INTEGRATED CONTROL OF DESKTOP MOUNTED MANIPULATOR AND A WHEELCHAIR

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ABSTRACT

This paper describes a system for movement assistance and indoor transportation, realized by desktop mounted manipulator and an omni-directional powered wheelchair, controlled by the same set of user's commands. The repeatable robot movements in a preprogrammed mode require one and the same initial wheelchair position irrespective of the manipulator. A design approach to a specialized automatic navigation system capable of performing fine guidance of the wheelchair to a preliminary determined place is discussed. Examples of navigation systems based on inductive and optoelectronic sensors are described too. A common control system of a wheelchair and a robot by usage of head movements is also included.

I. Formulation of the task

The main part of the robotic workstations is designed to assist disabled individuals in their every day needs such as eating, drinking, operating simple objects, etc. [1, 2]. A prototype desktop mounted manipulator for household tasks was developed and tested at the Bulgarian Academy of Sciences some years ago under the HOPE project [3, 4]. The manipulator uses an optoelectronic follow-up positioning system that responds to movements of the head and the eyelids. The user sets directly the spatial position of the gripper. Regardless of its simplicity, the algorithm allows simultaneous control of three DOF. Tests have shown that users can adapt quickly to the robot.

The control of the workstation is based on the assumption that an external helper has positioned the user at a preliminary determined location. Sitting close to the worktable, the user can operate the robot, performing unaided pick-and-place ADL tasks. The movement independence can be increased significantly if some indoor mobility is provided to enable the user to move freely from one place to other. Wheelchair mounted manipulators are one of the solutions to such a task. This paper proposes an alternative solution, suitable for indoor movement operation. Sitting in a powered wheelchair with high manoeuvrability (not in a stationary chair), the user possesses the ability to control both the manipulator and the wheelchair and also to access independently different places within the house, for example: to move near the window, to move in front of the TV set, to stay close to the bed, or to perform different movement tasks, using the robot. This approach has some advantages: it can be used by the elderly people who spend most of their time at home; the robot uses the main power supply; the size of the wheelchair is smaller because no manipulator is mounted on it.

The HOPE manipulator is controlled in a direct mode only, i.e. the user participated actively in the control process all the time. Further improvement of the control algorithm can be obtained if the robot automatically performs repeatable movements in the pre-programmed control mode. Almost all the movement tasks involve user's face or mouth. The automatic mode can be realized successfully if the robot, the user and the manipulated objects are located at the same initial position each time when a concrete task is being performed.

In the case of wheelchair mounted manipulator, the mutual position between the user and the manipulator is the same. The position between the manipulator and the objects depends on the precision of the wheelchair steering. The robotic workstation maintains the same initial position between the manipulator and the objects. In this case, the position of the user's face is determined by the position of the chair. It can be seen that all variants (wheelchair mounted manipulator; workstation and wheelchair) need accurate positioning. Achieving the exact location could be very burdensome. First, it would require many manoeuvres; second, it is time consuming and third, it requires considerable mental and physical efforts from the user. One way to overcome these problems is to use an automatically navigated wheelchair. This would significantly reduce the user's mental burden for successful control of the robot.

Many research projects have been devoted to indoor wheelchair guidance systems [5, 6]. Usually such systems perform "do-to-goal" commands and navigate the wheelchair to different locations within user's home, avoiding environmental obstacles. The cost of such systems is significant. Therefore, the use of a universal guidance system could greatly increase the total cost of the unit.

Two main issues are addressed to this paper:

- simple navigation system for automatic guidance with respect to the initial workstation position
- system for common control of the wheelchair and robotic workstation.

2. Design approach

The operator uses his/her wheelchair for independent indoor transportation. During the sessions of robot control, the same wheelchair is utilised as a normal chair. The initial position can be regained easily if the wheelchair possesses high maneuverability. The proposed navigation approach considers omni-directional wheelchair that provides three degree-of-freedom locomotion. Due to its high manoeuvrability, such a wheelchair can ease user's access to different places and simplify the steering process [7, 8]. A specific type of wheelchair will not be treated.

The wheelchair is navigated in two modes. During the *direct control mode,* the user sends commands to MMI and the wheelchair can move to various places in the house. When the user decides to operate the robot, he simply directs the wheelchair to the worktable. When the wheelchair is close to the workstation, the navigation system is activated and the wheelchair is guided in *automatic mode* to the preliminary determined place. As soon as the desired position is reached, the wheelchair stops automatically and the user can control the robot from that position.

4. The navigation system

The wheelchair navigation system is based on the following guidepoint. The schemes involve permanently installed coils or optical guidepoint markers. Specialized sensors, mounted on the wheelchair are used to servocontrol the steering mechanism, causing the wheelchair to move to the intended position. Three different schemes will be developed during the project. The first one is presented in Figure 1. Here are shown (top view) the positions of the worktable 1, the manipulator 2, and the objects 3. Two coils with ferromagnetic core (4 and 5) are embedded in the floor. Their axes are perpendicular to each other.

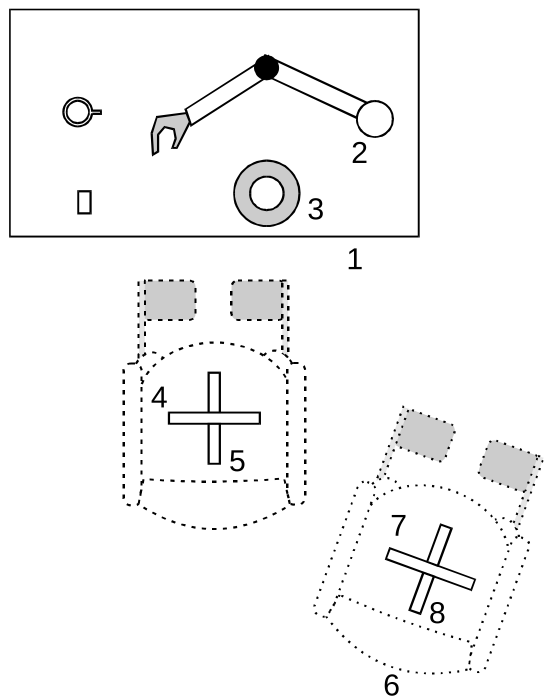

Fig. 1. Inductive navigation system

Coils 4 and 5 emit electromagnetic fields at different frequencies (f_1 and f_2). The locations of the coils mark the initial wheelchair position (where the wheelchair should be placed when the user controls the robot). Coil 4 is parallel to the long edge of the table while coil 5 is perpendicular to the same edge. A sensing head is arranged on the bottom of the wheelchair 6. This head consists of a pair of inductive pick-up coils with mutually perpendicular axes (7 and 8). Each coil is a part of a receiving resonance contour tuned at the same frequency f_1 or f_2. Inducted signals are used to servocontrol the steering mechanism, causing the wheelchair to reach the initial position where the signals attain maximal values.

The optoelectronic navigation follow - up system is shown in Figure 2.

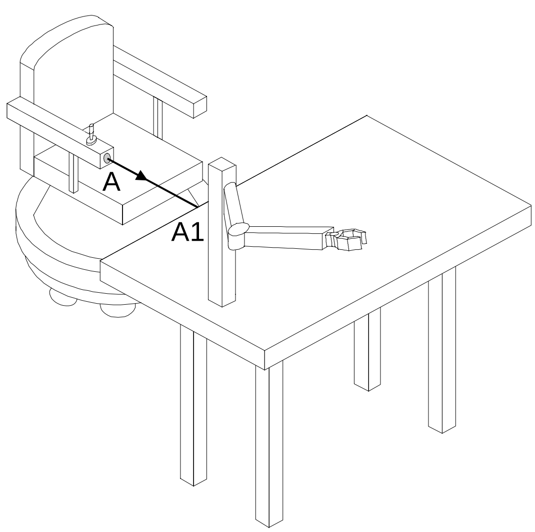

Figure 2. Optoelectronic navigation system

Light source A1 is mounted on the front side of the desk. Its place corresponds to the initial position of the wheelchair. A pulse of near infrared radiation is received by the sensor (A) which is mounted under the wheelchair hand rest.

An example of the construction of the optoelectronic sensor is shown in Fig. 3. Light source (A1) is mounted to the table 1. The light beam 2 is split by partially transmissive mirror 3 and the beam is detected by two photoreceivers 4 and 5 which are divided by optical partition 6. Two output signals are generated. The first (O1) is dependent on the displacement between the position of the sensor and the center of the light beam 2. The second output signal (O2) is dependent on the deflection between the light beam axis and the axis of the sensor. The light signal O2 becomes zero when the light intensity indicated by photoreceivers 4 and 5 equalizes with that sensed by photoreceiver 7.

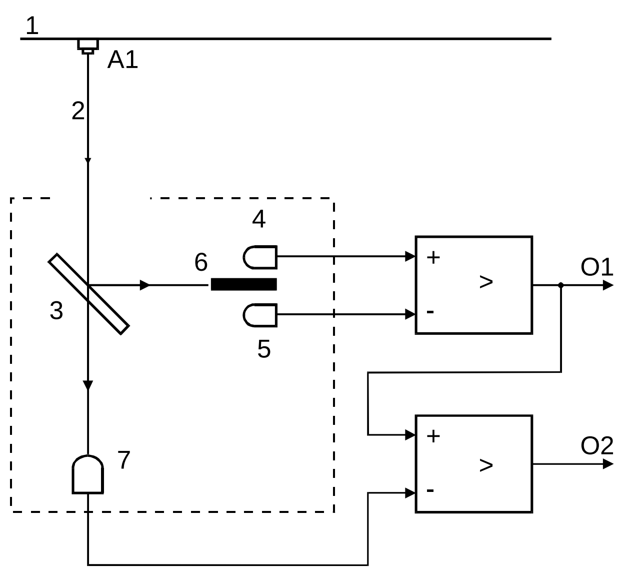

Figure 3. Optical navigation sensor

When the wheelchair comes close to the table, the distance between A and A1 (Fig. 2) decreases and the output signal O1 exceeds the preliminary defined level, hence, switching the wheelchair control system to automatic navigation mode. Referring to the signal O1, the wheelchair moves to the left or right until the sensor A matches to the beam centre. This is followed by a rotation, which is servocontrolled by the signal O2 and the wheelchair moves to the table. When the sensor signals exceed the preliminary determined level, the wheelchair stops.

An alternative variant of optoelectronic wheelchair navigation system is shown in Figure 4.

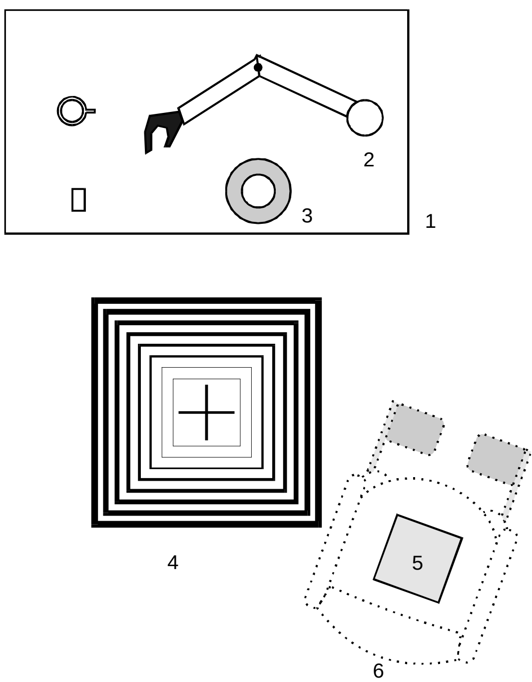

Figure 4. Pattern navigation system

The navigation system follows optical patterns 4 arranged on the floor that are sensed by optoelectronic head 5. The patterns are oriented parallel to the worktable. The width of the lines and the distance between them provide information about the current position of the wheelchair. The optoelectronic head consists of reflective optoelectronic sensors (LED's and photo receivers).

5. Common control of the robot and the wheelchair

The operator controls either the manipulator or the wheelchair at different time sequences. That is why one and the same user's commands can be used to control both the wheelchair and the robot. The use of a single command makes the control process easier for the user. In addition, the learning phase and adaptation to the control system, the total number of commands needed for the control of the wheelchair and the robot, are reduced. A system for common movement control is shown in Fig. 5.

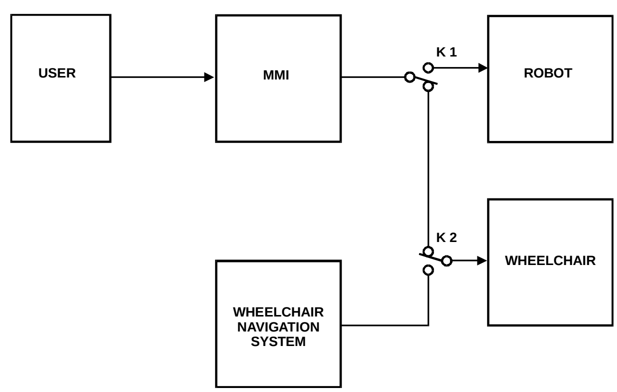

Figure 5. Motion assisting system

<u>Phases of control</u>:

A. Transport phase

When the wheelchair is far from the manipulator, the power supply to the manipulator is switched off. While driving the wheelchair, the user can move to various places within the house.

B. Navigation phase

When the wheelchair approaches the worktable then the output signals of the navigation sensors exceed the preliminary determined level. A special scheme is activated, the switch K2 turns on and the wheelchair is controlled by the wheelchair navigation system. Then, moving on a low speed, the wheelchair gets near to the initial position.

C. Initial position of the wheelchair

The wheelchair finds automatically its initial position and stops. Then a special signal is sent to the robot and it is powered. This is followed by the activation of switch K1 and the interface signals are directed to the robot.

D. Robot control

Operating the manipulator, the user can perform daily living tasks.

E/ Resume the transport phase

When the user does not need the assistance by the robot, he/she sets a special command that turns the switch K1 and the robot supply switches off. The wheelchair, controlled by its navigation system, moves away from the worktable on a trajectory that is perpendicular to the worktable. When the distance between the wheelchair and the table increases, the signals, received by the navigation system decrease and switch K2 turns the scheme to transport mode, enabling the user to control the wheelchair again.

6. Head control of wheelchair and manipulator

The HOPE manipulator [1] is based on head motions. The same commands can also be applied to wheelchair control.

The <u>robot control</u> uses optoelectronic positioning sensor that is mounted on a spectacles' frame and can detect the head position <u>with respect to the gripper</u>. Limited forward-backward head tilting and left-right head rotation are used for gripper movement in the "up-down" and "left-right" directions respectively. The optoelectronic system allows cordless data transfer.

Present approach considers omni-directional wheelchair. Such a wheelchair needs three proportional user's movements, which are transformed into commands for "left-right", "forward-backward" and "rotation" (Fig. 6).

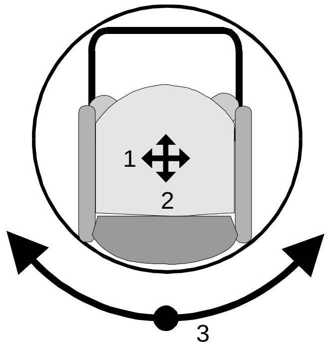

Figure 6. Omni-directional wheelchair

The wheelchair can be controlled by the same head motions sensed with respect to the wheelchair's headrest. The relation between the head motions and wheelchair direction depend on the user's movement abilities. The following scheme is possible:

- "forward-backward" head movements can control the wheelchair in the "forward-backward" direction
- lateral head tilting motions can control the wheelchair on "left-right"
- "left-right" head turning can control the wheelchair rotation to the left or right.

A single switch, located in the headrest, can detect the touch of the user's head to the headrest and can produce signals for the wheelchair's forward-backward directional motion and the power supply (i.e. on/off of the wheelchair batteries).

The optoelectronic system for the detection of the user's head position can be modified or replaced with advanced systems such as Peachtree [9], UHC [10], and Origin's head mouse [11]. Visual servoing of the user's face [12] can also be used.

Figure 7 presents a block diagram of a robot and wheelchair controlled by head movements. The scheme follows the conception of Fig. 5.

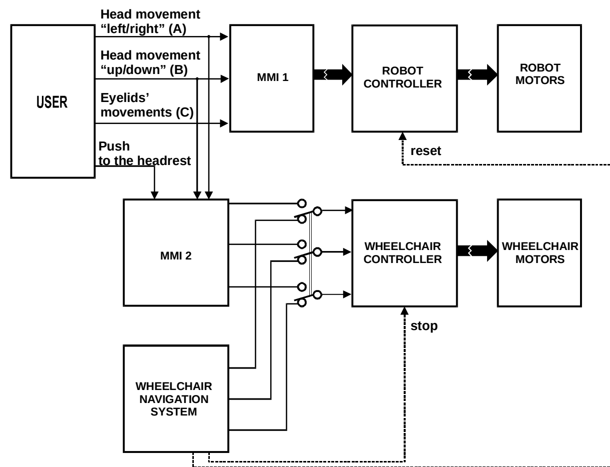

Figure 7. Head control of wheelchair&manipulator

The system for detecting the head motions consists of two parts designated as MMI 1 and MMI 2. The first part (MMI 1) detects the head motions relative to the gripper, while the second part (MMI 2) detects the same head movements relative to the headrest of the user's chair.

8. Conclusion

The combination of a desktop mounted robot and high manoeuvrability wheelchair can provide indoor independence of manipulation and transportation. Application of a special navigation system for automatic guidance of the wheelchair to the initial position reduces the user's participation in the control process. The concepts, presented above, do not fit to the algorithm of HOPE robot only. The same approach can be applied to different workstations and different kind of man-machine interaction.

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