

Remote Interaction with a Nao Humanoid in competitive games

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1 Introduction

In the context of RoboCup games, robots are fully autonomous. However, they surely could benefit from interaction with humans. For example, human soccer players benefit from receiving suggestions and sometimes even explicit instructions on what to do during the match. Similarly, an autonomous soccer robot could receive informed suggestions to enhance its planning

Andrebbe detta meglio sta cosa

. In this project, we aim to make a small step in that direction by developing a system that allows a human operator to remotely control and interact with a Nao Humanoid through a graphical interface.

1.1 Context and Motivation

Receiving instructions from a coach can be a game-changer in a soccer match. And also, receiving feedback from the robot when issuing a command drastically improves the interaction quality. This project was specifically designed to be used in the RoboCup 2024 SPL challenge, where two robots of one team had to compete against two robots of the opponent team, and one of the two robots for each team was controlled by a human operator. Furthermore, the rules of the challenge forced the human operator to turn his back to the field, in order to not directly observe the environment. This constrained us to make use of the directional robot-human communication also for the reconstruction of the world model.

1.2 Objectives

The main objective of the project is to develop a framework that allows the human operator to use the robot as a proxy to interact with the environment,

namely the soccer field. To do this, a form of bidirectional interaction between the human operator and the controlled robot is necessary. The human needs to be completely aware of the robot's surroundings, that is, the human can perceive the robot's surroundings only through the robot's sensors. The robot, on the other hand, has to be able to receive commands from the human operator and execute them in real-time. The robot should also be able to send feedback to the human operator in real-time.

Allungare un po' il brodo

Spingerei anche sul fatto che il tutto deve essere utilizzabile in un ambiente competitivo

1.3 Summary of the results

Our system achieved the objective of allowing a human operator to control a Nao by voice and using a graphical interface, and to receive feedback from the robot in response to the commands. The system integrates various modules, such as:

- **Communication**, which manages the communication between the robot and the human operator
- **Mental model**, responsible for representing the field by accessing only the robot's perceptions
- **Interaction**, by answering to the commands before executing them, considering also the feasibility of the execution itself
- **Memory**, the past command is held in memory, in order to resume it in case it is needed

The system was tested in the RoboCup 2024 SPL challenge, where SQPR Team reached the third place, demonstrating the effectiveness of the system in a competitive environment.

2 Related Work

Interpreting human signals has been a challenge for some time now in Robotics. Humans communicate through various modalities, including vision, audio, and motion. This multimodal nature provides rich information that sensory inputs can capture and analyze.

Recent advances in Deep Learning have facilitated the integration of multimodal data, significantly improving the comprehension of relationships within individual modalities, a key factor for precise message interpretation [1] [2].

In RoboCup Soccer, human-robot interaction is predominantly one-way, with human referees conveying game states and events to robots. A significant trend in the RoboCup SPL is the progressive reduction of network communication in favor of human-like signal interpretation, allowing robots to interpret human signals more naturally. [3]

A notable case worth to mention is also [4], where they propose an approach to improve the decision making process through the audience noise by extracting relevant features through MFCC coefficients and applying a reinforcement learning pipeline.

This case could fall into a broader category where the goal is to improve the communication from an ideal coach to the robot in order to improve planning and decision-making. In particular, [5] tackles this problem by designing a system that enriches the planning process with temporal goals and constraints given by human indications.

Our work is inspired by these studies, and the goal is to develop a system that allows a human operator to have a one-to-one interaction with a robot, acting like a coach in a soccer match.

3 Solution

The system can be divided in two main parts: the framework backbone, written in C++, which runs on the robot itself, and the interface, written in Python and Nodejs, responsible for issuing commands to the robot and receiving feedback or sensory information.

3.1 Framework backbone

The framework on which everything stands on is derived from that one of the German team B-Human [6], University of Bremen. At low level, the robot is controlled by three threads:

- Cognition: it is responsible for collecting all informations from the environment through cameras and sensors; also, it takes images and informations as input, and returns high level commands about the actions the robot has to execute;
- Motion: it converts high level commands of the thread Cognition in effective motion of the robot;
- Debug: it allows a communication between the robot and the host pc for the transmission of debugging information.

aggiungere immagine dei processi

The two main components for the collection and storage of information from the environment are called Representations and Modules. Representations store informations at the current instant, and they represent the actual overview of the world. Each representation is a derived class of the class *Streamable*, which allows a direct connection of all attributes and functions of the given representation with all other representations and modules. Furthermore, each representation has a single module provider, which is the only capable of modifying its attributes.

Instead, the task of the modules is to make computations which require specific inputs and returns determined output. In details, a module can specify the representations it needs in input through the macros `REQUIRES` and `USES`, and must specify the representations it is going to modify through the macro `PROVIDES`. A module must specify a function named *update*, that has the scope to perform the real updates of the informations inside the provided representations

The correct usage of `REQUIRES` and `USES` is established by a scheduler inside the software, which decides which is the right execution order of the modules according to cyclic dependencies between representations. For example,

@FLAVIO V. : inserire esempio di moduli/rappresentazioni

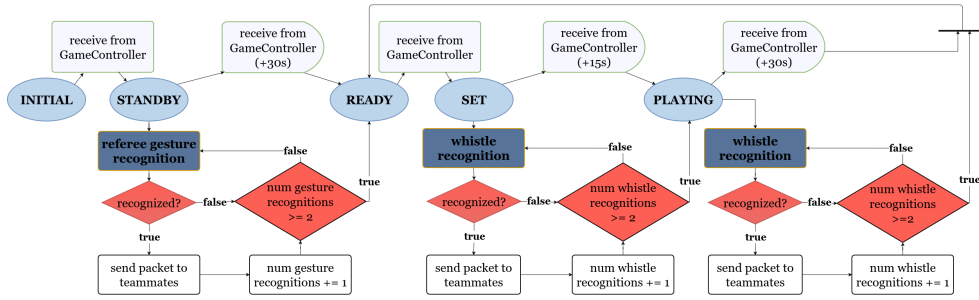


Figure 1: Complete pipeline of the game states

3.1.1 Memory

Boh

3.1.2 Social Reasoning

An important aspect of RoboCup SPL games are the game rules. These are conceived from year to year to shift the games to be more realistic. If we want, they could be considered as a form of social rules which the robots need to obey to while playing. Depending on the game state, some actions are not permitted. For instance, in SET the robots are not allowed to move. Similarly, one could impose a rule that avoids the robot to score in its own goal, even if it is requested to. Of course, in order to to some adequate social reasoning, it is necessary for the robot to have a sufficiently detailed model of the game state and the field.

3.1.3 Mental Modeling

Come rappresenta il mondo il robot? Stato del gioco e del campo fisico

3.2 Interface

We opted for a solution that prioritizes high-level commands and audio-visual feedback. The graphical interface is made by a bunch of buttons, that allow the human operator to send commands to the robot, and a 2D representation of the field that shows the robot's position and its reconstruction of the world.



Figure 2: The graphical interface

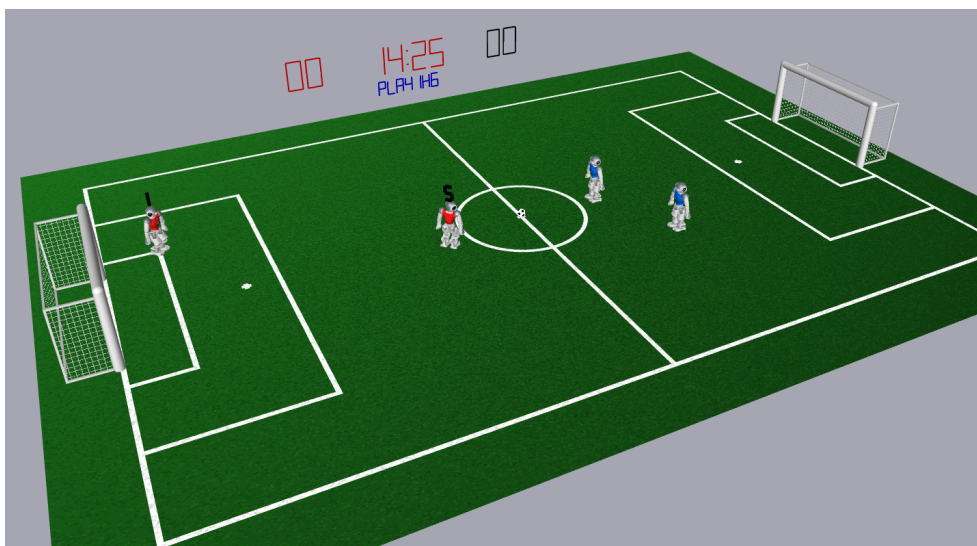


Figure 3: The Corresponding Field Configuration

4 Implementation

Dettagli sul codice

5 Results

Blocco 6 delle slide di iocchi

6 Experimental Evaluation

Blocco 6 delle slide di iocchi anche qui

7 Conclusion

Amen

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