Team-NUST

Team Description for RoboCup 2016

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Abstract. *This document discusses the team information and the impact of our research work in rise lab on humanoid NAO robots. It describes the details regarding our participation in RoboCup-SPL 2016. A Brief overview of few modules is discussed which include kick, vision, kinematics, localization and motion planning.*

1 Introduction

Team-NUST was established formally in 2013 with the aim of carrying out research in the rapidly progressing field of humanoid robotics, artificial intelligence, machine vision, motion planning, kinematics and navigation; with the motivation to participate in RoboCup Standard Platform League. We are working on robust and predictable kicking motion, multi objective behavior coordination, motion planning, situational awareness based on efficient perception and robust probabilistic multi-agent localization. The team is working in RISE Research Center, part of SMME-NUST, with publications in the field of cognitive robotics, machine intelligence focused on design, control and motion planning for robotics systems including mobile robots, humanoid robots, multi legged robots, intelligent bionics and robotic manipulators.

1.1 Team Constitution

Team-NUST comprises of students of NUST under supervision of Dr. Yasar Ayaz, Director RISE Research Center and Head of Department Artificial Intelligence and Robotics in SMME-NUST. The team’s supervisor, Dr.Yasar Ayaz (PhD Tohoku University, Japan), is a seasoned researcher in the field of humanoid robotics. He has also been included in Top 100 Educators of the world 2013 by IBC of Cambridge and has been featured in Marquis Who’s Who in the World 2013 as a notable academician and researcher in the field of robotics. A list of selected relevant publications of Dr. Yasar Ayaz have been listed in Appendix-A.

1. Dr Yasar Ayaz – *Supervisor*
2. Fahad Islam – *co-Supervisor*
3. Zain Murtaza – *Team Leader*
4. Neelam Umbreen
5. Saifullah
6. Asbah Ashfaq
7. Aqsa Riaz
8. Husnain Ahmed
9. Saadia Qamar

1.2 Brief Team Description

The work by TeamNUST is original and will provide a fresh perspective to the currently faced challenges in RoboCup SPL. Participation of Team-NUST in Robocup SPL will provide teams participating in the competition a means to get acquainted with the state of the art Robocup research being conducted at RISE research center. TeamNUST is also working on implementing a high level multi-robot architecture in Robocup the architecture we are working on is a hybrid of ALLIANCE and MURDOCH with some additive novel exceptions. Our participation in SPL will inspire other teams participating in SPL to focus on high level multi-robot task allocation and decomposition architectures. Team-NUST Robocup SPL Soccer team's work has been covered by several national TV channels and has also been presented at ICRA 2015 in Seattle, USA. Team-NUST has most recently published a paper in IEEE Robio 2015 Conference. Team-NUST qualified in 2014 and 2015 for Robocup Soccer SPL. However, in 2014, the team was unable to collect sufficient funds to participate in Brazil. In, 2015, the team managed to receive partial funding from a number of sponsors but still the funds were just short of the required amount. This year, Team-NUST has secured the funds to participate in RoboCup SPL 2016.

2 Brief Description of Current Work

2.1 KICK

For the kick, a new kick engine is developed with the capability of producing multi-directional, dynamic and impact controlled kicks. The engine only takes two inputs, the local coordinates of the ball and the target. Based on the target direction and distance, the ball dynamics and friction model is used to find the desired initial velocity of the ball.

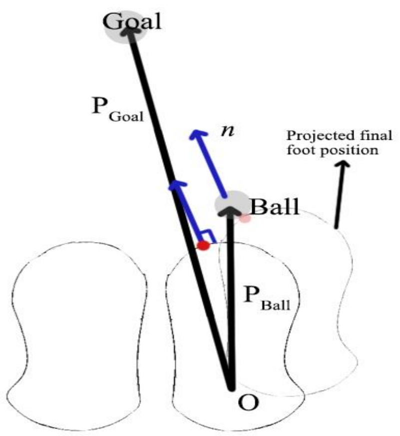

Figure 1: Kick Planning

Then a point on the foot contour is found which makes a perpendicular with the target direction and chosen as the contact point, where the foot contour is based on two approximate Bezier curves

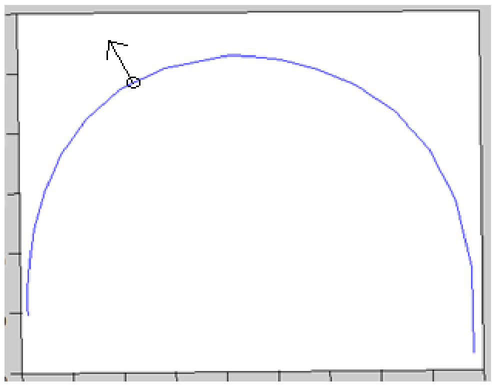

Figure 2: Approximated Foot contour with Bezier curve

The direction is projected back on a circle of radius 'r' to find the retraction point, where 'r' is adjusted depending upon the desired speed needed for the kick. Using the inverse kinematics, the joint configurations at the retraction point and the final ball hitting point are calculated. The dynamic model of the kicking leg is then used to find the mass matrix at the final configuration and further it is used to find the virtual mass in the desired kicking direction. Using the virtual mass, the ball mass and the desired ball velocity, a linear elastic collision model is constructed to find the velocity needed for the foot contact point. The resultant velocities are then converted into joint velocities and finally fed into the trajectory generator. The trajectory generator takes the retraction point and the ball contact point as the knot points. It uses the joint configurations (position, velocity and acceleration) at the knot points and constructs a quintic spline to provide smooth and continuous position, velocity and acceleration profiles. The trajectory is then executed.

2.1.1 Results

To find out the results of impacts, an overhead firefly MV 60 fps camera was used. The frames just before and after the impact were taken and the ball pixels displacement was detected. Matlab was used for calculating ball displacements and doing further calculation. The graph in Fig.3 shows the difference between the desired velocity and actual measured velocity using the experiment.

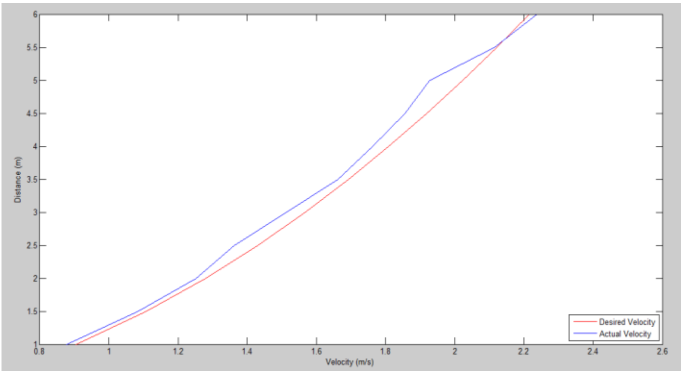

Figure 3: Velocity Results

The graph in Fig.4 shows the results of different straight kicks with desired distances (1m, 2m, 3m, 4m, 5m, and 6m). The standard error mean (SEM) in each case is: SEM_1 = 6.8%, SEM2 = 6.1%, SEM_3 = 2.01%, SEM_4 = 5.39%, SEM_5 = 3.57%, SEM_6 = 4.73%

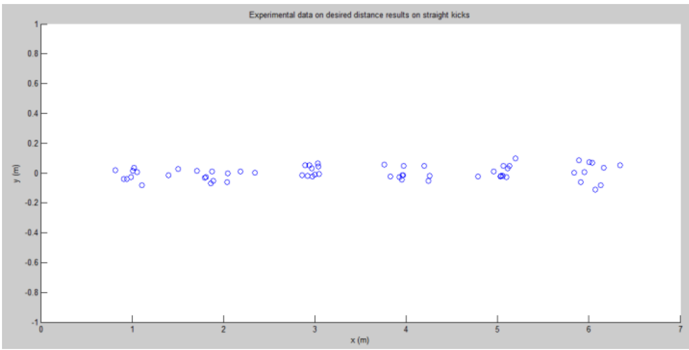

Figure 4: Desired Distance Results

Consideration is given to the allowed range of feet, and this is adjusted in the path planning stage before kick where the robot is aligned in an orientation such that it can perform the kick.

2.2 Vision

Areas of vision covered are soccer ball detection, robot detection, goal post detection, field area extraction and corners detection on the image. All the visions algorithm were focused on their robustness, resistance to lighting variations and accuracy of results. Color features were taken as starting point for detecting different field features like field bounding edges, field lines, corners and objects such as robots and goal post. The camera model is used along with forward kinematics to determine distance information of landmarks in scene.

Field area is extracted from each frame using an adaptive color range, and inverse perspective transform (which is derived from the camera model and forward kinematics) is applied on each frame to get a bird's eye view of the visible field area. This bird's eye view makes it easier to detect field corners and to distinguish goal post from field lines.

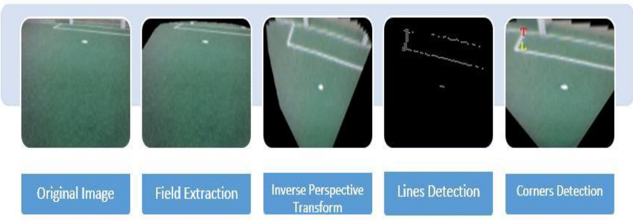

Figure 5: Detection of field, lines and corners

Robots are detected and tracked while they are in the field of view of the robot.

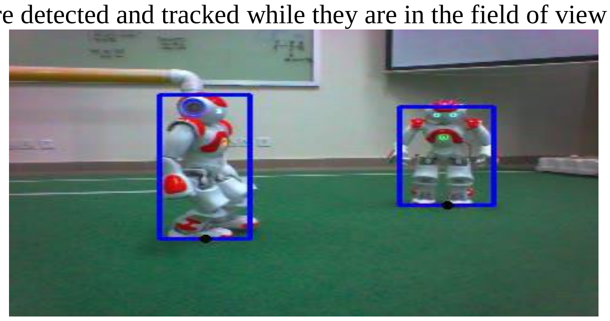

Figure 6: Robot Detection

Soccer ball detection is done by combining different methods used in object detection. These include color based detection and shape/polygons based detection etc. A simple illustration is shown in Fig. 7. Once detected, the ball is tracked using histogram comparison algorithm and position and size is updated after regular intervals to minimize error while tracking.

Figure 7: Color Based Ball Detection

2.3 Localization

The determined landmarks are used by the sensor models for Kalman filter and Particle filter. An odometric model is used for both filters. Particle filter is used to solve kidnap problem. Once a unimodal distribution is established Kalman filter is used to track the estimate with extra states to estimate slippage and odometric errors. We are working on localizing dynamic objects and adding them to world belief which is shared among all players at run time.

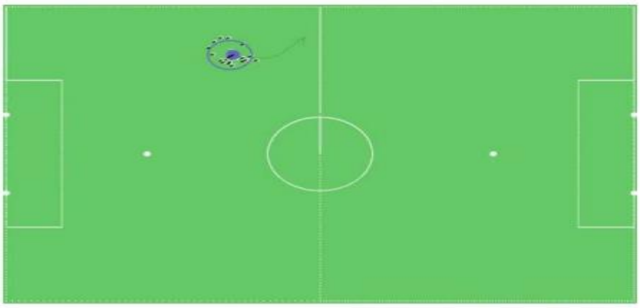

Figure 8: Localization in field

2.4 Motion Planning

Robot motion in the field was planned using different methods. Trajectory generator plans an estimated path for longer distances. Motion of the robot while approaching the ball at close proximity has been experimented using potential fields as well as footstep planning. A Bezier curve is generated towards the ball, considering robot direction towards the target and to generate the trajectory of kicking foot.

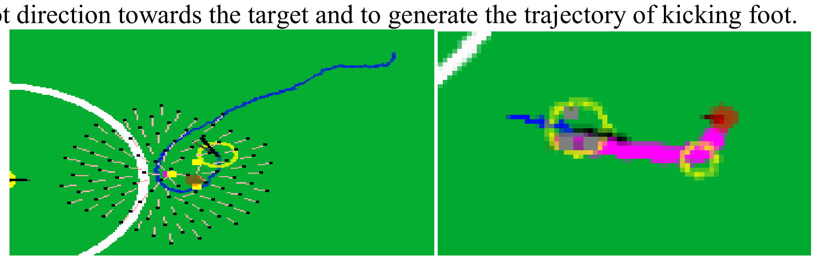

Figure 9: Motion: Potential Field (left); Footstep planning (right)

2.5 Goal Keeper

Taking right decision, in limited time, for a goalkeeper is of significant importance as it plays a vital role in winning a game. Heuristic based decision-making is used for goalkeeper. The goalkeeper's behavior is implemented using different components, each one providing different feature of a goalkeeper. Components are organized into different level or hierarchies to implement behaviors of a goalkeeper. Tasks that require several components are triggered in a hierarchical tree. Each component is made up of states and transitions that help the states to switch between each other. Pseudo code for state transitions is shown below.

- $[\ -\ ,\ start\ ]$ ⇒ [SeekingGoal]
- $[SeekingGoal\ ,\ goalFound]$ ⇒ [Positioning]
- $[Positioning,\ inPosition]$ ⇒ [SeekingBall]
- $[Positioning\ ,goalLost]$ ⇒ [SeekingGoal]
- $[SeekingBall,\ ballFound]$ ⇒ [Defending]
- $[Defending\ ,\ ballAtFeet]$ ⇒ [ClearingBall]
- $[Defending\ ,\ ballNear]$ ⇒ [MovingToTheBall]
- $[\mathrm{MovingToTheBall}\ ,\ \ ballNear]$ ⇒ [ClearingBall]
- $[\mathrm{MovingToTheBall}\ ,ballost]$ ⇒ [SeekingBall]
- $[\mathrm{ClearingBall}\ ,\ ballCleared]$ ⇒ [SeekingGoal]

3 Conclusion

Team-NUST is a new team in RoboCup-SPL, and the only SPL-team from Pakistan. The project is an immense inspiration and we are hoping to learn a lot from this experience which will serve as a very strong foundation for our future research work. With exception of a few instances, the work by TeamNUST is original and will provide a fresh perspective to the currently faced challenges in RoboCup SPL. Participation of Team-NUST will also generate awareness in the region regarding RoboCup, our work on SPL was also covered by various local media channels. Team-NUST is eagerly looking forward to participating in RoboCup-2016. We would like to thank National University of Sciences and Technology (NUST), Pakistan for sponsoring our RoboCup SPL research and funding us for the SPL 2016 participation.

APPENDIX A

1. Teppei Tsujita, Atsushi Konno, Shunsuke Komuzunai, Yuki Nomura, Tomoya Myojin, **Yasar Ayaz** and Masaru Uchiyama, “Humanoid Robot Motion Generation Scheme for Tasks Utilizing Impulsive Force,” International Journal of Humanoid Robotics (IJHR), World Scientific Publishing Company, Vol. 9, No. 2, pp. 1250008-1 to 1250008-23, 2012.

2. **Yasar Ayaz**, Atsushi Konno, Khalid Munawar, Teppei Tsujita, Shunsuke Komizunai and Masaru Uchiyama, "A Human-Like Approach Towards Humanoid Robot Footstep Planning", International Journal of Advanced Robotic
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5. **Yasar Ayaz**, Takuya Owa, Teppei Tsujita, Atsushi Konno, Khalid Munawar and Masaru Uchiyama, "Footstep Planning for Humanoid Robots Among Obstacles of Various Types,", Proceedings of IEEE-RAS International Conference on Humanoid Robots (Humanoids), pp. 361-366, Paris, December 2009.

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8. Teppei Tsujita, Atsushi Konno, Shunsuke Komizunai, Yuki Nomura, Takuya Owa, Tomoya Myojin, **Yasar Ayaz** and Masaru Uchiyama, "Analysis of Nailing Task Motion for a Humanoid Robot," Proceedings of IEEE/RSJ
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11. **Yasar Ayaz**, Khalid Munawar, Muhammad Bilal Malik, Atsushi Konno and Masaru Uchiyama, "A Human-like Approach towards Humanoid Robot Footstep Planning," Proceedings of JSME International Conference on Robotics and Mechatronics (RoboMec), 1A1-B02, Akita, May 2007.

12. **Yasar Ayaz**, Khalid Munawar, Muhammad Bilal Malik, Atsushi Konno and Masaru Uchiyama, "Human-like Approach Towards Footstep Planning," Chapter 15, Humanoid Robots: Human-like Machines,
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