NTU RoboPAL
Team Description for RoboCup 2013

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Abstract. This team description paper describes the organization, research focus and ongoing work of the NTU RoboPAL team entering the RoboCup Standard Platform league in 2013.

1 Introduction

Team NTU RoboPAL has been participated in the RoboCup Standard Platform League (SPL) competitions since 2009. We were in the top 8 teams in 2009, in the top 16 teams in 2010, won the 3rd place in 2011, and in the top 16 teams in 2012. The current team members consists of the following persons:

– *Chieh-Chih Wang* is an associate professor in computer science and information engineering and the director of the Robot Perception and Learning Laboratory. His research is in the areas of robot perception, computer vision and machine learning.
– *Chun-Hua Chang* is a PhD student in computer science and information engineering. His research involves SLAM in dynamic environments and tracking. He has been a team member since August 2009.
– *Chun-Kai Chang* is an undergraduate student in computer science and information engineering. His research involves robot perception. He has been a team member since August 2011.
– *Bang-Cheng Wang* is an undergraduate student in computer science and information engineering. His research involves locomotion, control, obstacle avoidance and planning. He has been a team member since August 2011.
– *Kun-Li Lin* is a PhD student in computer science and information engineering. His research involves robot perception and robot obstacle avoidance. He has been a team member since September 2012.

The following sections describe our research focus and ongoing work.

2 Research Focus

Our scientific interests are driven by the desire to build intelligent robots and computers, which are capable of servicing people more efficiently than equivalent manned systems in a wide variety of dynamic and unstructured environments. We believe that perception and learning are two of the most critical capabilities to achieve our goals. The RobotCup Standard Platform League provides an excellent scenario for us to exploit and explore robot perception and learning.

2.1 Simultaneous Localization, Mapping and Moving Object Tracking

Simultaneous localization, mapping and moving object tracking (SLAMMOT) involves both simultaneous localization and mapping (SLAM) in dynamic environments, and detecting and tracking these dynamic objects. Our SLAMMOT work [1, 2] provides a foundation for robots to localize themselves and to detect and track other teammates and opponents in the RoboCup scenario with a given map. In addition to LADAR-based solutions, we have proposed solutions to stereo-based SLAMMOT [3] and monocular SLAMMOT [4].

2.2 Simultaneous Localization and Tracking

Localization and moving object tracking are key components for robots to exhibit intelligent behaviors. Based on the theoretical foundation of SLAMMOT, our Simultaneous localization and tracking (SLAT) algorithm integrates information from multiple teammate robots and provides the estimates of the teammate robot poses and the opponent robot positions simultaneously [5]. With the more robust and accurate state estimates, it would be more feasible to design and perform better strategies to play soccer games. Our experiments also show that the localization performance can be boosted by integrating moving object tracking, which is especially useful for the cases where self-localization is challenging. For example, when a robot is focusing on a ball, it is still possible to accomplish localization through the teammates' knowledge on the ball position even map features are insufficient for self-localization.

2.3 Localization in Highly Dynamic Environments

State-of-the-art localization approaches often rely on the static world assumption using the occupancy grids. However, the real environment is typically dynamic. In [6], we propose the feasibility grids to facilitate the representation of both the static scene and the moving objects. The dual sensor models are introduced to discriminate between stationary and moving objects in mobile robot localization. Instead of estimating the occupancy states, the feasibility grids maintain the stochastic estimates of the feasibility states of the environment. Given that an observation can be decomposed into stationary objects and moving objects, incorporating the feasibility grids in localization yields performance improvements over the occupancy grids, particularly in highly dynamic environments. Our approach is extensively evaluated using real data acquired with a planar laser range finder. The experimental results show that the feasibility grid is capable of rapid convergence and robust performance in mobile robot localization by taking into account moving object information. A root mean squares accuracy of within 50cm is achieved, without the aid of GPS, which is sufficient for autonomous navigation in crowded urban scenes. The empirical results suggest that the performance of localization can be improved when handling the changing environment explicitly.

2.4 Locomotion, Obstacle Avoidance and Navigation

We have demonstrated the wide angle kick module in 2010 which allows our robots to efficiently adjusting ball kicking directions. However, it was not fast and stable enough to be practicable in intense games. In 2011, we have built better wide angle kicking as well as designed side kick motion patterns so that the robots can perform ball kicking as soon as possible. For the goalie, we have designed an agile diving motion to rapidly react to potential attacks.

The sonar sensors are currently utilized by many teams to avoid colliding with other robots. However, the sonar sensors can only detect obstacles farther than 30cm. The measurements closer than 30cm, nevertheless, are still critical in the situations such as a number of robots are chasing the ball closely. In addition to sonar measurements, visual images from the onboard cameras are used and fused under our SLAT framework for accomplishing robust obstacle avoidance.

Navigation plays a key role in RoboCup. The nearness diagram (ND) navigation method and the dynamic window approach (DWA) are two of the most popular navigation approaches in the literature. We have proposed a self-tuning ND navigation approach [7] to obtain smoother robot trajectories and a DWA* approach [8] to determine the optimal control policies.

2.5 From RoboCup to Driving Safety

Cars able to drive autonomously have been demonstrated over the last years in the 2005 DARPA Grand Challenge, the 2007 DARPA Urban Challenge [9] and by the Google Driverless Car project [10]. These projects have attracted significant attention globally. High-end sensors such as 3D laser scanners are critical to accomplish the challenging perception problems in both urban areas and at highways. However, these single-robot perception approaches still have limited visibility due occlusion by nearby moving entities and the limited range of their sensors. In [11], it is shown that cooperative perception can achieve sufficient accuracy by combining lower-cost sensors such as 2D laser scanners and stereo cameras with vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication provided by dedicated short-range communications (DSRC) technology. Single-robot perception approaches only insure their own driving safety and still have limited visibility, while in the cooperative perception all moving entities contribute by sharing their scene understanding. The localization and tracking accuracy is increased and there will be less visibility issues in the proposed framework. Our simulations show that the suggested multi-vehicle SLAT could achieve localization with sub-meter accuracy using stereo cameras only. With the use of 2D laser scanners, the reliability and robustness of the whole system can be assured as well as an increase of accuracy.

3 Ongoing Work

Our system for RoboCup 2013 is developed based on our system last year and only relies on the Aldebaran API. This year we are also developing our own walking engine. Based on our previous academic contributions and RoboCup SPL accomplishments, we are currently working on the following tasks.

3.1 Software Architecture

The overview of our system is shown in Fig. 1. Regarding the perception part, the odometry and the camera images are retrieved from the Nao platform through the shared memory, and then a set of feature detectors are executed to extract map and moving object features from the images. Based on the odometry data and the set of measurements from all the detection modules, our Multi-Robot Simultaneous Localization and Tracking (MR-SLAT) algorithm enhanced with Multiple Hypothesis Tracking (MHT) estimates the states of itself, the opponents, and the ball into multiple local beliefs. Then the most likely belief is shared to the teammates. Therefore, all of the teammates can merge all information immediately which servers as the input to our behavior engine. Our behavior engine computes the team formation by the planner, which encodes the target poses for all the teammates. Each teammate robot will be assigned a role according to its current state. For each role, the state machine is designed for the detailed behaviors. The behavior engine then sends commands to the walking engine and the special action engine.

3.2 Perception

In the perception part, the belief-merge algorithm is incorporated to improve the system robustness for the possibly unstable communication.

Multiple Robot Belief-Merge Enhances Robustness of Our System under Unstable Communication Environment Our previous measurement-based system achieves accurate pose estimation for all the robots and the ball by incorporating data from all the teammates. However, one of the most critical challenges is the packet loss issue, in which the unstable communication environment may cause the estimation bias due to the the packet loss. To tackle this issue, this year we developed the belief-merge module: every robot fuses its measurements locally and shares the fused belief to the teammates. Then it merges

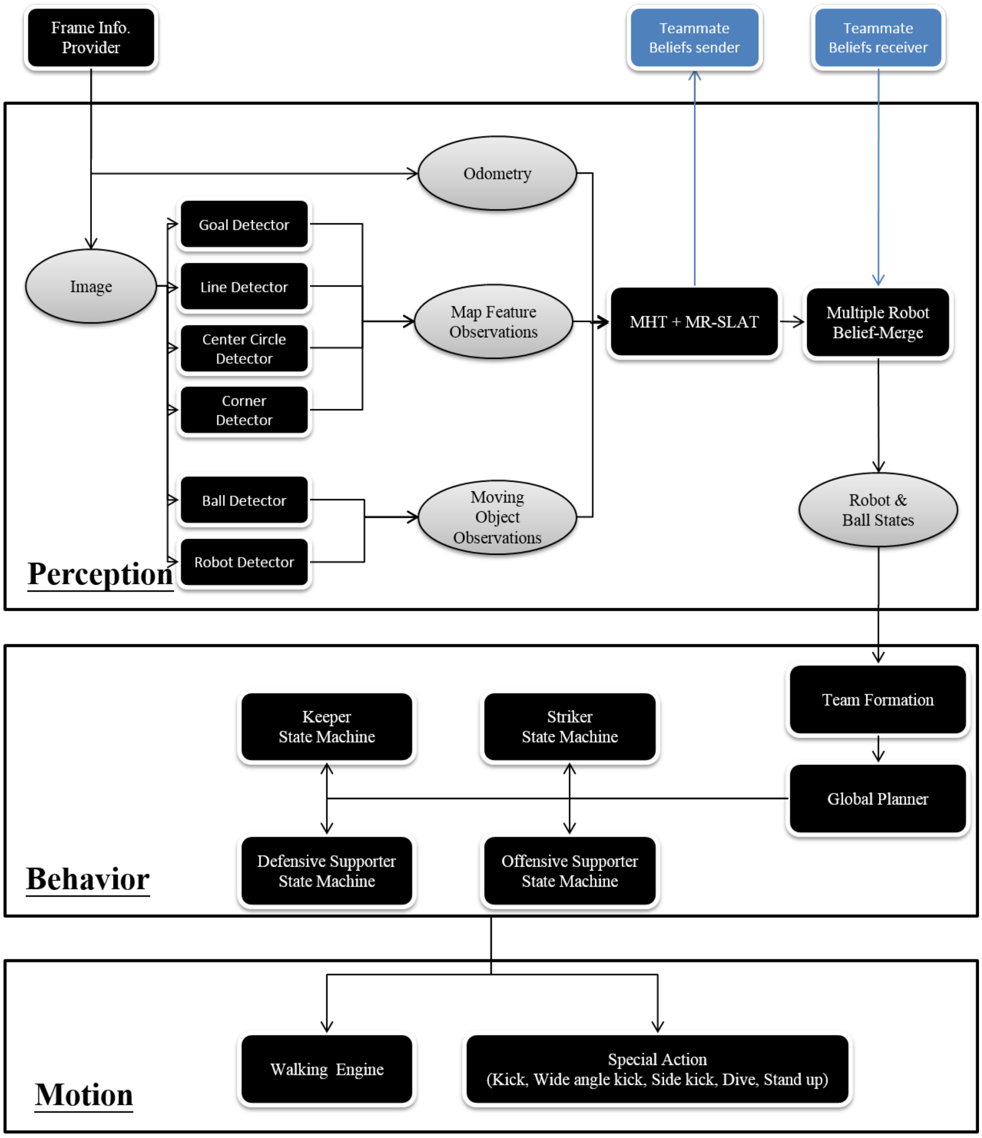

Fig. 1. Software Architecture

its belief and the received beliefs from the teammates to get the global view. Even if there are some lost packets, the robot can still get unbiased estimation after the latest packages are received. Accordingly, we can reduce the impact caused by the unstable communication, which enhances stability of our system under unstable communication environment.

3.3 Action

Planning In 2012, we only developed the rule-based behaviors, but it could be hard to be extended for complicated behaviors for multi-robot cooperation. This year we developed a global planner which decides the team formation and the cooperative behavior. Regarding the team formation, for example, in an offensive formation, all robots except for the keeper should move toward the opponent's goal. In a defensive formation, all robots should move around their own goal to help the keeper block the ball. A proper formation should be chosen according to the current ball position, poses of robots, and the score. The concept of team formation helps to simplify the problem of multi-robot planning. Additionally, as the size of the field is extended in 2013, we believe that the cooperative behavior, such as ball passing and defensive blocking, will be critical to win the competitions. Regarding the cooperative behavior, the planner will determine the best strategies to perform ball passing and defensive blocking.

Dynamically Wide-Angle Kick For performing kicking, a robot needs to stop walking first in our current implementation. We believe that kicking while walking can significantly reduce the overall kicking time and make kicking more agile. We are currently implementing a kicking mechanism to let the robot kick dynamically while walking without stopping to stand first. Extended from our previous wide-angle kick, the new kicking mechanism can make the robot kick the ball to different directions while walking.

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References

1. C.-C. Wang, C. Thorpe, and S. Thrun, "Online simultaneous localization and mapping with detection and tracking of moving objects: Theory and results from a ground vehicle in crowded urban areas," in *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*, Taipei, Taiwan, September 2003.

2. C.-C. Wang, C. Thorpe, S. Thrun, M. Hebert, and H. Durrant-Whyte, "Simultaneous localization, mapping and moving object tracking," *The International Journal of Robotics Research*, vol. 26, no. 9, pp. 889–916, September 2007.
3. K.-H. Lin and C.-C. Wang, "Stereo-based simultaneous localization, mapping and moving object tracking," in *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Taipei, Taiwan, October 2010.
4. C.-H. Hsiao and C.-C. Wang, "Achieving undelayed initialization in monocular slam with generalized objects using velocity estimate-based classification," in *IEEE International Conference on Robotics and Automation (ICRA)*, Shanghai, China, May 2011.
5. C.-H. Chang, S.-C. Wang, and C.-C. Wang, "Vision-based cooperative simultaneous localization and tracking," in *IEEE International Conference on Robotics and Automation*, 2011, pp. 5191–5197.
6. S.-W. Yang and C.-C. Wang, "Feasibility grids for localization and mapping in crowded urban scenes," in *IEEE International Conference on Robotics and Automation (ICRA)*, Shanghai, China, May 2011.
7. C.-C. Yu, W.-C. Chen, C.-C. Wang, and J.-S. Hu, "Self-tuning nearness diagram," in *International Conference on Service and Interactive Robotics (SIRCon)*, Taipei, Taiwan, August 2009.
8. C.-C. Chou, F.-L. Lian, and C.-C. Wang, "Characterizing indoor environment for robot navigation using velocity-space approach with region analysis and look-ahead verification," *IEEE Transactions on Instrumentation and Measurement*, vol. 60, no. 2, pp. 442–451, February 2011.
9. C. Urmson, J. Anhalt, D. Bagnell, C. Baker, R. Bittner, M. N. Clark, J. Dolan, D. Duggins, T. Galatali, C. Geyer, M. Gittleman, S. Harbaugh, M. Hebert, T. M. Howard, S. Kolski, A. Kelly, M. Likhachev, M. McNaughton, N. Miller, K. Peterson, B. Pilnick, R. Rajkumar, P. Rybski, B. Salesky, Y.-W. Seo, S. Singh, J. Snider, A. Stentz, W. R. Whittaker, Z. Wolkowicki, J. Ziglar, H. Bae, T. Brown, D. Demitrish, B. Litkouhi, J. Nickolaou, V. Sadekar, W. Zhang, J. Struble, M. Taylor, M. Darms, and D. Ferguson, "Autonomous driving in urban environments: Boss and the Urban Challenge," *Journal of Field Robotics*, vol. 25, no. 8, pp. 425–466, August 2008.
10. E. Guizzo, "How google's self-driving car works," http://spectrum.ieee.org/automaton/robotics/artificial-intelligence/how-google-self-driving-car-works, October 2011.
11. C.-C. Wang, C.-H. Chang, C.-C. Chou, T.-W. Chou, A. Dopfer, L. Wang, S.-C. Wang, and H.-C. Yen, "Cooperative perception for robocup and driving safety," in *the 43rd International Symposium on Robotics (ISR 2012)*, Taipei, Taiwan, August 2012.
12. C.-C. Wang, S.-C. Wang, C.-H. Chang, B.-W. Wang, H.-C. Chao, and C.-C. Chou, "NTU RoboPAL team report and code release 2011," Available on http://www.csie.ntu.edu.tw/~bobwang/RoboCupSPL/, January 2012.
13. T. Röfer, T. Laue, J. Müller, A. Burchardt, E. Damrose, A. Fabisch, F. Feldpausch, K. Gillmann, C. Graf, T. J. de Haas, A. Härtl, D. Honsel, P. Kastner, T. Kastner, B. Markowsky, M. Mester, J. Peter, O. J. L. Riemann, M. Ring, W. Sauerland, A. Schreck, I. Sieverdingbeck, F. Wenk, and J.-H. Worch, "B-human team report and code release 2010," 2010, only available online: http://www.b-human.de/file_download/33/bhuman10_coderelease.pdf.