Team-NUST Qualification Document for RoboCup-SPL 2016 in Germany

Zain Murtaza, Arbab Aimal Khan, Neelam Umbreen, Husnain Ahmed, Saifullah, Tahir Shahzad, Aqsa Riaz, Saadia Qamar, Fahad Islam, Dr. Yasar Ayaz

RISE Research Center
Department of Robotics and Artificial Intelligence,
School of Mechanical and Manufacturing Engineering,
National University of Sciences and Technology, Islamabad, Pakistan
rise@smme.nust.edu.pk, http://rise.smme.nust.edu.pk/, yasar@smme.edu.pk

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.*

Index Terms — *robocup*

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. Work by the already established teams in Robocup SPL including, but not limited to, B-Humans, RunSwift, Kouretes, Nao-Devils, UPennalizers and Dutch Nao inspired TeamNUST to work for this exciting platform.

The focus of TeamNUST is to span all the relevant areas prerequisite of an autonomous soccer gameplay by a participating team. 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.

2. TEAM INFORMATION

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.

Team-NUST was established as a platform to open and explore research areas of Robotics, focusing on humanoids, under the Legged Robotics Group of RISE Research Center.

Participation in Robocup will help Team-NUST in technical knowledge advancement, as we learn from other teams approaching similar challenges as us. It will provide an opportunity to better contrast our research and ideas with fellow researchers across the globe. RISE Research Center is one of the very few robotics oriented research institutes in Pakistan. Qualification and participation will earn recognition for related research in our community, generating interest in robotics from other academic institutes of all level, thus increasing awareness of robotics in general.

Team-NUST was the first team from South Asia to compete for qualification in RoboCup SPL.

2.1 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. Rise research center web site link is http://rise.smme.nust.edu.pk/.
The team consists of:

- Zain Murtaza – *Team Leader*
- Arbab Aimal Khan
- Neelam Umbreen
- Husnain Ahmed
- Saifullah Asad
- Tahir Shahzad
- Aqsa Riaz
- Saadia Qamar
- Fahad Islam

The team's supervisor, Dr.Yasar Ayaz (PhD Tohoku University, Japan), is a seasoned researcher in the field of humanoid robotics. His papers on Humanoid Robotics span footstep planning, navigation and control; and have been cited by leading universities in more than 12 countries including USA, Japan, France, Germany, South Korea etc. 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.

2.2 ROBOTS

Team-NUST has the following robots currently available for the competition

- Two (2) H-25 NAO v4
- Five (5) H-25 NAO v5

3. PREFERENCES

Team NUST is willing to participate in 3 SPL competitions. Preference is

(1) Indoor team competition
(2) Drop-in player competition
(3) Technical challenges

4. CODE USAGE

Forward kinematics module (by Kouretes) is used for IPT and image pixel to Robot Frame coordinates conversion. We thank them for their code release.

5. PAST HISTORY

Team-NUST qualified for Robocup Soccer SPL in 2014 and 2015 but was unable to participate both times due to funding issues. This time we have devised a proper plan for our funding problem and we are very hopeful that we will participate in RoboCup 2016.

6. IMPACT

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 [1] and MURDOCH [2] with some additive novel exceptions. This work is not yet implemented due to some low level module integration problems, it is still under testing phase and also not yet published. Our participation in SPL will inspire other teams participating in SPL to focus on high level multi-robot task allocation and decomposition architectures and will also have a positive effect on area of task allocation and decomposition which is still developing.

As the only team from Pakistan, it will increase the diversity of the participating teams and help form new international collaboration avenues for future research. NUST has recently been ranked as the best engineering university of Pakistan. The university attracts the brightest of the nation's young scholars. Robotics, an emerging field at the university, is seeing exponential growth in student interest and enrollment. RISE Research center at NUST is currently the most advanced robotics facility in the country that houses the Robocup Soccer Team. Robocup is one of the largest research projects at RISE and responsible for sparking interest in a lot of tangent areas. Demonstrations of robots playing soccer by the Robocup SPL Team at RISE have resulted in directing focus of researchers, students, faculty, and industry towards robotics. Among the numerous projects inspired by research on Robocup, a masters student team is working to develop Therapy for Autism using Human Robot Interaction. Robocup has also accelerated the study of whole body motion planning of humanoid robots at RISE. The 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.

Participating in Robocup SPL 2016 will have a tremendous impact on Robotics in Pakistan. As no team other than team-NUST qualified from South Asia last year, it will be an excellent opportunity to encourage robotics research at a national level and to encourage students' interest. Therefore, it will be a great honour for team-NUST to participate in Robocup SPL 2016.

7. OTHER

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 dedicated team members working on marketing and sponsorship. The team is very hopeful that 2016 will finally be the year that the students from Pakistan get to participate in Robocup SPL.

8. BRIEF DESCRIPTION OF OUR WORK

8.1 KICK

Kick developed is multi-directional with varying speeds. Its structure is key frame based. The Kick module is dependent on two main modules; trajectory generation and inverse kinematics. The kick module takes a total of three points of kick foot, which are calculated by trajectory generator. The joint values of the kicking leg are then calculated using inverse kinematics algorithm and interpolated to generate the kicking motion. The kick motion is divided into three phases. The pre-kick phase, where the robot shifts its Centre of Mass (CoM) on the support leg and initializes the balancer to maintain balance on single foot. The kick phase, in which the kicking foot is interpolated between the three points of trajectory. The final phase is independent of the nature of kick, it adjusts the kicking foot in the pre kick pose and shifts CoM back to both feet.

8.1.1 TRAJECTORY GENERATOR

The trajectory generator takes as input the location of ball and location of ball’s ideal final location. If the goal is not a strict ending point (like goal post) the speed is set to maximum otherwise it is adjusted to the required distance. The trajectory generator provides three points as output, the back point (pointA), the final point (pointB) and a point to adjust the curve of kick (pointC).

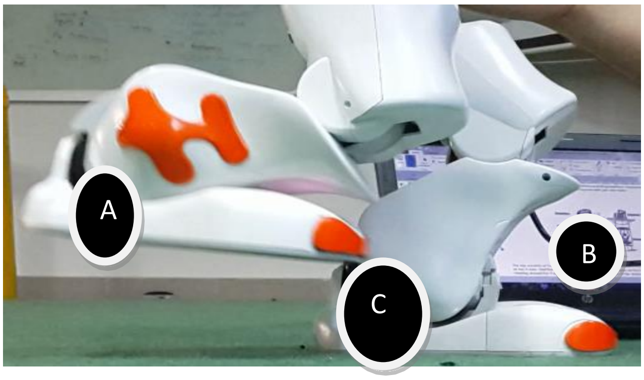

Fig.1 Kick trajectory points

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.

8.1.2 INVERSE KINEMATICS

A DH parameter based model of the legs of NAO is developed. The model is based on the legs of NAO only, and is not effected by the upper body motion. The module calculates leg joint values to achieve the required location of foot. The ankle angles are adjusted so the foot remains parallel to the floor to ensures a straight impact to the ball and avoid collisions with the floor.

The hip roll is adjusted first to get the foot in proper orientation. Then the hip pitch is then adjusted iteratively, followed by a trigonometric solution to get knee pitch. The algorithm gives results with error less than 0.1% average. If a point is outside the allowed workspace, the algorithm clips it to nearest allowed point.

We are focusing on developing an online dynamic kick, which is in final stages we believe it to be ready before competition starts.

8.1 VISION

Areas of vision covered are 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. Each frame is converted to birds eye view using inverse perspective transformation which is again derived from camera model and forward kinematics. This bird's eye view makes it easier to detect field corners and to distinguish goal post from field lines.

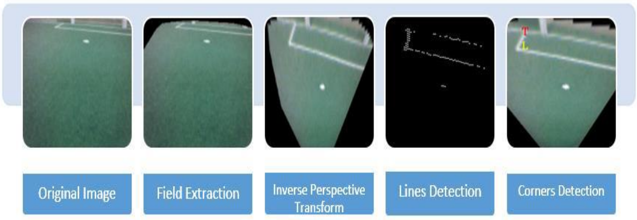

Fig.2 Detection of field, lines and corners

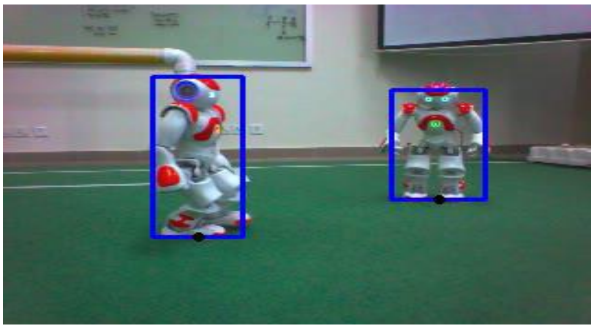

Fig. 3 Robot Detection

4.3 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 which is in the final stages and we are hopeful it will be ready before the competition starts.

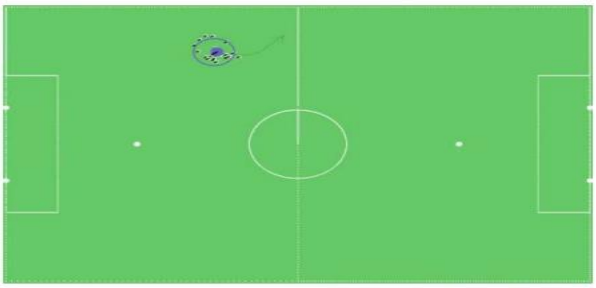

Fig. 4 Localization in field

8.5 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.

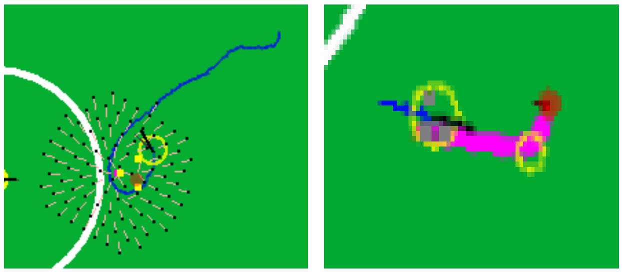

Fig.5 Motion: Potential Field (left); Footstep Planning (right)

9. 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 funds will be finalized after the qualification. We are very hopeful that we will participate in RoboCup 2016.

ACKNOWLEDGMENT

We would like to thank National University of Sciences and Technology (NUST), Pakistan for sponsoring our RoboCup SPL research.

Forward kinematics module (by Kouretes) is used for IPT and image pixel to Robot Frame coordinates conversion. We thank them for their code release.

REFERENCES

[1] L. E. Parker. Alliance: An architecture for fault-tolerant multi-robot cooperation. *IEEE Transactions on Robotics and Automation*, 14(2):220–240, 1998.

[2] B.P. Gerkey and M.J. Matari´c. Murdoch: Publish/subscribe task allocation for heterogeneous agents. In *Proceedings of the Fourth International Conference on Autonomous Agents*, pages 203–204, Barcelona, Spain, 2000.

APPENDIX A
Selected Papers of Dr. Yasar Ayaz

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 Systems (IJARS), Vol. 8, No. 4, pp. 98-109, 2011.

3. Teppei Tsujita, Atsushi Konno, Yuki Nomura, Shunsuke Komizunai, **Yasar Ayaz** and Masaru Uchiyama, "An Impact Motion Generation Support Software", Chapter 11, Cutting Edge Robotics 2010, Advanced Robotic Systems Journal and In-Tech Publishing Company, pp. 175-186, 2010.

4. **Yasar Ayaz**, Atsushi Konno, Khalid Munawar, Teppei Tsujita and Masaru Uchiyama, "Navigation Planning with a Human-like Approach", Chapter 11, Mobile Robots Navigation, Advanced Robotic Systems Journal and In-Tech Publishing Company, pp. 223-240, 2010.

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.

6. **Yasar Ayaz**, Atsushi Konno, Khalid Munawar, Teppei Tsujita and Masaru Uchiyama, "Planning Footsteps in Obstacle Cluttered Environments," Proceedings of IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM), pp. 156-161, Singapore, July 2009.

7. **Yasar Ayaz**, "Footstep Planning Among Obstacles for Humanoid Robots", Doctoral Thesis (Robotics and Machine Intelligence), Graduate School of Engineering, Tohoku University, Japan.

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 International Conference on Intelligent Robots and Systems (IROS), pp. 1570-1575, France, September 2008.

9. Teppei Tsujita, Atsushi Konno, Shunsuke Komizunai, Yuki Nomura, Takuya Owa, Tomoya Myojin, **Yasar Ayaz** and Masaru Uchiyama, "Humanoid Robot Motion Generation for Nailing Task," Proceedings of IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM), pp. 1024-1029, China, July 2008.

10. **Yasar Ayaz**, Atsushi Konno, Teppei Tsujita, Masaru Uchiyama and Khalid Munawar, "Obstacle Stepping Over Strategy for Humanoid Robots," Proceedings of SICE System Integration Division Annual International Conference (SI), pp. 533-534, Hiroshima, December 2007.

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, Advanced Robotics Systems Journal and I-Tech Education and Publishing, 2007.

13. **Yasar Ayaz**, Khalid Munawar, Muhammad Bilal Malik, Atsushi Konno and Masaru Uchiyama, "Human-like Approach to Footstep Planning Among Obstacles for Humanoid Robots," International Journal of Humanoid Robotics(IJHR), vol. 4, no. 1, pp. 125-149, 2007.

14. **Yasar Ayaz**, Khalid Munawar, Muhammad Bilal Malik, Atsushi Konno and Masaru Uchiyama, "Human-like Approach to Footstep Planning Among Obstacles for Humanoid Robots," Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 5490-5495, Beijing, China, October 2006.

15. **Yasar Ayaz**, "Autonomous footstep planning for humanoid robots," Master's Thesis (Electrical Engineering: Controls and Signal Processing), College of Electrical and Mechanical Engineering, National University of Sciences and Technology (NUST), Pakistan, 2005