Man–Machine Interface with Applications in Mobile Robotic Systems

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INTRODUCTION

This article focuses on the current state-of-the-art assistive technologies in man-machine interface and its applications in robotics. This work presents the assistive technologies developed specifically for disabled people. The presented devices are as follows:

- The head joystick works on a set of instructions derived from intended head movements. Five laser diodes are attached to the head at specific points whose light rays' spots are scanned by a set of CCD cameras mounted at strategic locations (on the ceiling, on the wall, or on a wheelchair).
- Automatic parking equipment has two laser diodes attached at the back of the wheelchair, and their light rays' spots are scanned by the CCD cameras.
- A range-inclination tracer for positioning and control of a wheelchair works on two laser diodes attached onto the front of the wheelchair. A CCD camera mounted on the front of the wheelchair detects the light rays' spots on the wall.
- The body motion control system is based on a set of instructions derived from intended body motion detected by a six component force-torque transducer, which is inserted between the saddle and the chassis of the wheelchair.
- An optoelectronic handy navigator for blind people consists of four laser diodes, the 1-D CCD array (alternatively PSD array), a microprocessor, and a tuned pitch and timbre sound source. The functionality of this system is based on the shape analysis of the structured lighting. The structured lighting provides a cutting plane intersection of an object, and a simple expert system can be devised to help blind people in classification and articulation of 3-D objects. There are two parameters involved: the distance and the inclination of the object's articulation. The time-profiles of the distance and inclination are used to adjust the frequency and amplitude of the sound generator. The sound representation of a 3-D object's articulation enables the skill-based training of a user in recognizing the distance and ambient articulation.

The head joystick, the automatic parking equipment, the range-inclination tracer, and the body motion control system for the wheelchair control are suitable for people who have lost the ability to use their own lower limbs to walk or their upper limbs for quadriplegics. The optoelectronic handy navigator is suitable for blind people. The mentioned sensory systems help them to perform daily living tasks, namely to manage independent mobility of electrical wheelchair or to control a robot manipulator to handle utensils and other objects. The customization of described universal portable modules and their combinations enable convenient implementation in rooms and along corridors, for the comfort of the wheelchair user. Smart configuration of the optoelectronic handy navigator for blind people enables the built-in customization into a handy phone, handheld device, or a white stick for blind people.

BACKGROUND

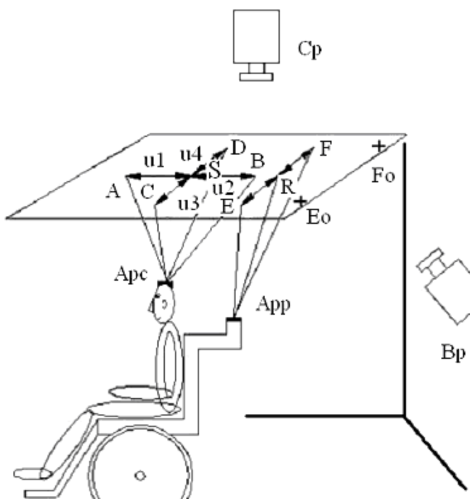
Significant progress in human-computer interfaces for elderly and disabled people has been reported in recent years. Some examples for such devices are the eye-mouse tracking system, hand gesture systems, face gesture systems, head controller, head joystick, and human-robot shoulder interface, all presented at recent international conferences. The aim of this article is to publish further progress in the field of assistive technologies like the head joystick, automatic parking equipment, range-inclination tracer, body motion control system, and optoelectronic handy navigator for blind people.

HEAD JOYSTICK AND AUTOMATIC PARKING EQUIPMENT

Following parts of the modular sensory system enables the processing of multi-DOF information for the control and the positioning of a wheelchair by means of two types of modules for alternative use, as shown in Figure 1.

The module Apc (the module of four laser diodes) is designed for tracking the head motion of the wheelchair user. The ceiling-mounted CCD cameras detect the Apc laser rays. The fifth, auxiliary laser diode with redundant light

Figure 1. The modules Apc and App positioned relative to the plain of the ceiling and the module Bp of the CCD camera mounted in perpendicular view or in perspective view against the light spots on the ceiling



spot is used for the verification of accurate functionality. The module App (the module of two laser diodes) is designed for automatic parking of the wheelchair into a predefined position in the room. The third auxiliary laser diode with redundant light spot is used for the verification of accurate functionality. The modules Apc and App have the presetting control 1 of the angle 2s contained by mutual opposite light rays 2, as shown in Figures 1 and 2. The auxiliary fifth or third laser diode is centered in the axis. The camera with 2-D CCD array can be arranged in two ways:

- The perpendicular view downwards against the translucent screen, which is mounted parallel to the ceiling. The module Cp for direct sampling is shown in Figure 3. The light spots reflected by light rays of Apc, or App respectively, are sampled by the camera with a 2-D CCD array. The module Cp for direct sampling of the light spots (no. 3) consists of the camera with 2-D CCD array (no. 6) with focusing optics (no. 5) and the flange (no. 1) mounted perpendicular to the translucent screen. The light spots from the laser light rays are projected onto the translucent screen (no. 4). The translucent screen spans the entire ceiling of the room. In larger rooms, four Cp modules are attached onto the ceiling in front of the laser rays.
- The perspective view of the ceiling and light spots of the laser ray images spots from the modules Apc and App are shown in Figure 1. The module Bp, depicted in Figure 4, is shown in Figure 1 in perspective view on the wall. The camera with 2-D array makes the sampling of the light spot position from the laser light rays on the ceiling plane. The X-Y coordinate system on the ceiling is used to monitor the parking position of the wheelchair.

The module Cp is mounted on the ceiling against the modules Apc and App, respectively. The Apc module is attached to the head of the wheelchair user, and the rays are intersecting the ceiling plain of the Bp or Cp modules respectively, in light spots A, B, C, and D. The intersection of abscises AB and CD is the point S centered by auxiliary laser diode. The lengths of abscises AS, SB, CS, and SD are u_1, u_2, u_3, and u_4. The App module is attached to the wheelchair, and the light rays intersect the ceiling plain in light spots E, F in equal distance u from the middle point R centered by auxiliary laser diode. The light spots position and configuration is analyzed and processed for the navigation of a wheelchair.

Purposeful head motion of the module Apc represented by the light spots configuration is sampled by means of the modules Bp, or Cp from the ceiling. The following commands are used for three degrees-of-freedom control of the wheelchair with an adjustable operating height of the wheelchair perpendicular to the 2-D coordinate frame on the ground:

- **Start:** The head movement with the module Apc outwards the dead zone position of the light spots.
- **Stop:** The head movement with the module Apc inwards the dead zone position of the light spots.
- The dead zone is defined by the ratio u_1/u_2 and u_3/u_4, for example (only for perpendicular view of the CCD Camera) by the interval <0,8; 1,2> and for the angle Ω by the interval <-15^0;$+15^0$>. Inside these intervals, following commands are not valid because of physiological trembling of the head. Outwards these intervals are valid following commands.
- **Forward, Backward for the First DOF:** The dividing ratio of diagonals $u_1/u_2 > 1,2$ respectively $u_1/u_2 < 0,8$.
- **Up, Down for the Second DOF:** The dividing ratio of diagonals $u_3/u_4 > 1,2$ respectively $u_3/u_4 < 0,8$.
- **Turn to the Left – Turn to the Right for the Third DOF:** Last increment of the angle Ω is positive $\Omega > +15^0$, respectively, and negative $\Omega < -15^0$ oriented.
- The magnitude of the dividing ratios u_1/u_2, u_3/u_4, and the angle Ω is assigned to the velocity of the wheelchair motion for each DOF.
- The motion control system of the wheelchair enables parallel control of all three degrees-of-freedom.
- The light spot A from the module Apc is recognized by means of the enhanced intensity, color, or shape in contrast with light spots B, C, and D. This is needed for the orientation of the wheelchair against the basic light spot position.

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