Excerpt from
Harmo, P. Halme, A. Pitkänen, H. Virekoski, P. halinen, M. Suomela, J. Moving Eye – interactive Telepresence over internet with a Ball Shaped mobile Robot. IFAC Workshop on Internet BasedControl Education, Madrid, Spain, December 12-14 2001.

Equipment

The system

The Moving Eye system consists of remote user stations, the Internet, server/gateway computer, servo controlled camera, a ball robot called "Rollo", local network and local devices. See figure 1. Depending on the application the system structure varies.

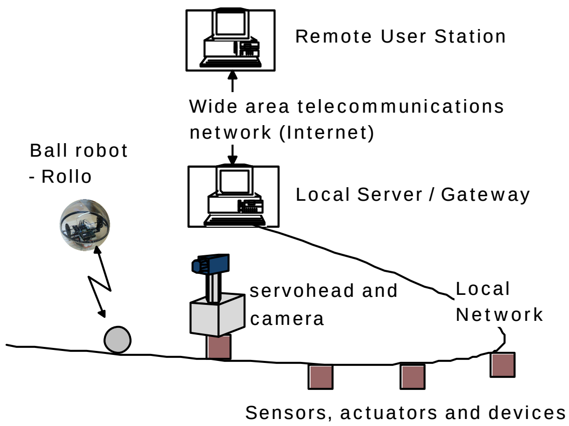

Figure 1. The Moving Eye general system structure

Ball shaped robot – Rollo

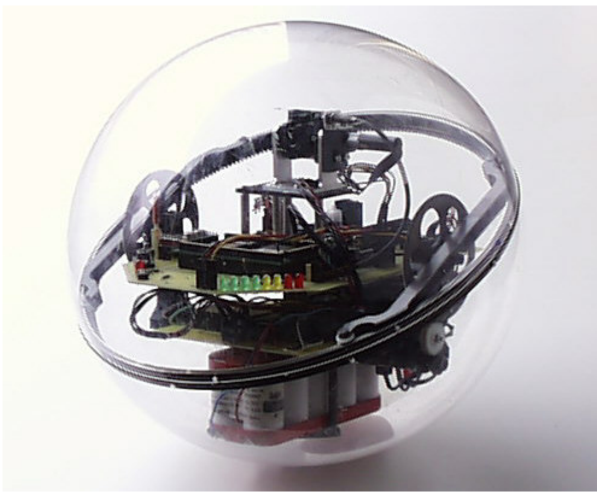

Figure 2. Rollo

Rollo has a spherical transparent cover (Fig.2). It is moved with two electrical motors. The energy source is a NiCd battery, which provides autonomy of several hours. For visual and audio perception the robot is equipped with a camera and a microphone and a video link. The camera can be tilted +-100 deg. When it points upwards it is used for detecting visual beacons on the ceiling. The communication to the control station is done with a radio modem. The robot is equipped with a micro controller board (Phytec MiniModul-167 using Siemens SAB C167 CR-LM micro controller). The robot has sensors for temperature, pan, tilt and heading of the inner mechanics, and pulse encoders for motor rotation measurement. The software is written in C language.

The local server transmits controls to the robot using commands that are kinematics invariant (i.e. uses the work environment variables only). The commands include heading, speed and running time/distance. Commands can be given one by one or as a list. The system has also an automatic localisation command, which causes the robot to stop, wait for some time to smooth out oscillations, turn the camera to vertical position, find the visible beacons and automatically calculate the position, which is returned to the control station.

Mechanical Structure. The plastic covers of Rollo (Fig. 3) are connected together with an equatorial rim. The inner mechanics (internal drive unit) of the ball is hanging from the rim. The rim can be rotated around two axes of the inner drive unit (IDU). When rim is rotated around the X-axis the rim and the ball rotates to the direction of the inner mechanics (in the fig.3 either towards to or away from the reader). When rim is rotated along the Z-axis (the contact points of the inner mechanics and rim change) and the rim plane is in horizontal position the heading of the inner mechanics change assuming that there is some friction between the ball cover and ground.

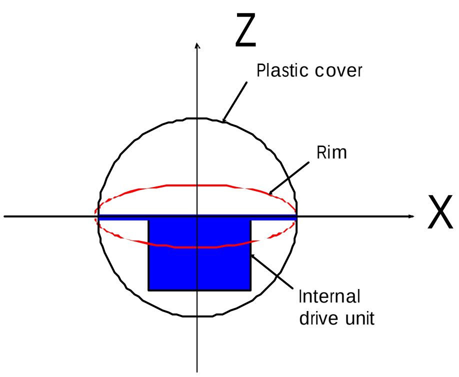

Figure 3. Functional principle of Rollo

Position estimation using ceiling beacons

The on-board camera can be turned to vertical direction to look at the ceiling. There are coded beacons on the ceiling so that in each location of the environment the camera can see at least one of them. The positions and orientations of the beacons are known. It is assumed that the floor is flat and its distance from the ceiling is known.

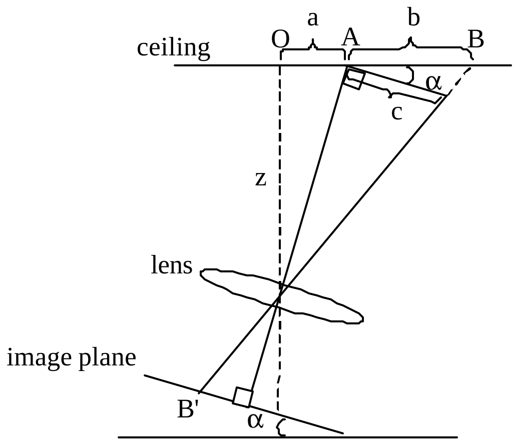

Figure 4. Using a simple camera model when image plane is tilted (one-dimensional case). **a:** Distance of the ball's position O and the point A where the normal from the lens of the camera meets the ceiling. **b:** Distance A to the known marker B on the ceiling. **c**: Normal projection of the distance b. a : Inclination angle in one-dimensional case.

The robot position can be calculated using the simple camera model (pinhole model) from the known marker B position and direction, when the room height (z) and focal length of the camera (f) are known and when the inclination angle α**,** the robot heading and the position B' are measured.

Local Server

The local server can be a normal PC or a special server PC running with Windows NT, Linux or Unix operation systems. Its functions are to provide the user access to the robot, camera controls, video, audio, data and environment controls. The server is used for downloading the user interface program to the user stations as well. The local equipment can be connected straight to the server or through a local area network. In real applications the server is remotely maintained and it does not need to have a keyboard or display.

User Stations

User software contains virtual model of the remote environment. Video and virtual model are overlaid to produce the augmented reality in this software. This software also contains user interface to simulation model of Rollo as well as controls for controlling Rollo's movements.

applications

Educational system

The educational system has been developed for virtual laboratory exercises, which university students can do over Internet. The exercises are part of the IECAT

(Innovative Educational Concepts for Autonomous and Teleoperated Systems) project. http://ars-sun1.ars.fh-weingarten.de/iecat/iecat.html

The laboratory experiment environment utilizes the Moving Eye system in an office environment. The mission of Moving Eye is to inspect and monitor the office and some of its equipment. The robot can be programmed as an autonomous device or it can be teleoperated via Internet. Because of quite a nasty dynamics of the robot and network delays direct teleoperation is not working well. Instead, teleoperation is built on a model-based concept where the operator uses the augmented reality to plan the route of the robot before giving motion commands.

The overall experimentation system includes versatile possibilities to set up interactive laboratory exercises from an elementary level to more advanced levels. Topics include mechatronics, robot kinematics and dynamics, localisation and navigation, augmented VR-techniques, communication systems and Internet based control of devices.

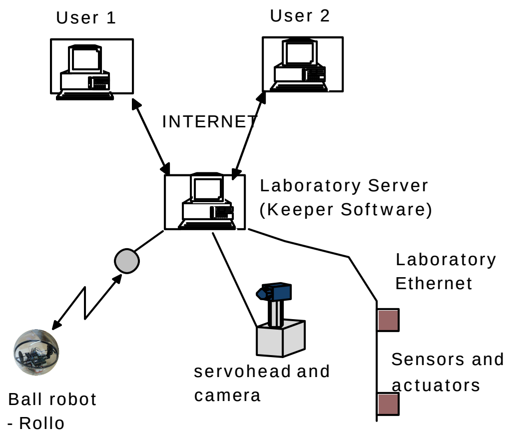

Figure 9. The educational telerobotic system

The educational system consists of 5 experiments. The first experiment includes series of pictures, video, and simulation experimentation, which explain the technical components and structure of the ball shaped robot. The idea of the second experiment is to learn the mission environment and to become acquainted with the augmented telepresense system. The office corridor 3D-model is shown to the user. He can move in this virtual environment with the virtual Rollo and look it trough the robot's virtual camera. From the wall real camera he can see the overall real picture as well as the augmented view.

The kinematics of the Rollo is non-trivial. The dynamics is still far more complex. However, it is necessary to know both at least to some extent to get an idea how the robot moves. The third experiment introduces the main mechanical equations. The students are asked to simulate these equations with Matlab and to get an idea how the real robot moves when commanding the motors. The existing command library of the robot is introduced.

In experiment 4 the position of Rollo is obtained using the on-board camera and beacons fixed on the ceiling of the corridor. The last experiment is called the *Moving*

Eye mission. Here Rollo monitors and guards an office during non-working hours. In the mission the robot travels around the office and transmits images from given targets, which are defined using the virtual model.

Home Helper System with Rollo

The *Home Helper* system intends to commercialise the use of the Moving Eye concept for home environments. The system will be used for people, e.g. senior citizens, to manage to live better and safer at home.

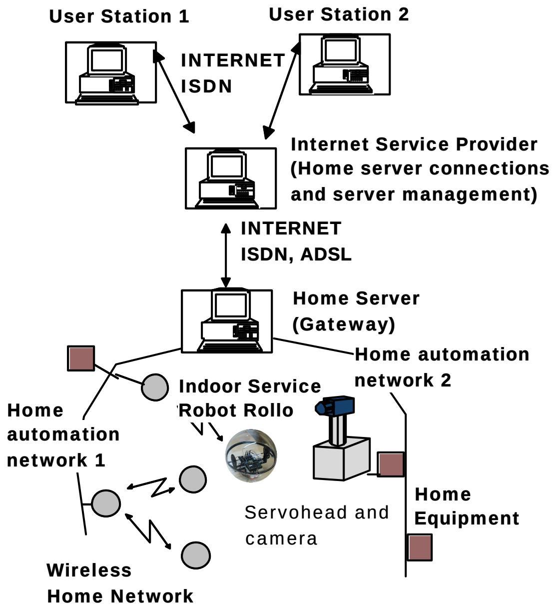

Figure 10. The Home Helper system layout consists of Internet service providers' external Internet servers, home gateways, local networks, wired and wireless local devices and home robots.

The Home Helper system provides a mobile multimedia platform for communications between home and outside assisters. The system is connected to various networked devices at home. The devices provide possibilities for remote security surveillance, teleoperation of the devices, and interactive assistance to people living at home.