Project Specification 2011:

Autonomous vehicles for transports in limited spaces

In limited spaces like in a mine or parcel storage compartment a set of vehicles are intended to share the available common space and still be able to efficiently carry out their individual transportation tasks. This requires that fatal deadlock and collision situations are avoided. Assume that each vehicle only know about its own part of the whole set of tasks. This means that all the vehicles have to cooperate by coordinating the sharing of the common space in a decent and fare way by following a set of shared rules; for an analogy see regulations for preventing collisions at sea between ships.

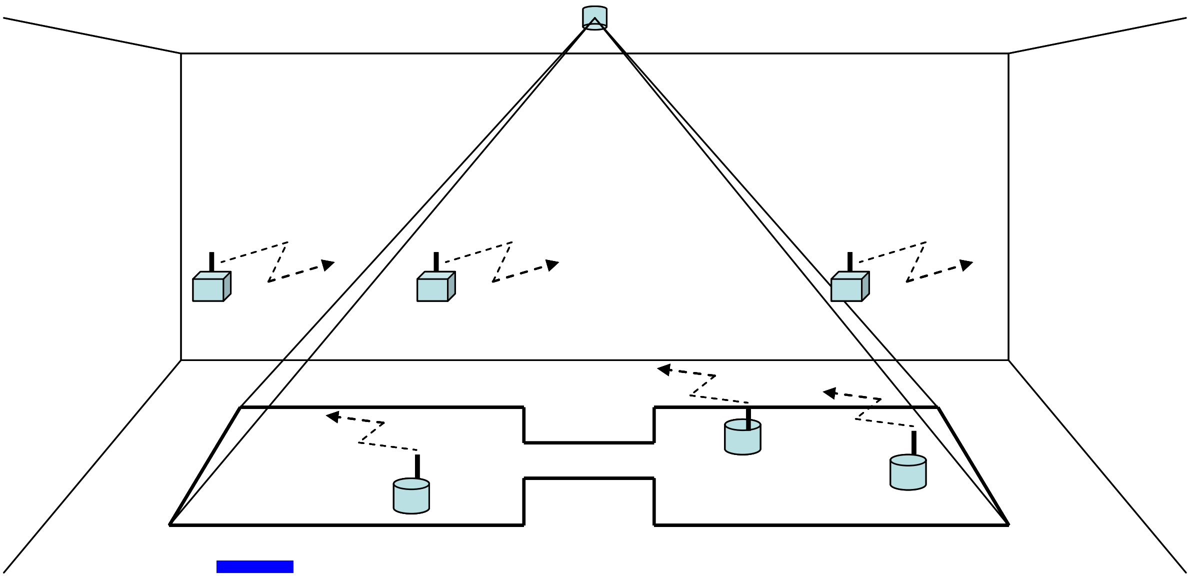

Fig. 1 Project playground consisting of two rooms with a passage in between, the room boarders, a target (illustrated by a thick blue line), the vehicles, the base stations and a shared camera placed in the roof of the lab.

The playground and test scenario for the project is a common space divided in two rooms separated by a narrow passage (like a corridor or a channel), see figure 1 above. The passage is so narrow that only one vehicle at a time can pass. The vehicles shall in the scenario also be able to drive short distances out side the rooms, i.e. out of range of the camera, and approach close a target wall by use of an on-board short distance measuring system and then return back to the rooms using dead counting.

The transport work to be carried out by a vehicle is given as a list of <x, y> positions (waypoints) to be visited, one by one in the order given in the following format: **(** $<x_1,y_1>$ $<x_2,y_2>$ ... $<x_n,y_n>$ **)** where the coordinates are given as integers within the range defined by the maximum pixel resolution available from the camera used, i.e. 1600 x 1200. The next position to visit can be acquired by use of a command **`position`**, sent to the System-PC**.**

The coordination among the set of vehicles is supported by an access control and resource reservation server implemented as a common program task allocated to and running on a common PC called the System-PC. To handle resource reservations the server program supports a resource management protocol based on the exchange of three messages: **`reserve, admit, free.`** A so called Project-PC can send the **`reserve`** message and get the **`admit`** message in return. A Project-PC shall send the **`free`** message to the System-PC when the reservation no longer is needed.

There is also a message to ask for information about the current system clock time **`get_time`** that returns the current System-PCs view of the time. This service can be used to get a synchronous common view of the clock time among the system members.

No vehicle is allowed to block the entrance or exit of the passage for any other vehicle. For this reason and to simplify coordination of the resource usage there is a need for a embark border line at each end of the passage, defined as a 40 cm radius, measured from the centre of each end of the passage, see figure 3. The vehicles must send their requests no earlier than 10 cm before this border line and has to slow down and stop before the border and if needed wait there until they get admit to embark the passage. When having left the passage they have to free the resource usage permit, using the `f` message, within at most 100 ms, after passing the embark border.

To handle several different tasks each vehicle is supported by a Project-PC (programmed by each project group) that periodically can acquire pictures from a shared camera mounted in the roof above the playground. The picture information can be used to estimate the position and direction of each vehicle.

The trajectory planned for and then followed by a vehicle should be smooth to allow for fast and energy efficient transports and the track must be changed dynamically when unexpected hinders appear. Other vehicles approaching may result in necessary deviations from the planned trajectory and must be compensated for by updated plans and possibly also result in “give way” manoeuvres depending on how the solution space is used.

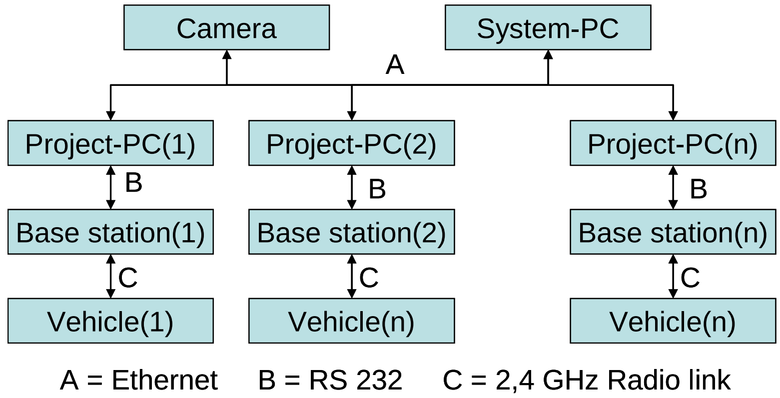

Fig. 2 Block Structure of the System

Each group is responsible for the image acquisition and processing needed to obtain the position coordinates of their own vehicle, as well as the obstacles, be it static e.g. walls and corners, or dynamic, e.g. other vehicles.

The vehicles shall respond to stop and start/restart messages and answer by reporting about their position and direction as estimated at the vehicle control level.

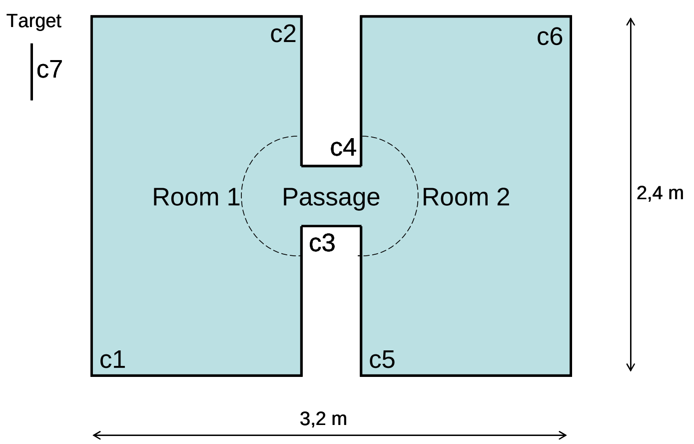

Fig. 3 Size of the playground (measured in pixels)**: c1 = <0, 0>, c2 = <700, 1200>, c3 = <700, 500>, c4 = <1100, 700>, c5 = <1100, 0>, c6 = <1600, 1200>, c7 = defined at examination.**

Vehicles shall drive as fast as possible and be positioned precise enough (for example by analysis of time stamped camera pictures combined with dead counting and feedback from step counting encoders, attached to the wheels of the vehicle).

The camera has a maximum resolution of 1600*1200 pixels. With a playground measuring 3,2*2,4 m the picture measurement resolution will be 2*2 mm.

Vehicles shall be able to drive close to a target in the form of a wall that also shall be approached by the vehicles in direct angel to a position defining the centre of this wall and at a distance of 15 cm.

The vehicles shall avoid collisions and maintain at least 5 cm of security distance between each other.

The vehicle platforms, i.e. the PIE:s, are equipped with optical light based near distance sensors that can be used to detect unexpected hinders and stop the vehicle in case vehicles comes too close. The diameter of a PIE is 260 mm.

The radio communication between a base station and its related vehicle shall be robust especially to the communication taking place between other such base stations and vehicle pairs but other external disturbances from for example closely placed Bluetooth and WLAN equipment must also be considered.

Potential disturbances and failing nodes shall be possible to detect and log for example as a set of measures or by a counter per vehicle instance or event type.

Project material

1. A common playground that the vehicles have to share and act within, as illustrated in figure 1.
2. One vehicle is available for each project group. It is based on the so called PIE:s (small ground mobile robots equipped with radio and sensors).
3. One shared System-PC where the system (resource) supervisor will run.
4. One Project-PC for each project group.
5. One radio base station (wireless access point) for each project group based on an ARM7 processor and the same type of radio module as used in the PIE:s.
6. One shared network attached video camera AXIS 223M, http://www.axis.com, mounted in the roof and accessed as an HTTP-server. The camera is supported by an associated framework for reading and processing of detected JPEG compressed picture and picture sequences (MPEG4 is also supported). Matlab with script commands can be used for reading of pictures from the camera in a client-server fashion from the Project-PCs. For example, by using the command imread as follows imread('http://ideax2.hh.se/axis-cgi/jpg/image.cgi?resolution=1600x1200')
7. Ethernet based LAN for communication between System-PC, camera and the Project-PC:s.
8. Eclipse based software development platform (editor, compiler, debugger for C programming and the ARM processor) tailored for HW close embedded programming and experiments with sensors etc.
9. MATLAB version R2008a.
10. SAM7-H256 development board for T91SAM7S256 ARM7TDMI-S Microcontroller, from OLIMEX
    a. http://www.olimex.com/dev/index.html
    b. Development board and Programmer http://www.olimex.com/dev/arm-usb-tiny.html
11. Real-time operative system Free RT-OS, http://www.freertos.org/

12. Radio module MOD-NRF24L from Olimex for wireless communication, a 2.4GHz radio transceiver module based on Nordic Semiconductor chip called NRF24L01.
13. Motors, encoders and drive units http://www.robot-electronics.co.uk/acatalog/Drive_Systems.html
14. Short range distance measuring device http://www.pololu.com/file/0J85/gp2y0a21yk0f.pdf
15. Battery12V 5Ah NiMh http://www.all-battery.com/12vnimhnicdbatterypackseries.aspx