Height (cm)**	**DOF**	**Power Source**	**Continuous operating time**	**Motor type**	**Main controller**
H6 [2]	2000	51.0	136.1	33	Lead-acid battery (12V 5.0Ah)	10 to 15 min.	DC	Dual PentiumIII-750 MHz (100 MHzFSB) with 256MB SDRAM and 6.4GB 2.5 inch IDE HDD
HRP-2 [1]	2002	54.1	154.96	30	NiMH battery (48.0V 18Ah)	60 min.	DC	Real time controller, Pentium III, 933 MHz. with ART-Linux operating system.
QRIO [20]	2003	6.5	58.0	28	Sony's proprietary lithium ion battery	60 min.	DC	Two 64 bit RISC processor, two 64MB DRAM, Sony's original real time OS (Aperios) with Open-R control architecture.
KHR-3 (HUBO) [4]	2005	55	125.0	41	24V 20Ah Lithium polymer	120 min. with movement	DC motor with harmonic drive reduction gear mechanism	Pentium III 933 MHz embedded PC with Windows XP and RTX.
MAHRU-III [20]	2007	62	150.0	32	Lithium polymer battery, 48V 20A	30 min.	DC	Duel CPU boards structure with RT-Linux as real time OS.

TABLE 2: Specification of some world greatest Androids in early 21st century.

Android	Year	Weight (kg)	Height (cm)	DOF	Power Source	Continuous operating time	Motor type	Main controller
iCub [7][20]	2007	23	90.0	53	Two power supplies from Xantrex (XFR-1.2Kw-35V-35A and XFR-2.8Kw-60V-46A)	No battery, connected with power supplies.	DC and Servo (for eyelids)	On board PC 104 hub computer connected with an off-board computer system through Gbit Ethernet cable.
REEM-A [20]	2007	40	140.0	30	Lithium-ion	90 min.	DC	Intel Pentium M (1.6 GHz)
REEM-B [20]	2008	60	147.0	51	Lithium-ion, specially designed for REEM-B	120 min.	DC	Intel Core Duo (1.66 GHz) Geode(500 MHz)
NAO [8]	2008	4.5	57.0	25	Lithium-ion 55 Wh	90 min.	Brush DC motors	CPU is an AMD Geode, running at 500 MHz accompanied by 256MB of RAM
MAHRU-R [20]	2008	67	145.0	35	--	--	DC servo motor with belt-pulley and harmonic drive gear	micro-ATX CPU board with Linux Fedora Core 5 (RTAI/Xenomai)
HRP-4C [9]	2009	43	158.0	42	NiMH DC 48V	20 min.	DC motor with harmonic drive gear	Pentium M 1.6 GHz (PCI-104 SBC) for motion control and VIA C7 1.0 GHz (Pico-ITX motherboard) for speech recognition
MAHRU-Z [20]	2010	55	130.0	35	--	--	--	--

TABLE 3: Specification of some greatest Androids from 2007 to 2010.

Table 2 and table 3 show the basic specifications of some world class humanoid robot platform appeared in the early 21st century. These androids from different institutes and companies of various countries show the greatest accomplishment of human in the field of humanoid robot research and development.

3. FUTURE OF ANDROIDS

In the next two decades robots will be used as the replacement of humans in most the manufacturing and service jobs. Economic development will be primarily determined by the advancement of robotics. Japan's current strength in this field says that they may become the economic leader in the near future. Microsoft is currently working to stabilize the fragmented robotics market with its new software, Microsoft Robotics Studio. Walking smoothly is not easy for a robot, especially when the ground is bumpy. Researchers at Japan's Waseda University have developed a pair of four foottall robotic legs that can move efficiently across uneven terrain. The Biped Walking Robot uses foot like sensors to measure the forces between its base and the floor, maintaining on-the-fly balance based on the weight of its load. In near future humanoids will exhibit emotion, forge relationships, make decisions, and develop as they learn through interaction with the environment. Robots that can incrementally acquire new knowledge from autonomous interactions with the environment are the main target to accomplish. Humanoid Robotics also offers a unique research tool for understanding the human brain and body. Humanoids have provided revolutionary new ways for studying cognitive science. According to an article in www.korea.net, in 2007 the global market for robots grew by 18.9 percent to an estimated USD 8.12 billion. The markets of manufacturing and service robots registering growth are at USD 5.89 billion and USD 2.23 billion, respectively. The industry for service robots, including humanoid robots, is hard to estimate because of its early stages of development, but it is forecasted that the market will be worth between USD 17 billion and USD 50 billion by 2012. The largest concentrations of activity are presently in Japan and Korea, two of the major leaders in the production of service robots. It is predicted that by the near future the Intelligent Service Robot industry will grow to the same size as the IT industry in 2005. Japan’s Mitsubishi Research Institute predicts that each household would own at least one robot by 2020.

4. CONSLUSION

According to the famous Japanese mechanical animation designer Mr. Yutaka IZUBUCHI, the ratio of each body-parts of a humanoid system is very important for personification and friendliness. So, humanoid robot sizing is a very significant factor where Golden Ration based analysis and design can be considered. Cooling system for the actuators, especially for the leg, can be employed like the humanoid system HRP-2, Japan. Because of the continuous work, the raising of the temperature inside the actuators can be controlled by adding the cooling system that will help the robot to work for longer time. Damping mechanism is also another important factor that can be considered for the humanoid structure, particularly in designing the lower torso. The damping mechanism will help the humanoid to absorb the opposite force of the ground in landing its foot while walking, running or jumping. This damping technique may improve the control system to make the humanoid more stable and smooth in navigation. Human articulation has damping mechanism that is controlled by the muscle strength. This mechanism also can be achieved by using special actuators in the joints of the humanoid system, where a huge amount of researches are needed to accomplish this technique. To communicate with the environment, large number of appropriate sensors should be applied on the robotic platform where visual systems are very important and vital to understand the outer world. Distributed power supply unit will make the humanoid system more efficient by balancing the weight of the body parts. Moreover a good controller with appropriate, suitable and efficient control algorithm should be developed and applied to the humanoid to make an intelligent and reliable humanoid robot. The field of humanoid robotics is extensively and unavoidably multidisciplinary and has interrelations to a host of new horizon technologies, such as, Mechatronics Engineering, Neurobio Engineering, Neuromorphic Engineering, Nanoelectromechanical systems and so on. The robotics industry is experiencing exponential growth worldwide and stands poised to become one of the most exciting and expansive markets for technology in the twenty-first century. Robots will soon be everywhere, in our home and at work. They will change the way we live. This will raise many philosophical, social, and political questions that will have to be thought and answered. In science fiction, robots become so intelligent that they decide to take over the world because humans are deemed inferior. In real life, however, they might not choose to do that. Robots might follow some particular rules such as Asimov's Three Laws of Robotics, which will prevent them from creating danger for mankind.

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