Cooperating Robots
Lecture Notes
Introduction

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The purpose of this spring course is that you design and execute experiments with movable robots. We have available a programming system which will help you part of the way. DIKU currently has two SoccerBot robots, each with radio link that allow them to communicate with each other and with a PC. Our plan is to build a fleet of mobile communicating robots. You can see a description of the robots in a paper by Thomas Bräunl and Birgit Graf [3]

1 System Overview

The system consists of a PC, a camera which is mounted in the ceiling, and two robots that drives around on the floor. Each robot can communicate with the other robot and with the PC. Each robot has mounted a camera and three distance sensors. The camera surveys the robot arena and is connected to the PC through a gray scale frame grabber card.

The system has these characteristics

- It is possible to program the robots to be either autonomous or controlled by a process on the PC. An image process on the PC should make it possible for a robot to request various information like position of itself and other robots, a geometrical description of the scene it moves around in, or to send information about where it believes it is positioned or what it sees through its on-board web-camera.

  In the case of PC control, it is possible for such a process to send simple commands (turn left/right, move forward, etc.) to a robot which will then execute them.

- The surveillance camera in the ceiling can be used to obtain the positions, orientations, etc. of the robots in the arena. This information can either be used as ground truth in navigation experiments or as a sensory input to the robots navigating around the arena, e.g. it should be possible for an autonomous robot to request its position from the PC. This goal is partially met.

- A command protocol and interpreter programs on the robot and PC is implemented for handling communication from PC processes to robots, and from robots to other robots and to the PC.

Our system consists of cooperating processes. The robots are each a process, on the PC several processes run, at least a camera process and one for each robot. We have an infrastructure that makes communication possible between this set of processes. Building upon this infrastructure we can execute our experiments. With an analogy to the insect world, each ant is a process, and life in the ant hill is a result of communication between these processes. With another analogy to biology, each neuron is a process, and animal behavior is the result of neuronal communication.

Lectures

The plan is two hours a week: one in the laboratory, where the students demonstrate their solutions to exercises, one in the class room, where I present (some of) the necessary background.

Introduction

Sensors and motors. Infrared sensors, Cameras (Bräunl). Image processing. Operations. Feature extraction. Reduction to 1D (Gonzales). The house fly's locomotion strategy (Franceschini).

Architecture. Brook's subsumption model (Tu). Cooperative mobile robotics (Uny). Braitenberg architectures (Pfeiffer).

Genetic algorithms (Lipson).

Swarm intelligence. Computation of trajectory. Boids (Reynolds, Tu).

Pattern recognition. The k-means and the EM algorithm.

Learning. Information theory(Ryabko). Lempel-Ziv coding (Bell)

Environment maps, topological (Bruske) and metrical maps. Kohonen nets (Kohonen, Koikkalainen, Wichert).

Robot language. Luc Steels (Steels).Find reference!

Chaos (Schöner, Bauer).

Inference

Exercises

Move in a circle. Exercise the motor commands with a Hello World program.

Follow the wall of an obstacle. Exercise the infrared sensors. Careful: They have not been calibrated! Useful also to avoid obstacles.

Program a robot to follow the course defined by a spline. The parameters are communicated on-line over the radio link.

Detect and track a moving object with the robot's camera while the robot is at a stand-still. The camera should not be moved. Exercises elementary image processing. (If there is such a thing).

Detect motion when the robot stands still, then move towards the moving object. Stop when close enough. Compute simple trajectory and use infrared sensors to stop before contact.

One robot is controlled by remote control. The other robot is to follow and at the same time to avoid obstacles.

Turn 360° and record vertical lines in the environment. Make a chart with their positions in degrees. Also make a chart of infrared sensor input if distance in sensors' range. Compare charts for possible classification of landmarks as bounding contours of objects.

Detect motion from a *moving* robot. Move towards the moving object. Stop when close enough. Compute simple trajectory and use infrared sensors to stop before contact. Hint: move in straight line. Compute parallax of landmarks. Distance relative to speed can be computed. If landmark's distance changes, the landmark moves. This is the strategy of a house fly.

Design and detect visual landmarks. Place landmarks in arena. This requires image recognition of icons.

Implement a randomly moving robot with posesses obstacle avoidance behavior.

Distinguish between a few robot behaviors using images from the ceiling-mounted camera.

Determine a sequence of known atomic actions executed by the robot using the mounted camera. Verify the result by asking the robot to execute the inferred command sequence and compare to its original behavior.

Implement the programs by which a robot can ask for and be told its position on the floor.

Projects

The success criterium for the class is that the students initiate design and implementation of a non-trivial behavior for a mobile robot. It is realistic that more time is needed for a satisfactory result than available at this class. The students are encouraged to continue their projects after termination of the present class.

Two different architectures are advocated in this course. They both have a common module. This module can be implemented in two ways. It is thus possible to initiate work on common grounds and differentiate to a specific project during the course.

The common first module of both proposed designs are to implement a "vision" module for a robot. The word vision is quoted, since I suggest 1-dimensional and not 2-dimensional vision. This simply for engineering feasability. . This module can be implemented either using the ceiling-mounted camera or it can be based on data from the on-board camera and the infrared sensors. This last approach is based upon the locomotion strategy of the house fly [6]and invokes basic pattern recognition principles.

One design then follows the design of Tu and Terzopoulos [17], with the important exception that our system function in the physical real world, where Tu's system functions in the virtual world. This design incorporates the exiting ideas of Reynolds [14] and builds upon Brook's subsumption architecture. [6]. This design follows the main stream in AI.

Another design will also be presented. It is based on information theory and string matching. It is connected to data compression and raises an interesting algoritmic problems. It is also more closely connected to biological vision.

Credit

Credit for the course is 7.5 ECTS. They are obtained by submitting a report on the course whose most important component should be (a subset of) the exercises solved.

Links

http://www.red3d.com/cwr/boids/ contains much information and many references on swarm intelligence.

http://robotics.usc.edu/~maja/bbs.html Useful info on behavior-based control.

http://www.diku.dk/research-groups/image/teaching/Robotlegestue Al info om robotterne.

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Litteratur

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