SPQR
RoboCup 2009 Standard Platform League
Qualification Report

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1 Introduction

SPQR[1] is the group of the Faculty of Engineering at Sapienza University of Rome in Italy, that is involved in RoboCup competitions since 1998 in different leagues: Middle-size 1998-2002, Four-legged 2000-2007, Real-rescue-robots 2003-2006, @Home in 2006, Virtual-rescue since 2006 and Standard platform League (Nao Division) since 2008.

SPQR team (lead by Luca Iocchi and Daniele Nardi) is composed by two groups from the Computer and System Science Department of Sapienza University: the *Artificial Intelligence* group and the *Robotics* group and includes two PhD students and several undergraduate students. SPQR indends to participate in the RoboCup'2009 Standard Platform League with the upgraded version of NAOs, according to the rules and the deadlines provided by the Technical and Organizing Committees.

The main research motivation for participation in RoboCup 2009 is *to study the integration of complex control systems for humanoid locomotion with artificial intelligence techniques that have been typical developed on other mobile robotic platforms.*

This report presents a qualification proposal for participating in RoboCup 2009 Standard Platform League with Nao humanoid robots. We first present our achievements for RoboCup 2008 and then our plan for 2009.

2 RoboCup 2008 achievements

The achievements of development for RoboCup 2008 are: 1) porting of the OpenRDK framework on the Nao platform; 2) implementation of biped locomotion abilities (walking and kicking) using learning techniques; 3) porting and adapttion of techniques used on AIBOs: color segmentation and object recognition, localization, behavior control based on Petri Net Plans, multi-robot collaboration.

During RoboCup 2008 competition, in Suzhou, we also experienced some problems due to the interconnection between our software and the Naoqi library. These problems, that affected our performance, have been now solved.

2.1 OpenRDK: a modular framework for rapid development of robotic applications

During the development of many RoboCup applications (ranging from middle-size, to legged, rescue and @Home robots) we have gained a lot of experience and developed a set of reusable modules. Except for the AIBOs, that have a specific platform and operating system, all the other robots and robotic applications have been developed by using a common framework (formerly, SPQR-Robot Development

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[1] spqr.dis.uniroma1.it

Kit (RDK) [6], now OpenRDK [1]). that allows for rapid development of robotic applications on different platforms and for reuse of software components.

In preparation of RoboCup 2008, we have adapted our framework to the NAO humanoid robot and it is now available with an open source license to all the community from `openrdk.sf.net`.

The OpenRDK allows for an effective interaction among modules that compose a robotic application, easy development of complex applications, and for advanced mechanisms for remote inspection and debugging. OpenRDK is not in alternative with NAO robot libraries (i.e., Naoqi), but instead it povides a higher layer over it, with support for modular design, development and remote debugging.

2.2 Parametric biped gait and policy gradient learning

Biped locomotion has been obviously the main novelty with respect to AIBO development. We developed a static parameterized biped gait model that controls the legs and arms in order to make NAO track arbitrary curvilinear trajectories. We have decided to adopt a static gait model, since no accurate dynamic model of NAO is available at this time.

The trajectories are defined by the requested velocity command $(v, \omega) \in \mathbf{R}^2$, with v the forward linear velocity, and ω the angular velocity, as for non-holonomic robots. Our gait model is similar to the one presented in [7]. However, the motion control scheme that we developed presents a fundamental novelty with respect to most works in the field of humanoid gait generation: the motion control scheme that we propose is valid for generic curves of radius $R = v/\omega$. This includes the particular cases of pure rectilinear (ω null, thus $R = \infty$) and pure rotational (v null, thus $R = 0$) walks. With this approach, our walk reproduces a natural-looking human walk.

In order to optimize the parameters of the walking gait we adopted machine learning techniques and in particular we experimented Policy Gradient algorithm [10] and a novel extension that was tested both on the AIBOs [2, 4] and on the NAOs [3] (see also videos in `www.dis.uniroma1.it/∼iocchi/RobotExperiments/HumanoidLearning`).

2.3 Dynamic color segmentation and object recognition

In order to improve robustness of color segmentation and to avoid long and tedious calibration processes, we have developed a dynamic color segmentation method [8] that is able to provide robust and efficient color segmentation with very few calibration effort.

The method is mainly based on fast analysis of a mono dimensional color space: the H component of the HSV. By analyzing color distribution of the current image, we are able to compute a transformation function that transforms such distribution in another distribution. The resulting distribution provides for efficient color segmentation based on static threshold, but being computed according to the current image is also very robust to illumination changes. Evaluation of the approach shows that the method achieves performance that are comparable with those obtained by manual calibration, being at the same time robust to illumination changes.

Image processing and object recognition on legged robots usually has to take into consideration limitations in CPU power. For AIBO robots we have developed a hierarchical approach for examining the image pixels: first a set of *sentinel pixels* that are non-uniformly spread on the image are analized; then, for those pixels that activate some condition, a region growing approach is used to analize adjacent pixels and then these regions are grouped in blobs that are then analized for object recognition. This approach provides for similar results with respect to complete scanning of the image, but it significantly reduces the computational time.

2.4 Localization

Our approach to localization uses a probabilistic technique based on particle filters. In [11] we have compared different solutions based on particle filters investigating the use of two different strategies: the well known Sample Importance Resampling (SIR) filter, and the Auxiliary Variable Particle filter (APF). As a result of the experiments performed we have detected situations where one strategy is better than the other as well as hints about the use of sensor resetting, that is common in this kind of implementations. We are currently working on integrating in the localization technique information about the game state (or in general about the task state) aiming at choosing the localization strategy and parameter setting that are more suitable for the current situation. Localization is based on perception of known landmarks: beacons, goal poles, lines and corners, for which different sensor models are used in the particle filter implementation.

2.5 Petri Net based behavior control

The behaviors of a complex soccer robot require to be represented by plans with high representation power, in order to express all the capabilities of the robot. In particular, it is important to model the following features: 1) sensing actions implementing `if-then-else` or `while` constructs able to determine the robot behavior according to the current situation at run-time; 2) concurrency of actions (e.g., moving the head while going to a position); 3) interrupts (e.g., aborting a `go-to-ball` action if the robot can not see the ball anymore; 4) action synchronization between two parts of the robot (e.g., head and legs); 5) action synchronization between two or more robots.

In order to represent the above mentioned features, transition graphs are not adequate, since, for example, concurrency and interrupts can not easily be modeled. Therefore, we adopted a formalism, called Petri Nets Plans (PNP), which is enough expressive to describe plans with all the above mentioned features (see [13, 14] for further details).

As a difference with other approaches based on extensions of transition graphs, such as XABSL [12], we clearly distinguish action specification from action implementation, obtaining a framework which permits easier debugging: first, the semantic is well defined and easily verifiable by automated verification programs; second, we have a high granularity of actions which are grouped by functional properties and physical resources used.

The plan execution module based on PNP formalism has been successfully used in all our robotic applications (Four-Legged soccer, Rescue and @Home), providing a high flexibility and being easy to use, thanks to graphical tools for writing, verifying and debugging plans.

2.6 Multi-robot coordination

Although it has not be possible to test the feature so far, we have ported to the NAO robots the implementation of a distributed coordination protocol that allows the robots to assign themselves tasks according to the current situation of the environment. During the last years we have experimented many coordination protocols for dynamic task assignment, using both full broadcast communication [9], and token passing based approaches [5]. These systems have been demonstrated to work effectively in soccer applications (both in middle-size and in the four-legged leagues).

3 Development for 2009

In preparation of RoboCup 2009 we aim at improving stability and velocity of the locomotion skills. We are going to develop and optimize through machine learning new behaviors to approach the ball and kick.. From the motion perspective, we are also working on specific actions for the goal keeper. Following the research done on the Aibo platform, we are going to move multi-agent technologies to the humanoid platform. In particular we are going to develop multi-agent cooperative perception algorithms, for example as object tracking techniques. These methods are proved to be useful to allow a single robot to have a better knowledge about the environment. This goal is achieved using perceptions from other teammates as extension of proprioceptive sensors. The idea is to mantain two different view of the environment: a local one, given by history of own perceptions and a global one, given by the overall perceptions coming from all the robots in the team. Each robot can make some inference on the global model even if it has a narrow field of view thanks to fusion of both information, local and global.

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