5dpo Team Description

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Abstract. The 5dpo team presented a solid set of innovative solutions. The overall workings of the team are presented. Mechanical and electronic solutions are explained and closed loop working is discussed. Main innovative features include I-R communications link and circular bar code for robot tracking. Low level control now presents a dynamics prediction layer for enhanced motion control. Team strategy is also new and a multi-layered high level reasoning system based on state charts allows for cooperative game play.

1 Robot Design and Communications

The mechanical design of our robots for 2001 is essentially the same as the one used last year in the Euro-RoboCup Amsterdam 2000 and Padderborn Euro-RoboCup 2001. Electronic design has undergone a serious streamlining featuring a single hardware electronics board.

As in previous implementations, our robots are fitted with two differential wheels. Separated stepper motors drive the wheels independently. There is no third wheel and a pair of pods sustains the robot. A castor would result in a more complex mechanical design as well as an increased uncertainty in its dynamical model.

Embedded Ni-Cd batteries presently power the robots for more than 1 hour. The motors are driven by two H-bridges that are directly powered from the batteries. The on board controller for the motors is an 8-bit RISC microcontroller (Atmel AVR90S8515). All digital circuitry gets its power from a switching regulator.

2 Communications

There is another microcontroller, an Atmel AVR90S2313 that handles all real time communications. There are two small single frequency Radio Frequency (RF) modules (433 MHz and 418MHz). The software can automatically switch

the active RF module. To minimize the latency of the communications channel, we transmit a lot of small packets. An additional communication channel is provided through an InfraRed (IR) link. We successfully used the IRDA HSDL-1001 chips to communicate with the robots in spite of the heavy lighting conditions. The emitting LED's are at the camera level, pointing down. On the receiving side an automatic gain controller and adequate filtering are necessary to get reliability. The HSDL-7001 chip is used to perform Encoding/Decoding. Alignment problems and also power concerns led to having 3 emitting nests of a total of 8 LED's HSDL-4220. These LED's were submitted to bursts of 1.6 μsecond under a current of 0.5 Amps. The information transmitted via IR and RF is the same but packing is different so two different serial ports are used to transmit the information form the external global controller. All transmission methods send a packet that specifies the target speed for each wheel for all robots. Each packet also has the On / Off state of the kicking device and a one-byte position of the ball handler actuator but only for one robot (to keep packet size small). This ball handler is a guiding bar based on a servo that either guides the ball or allows the previously spinning kicking device to hit the ball thus creating a very powerful kick.

3 Robot Software

Robot embedded software for both microcontrollers has undergone a redesign process during the porting of the code from assembly to C. The C code is now compiled with the freeware AVR-GCC program. This was done in order to allow for code understandability and maintainability.

Communication channels are now RF and IR. Special packets allow for remote robot configuration such as robot number, future receiving frequency, etc.

Embedded software accepts orders for both motors in several categories such as speed and number of steps to be ordered and if the orders are to be carried immediately or after the current command has ended.

4 Vision and Control

The vision system is based on two general consumer PAL camcorders, one for each mid-field. A different PC processes each image with a vision board based on a BT878 vision acquisition system. This allows for parallel processing of the images whilst using cheap hardware and also maintaining standard Operating System device drivers. The image processing software has been ported to Delphi under Windows. Socket communication has been introduced in order to provide communication of the 2 processed images to another independent program, the decision module that may be in another PC.

The global state of the system is updated based on the vision. A fuzzy system classifies the color of each pixel and aggregates them in contiguous groups. The observed groups are matched and that information is incorporated in the state resorting to a set of Kalman filters tuned to the dynamics of each kind of object.

By observing the present system state as well as a global mid-term strategy, short-term orders are generated and sent to the players. Robot intelligence is based on such a three layered state diagram engine. This means that each robot has a Role that may require a number of Tasks that, in turn, may require a mesh of different Actions.

The loop is closed through the cameras, as seen in Figure 1. It must be stressed that while the "sampling" frequency of this loop is 25 Hz, there is some intrinsic lag that degrades its optimal performance. The PAL signal takes 20 ms to deliver each frame, then some time is lost processing it, the decision subsystem must decide the new course of action and there is also the time spent sending the orders over the RF channel to the robots. System overall performance benefits from a prediction math layer where low level control is calculated taking into consideration known system lag.

The vision system uses a round-shaped bar code to keep track of which robot is which (as in Figures 2 and 3). Around the circular color of the team (yellow or blue) there is room for 6 bits of black or white sectors of 60 degrees. As only 5 robots are needed on the field at the same time, from all the possible 6 bit combinations, the chosen combinations were those that had the maximum transitions and those that are not a rotation of previously chosen codes. Using the team color of the center of the bar code and going through the pixels at a known radius from the center, we are able to retrieve a binary code of a robot as well as its orientation. Orientation noise is less then 4 degrees for our system.

Team tactics are quite stable. In any case, the defense robots stand in alignment in such a way that the robot that holds the ball can't easily shoot for goal. Team behavior is based on robots changing roles on certain conditions. Certain robot roles and actions have priority over others and thus co-operation is based on well-defined priorities. This prevents robots from the same team from harassing each other.

Speeds for the stepper motors are risen above the maximum stable speed using current calculated speed and known motor acceleration performance. This means that under certain conditions the stable speed of 0.5 m/s will be surpassed to over 1.2 m/s.

5 Final Remarks

The new IR link proved it self very useful to allow for extra practice time during the competition and also as a redundant link during the games.

Driving the stepper motors on the non-stable region is also very important to get near the ball quickly and allows for impressive speed displays with our inexpensive motors.

The prediction layer for the low-level control allows for very fast and exact dynamic control.

The use of two cameras allowed for much less ball occlusion and the global state obtained through Kalman filtering proved very reliable and easily merges all available information.

The circular bar code also worked fine simultaneously identifying without ambiguity the number of the robot as well as its orientation.

The priority-driven three layered control system for the high level reasoning of the team proved powerful yet very easy to maintain and debug.

The overall performance of the team is very good and several small improvements will be carried out but we are planning a whole new platform with omni-direccional drive for the future.

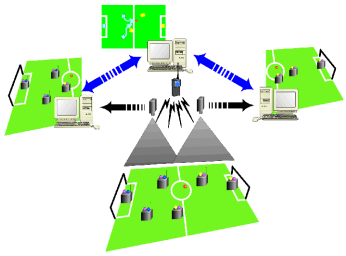

Figure 1: Diagram of the closed loop workings of the team

Figure 2: Human and robot team also showing robot's bar codes

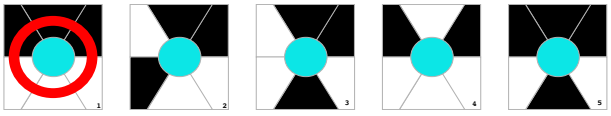

Figure 3: Actual chosen bar codes and a sample scan circle on number 1