A Visual Knowledge-Based Navigation for a Robotic Wheelchair

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ABSTRACT: *This paper describes and evaluates an intelligent wheelchair, adapted for severely disabled persons with mobility impairement. The wheelchair concept is an assistive device that allows the user to select arbitrary local destinations through a tactile screen interface. The device incorporates an automatic navigation system based on a vision system and knowledge base that drives the wheelchair, avoiding obstacles even in unknown and dynamic scenarios, providing the disabled person with a high degree of autonomy, independent from a particular environment, i.e., not restricted to predefined conditions. In this paper a system is proposed to enable an efficient use of the knowledge base for the perception and navigation of the environment. To support this task, a vision system has been developed in parallel with other sensors. The architecture of the vision system is basically modular to enable a flexible transfer of data between the different modules, and makes any further modification possible and easy. The execution of the different tasks is coordinated by the central module called the supervisor which triggers each module at the appropriate time in order to control the behavior of the wheelchair. One of the most important module in the system is the knowledge base module which uses the acquired and predicted data to construct a scene model. This model is the main interpretation of th environment, since it reflects the perception and prediction processes necessary to a robust and secure navigation. The results indicated that this robotic wheelchair effectively provided mobility and autonomy to the target population.*

Keywords: Artificial vision, Robotic wheelchair, Knowledge base, Visual navigation, Scene analysis

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1. Introduction

Due to the shift of the age structure in today's industrial populations, the demands of the handicapped and the elderly are more and more being recognized by politics, industry, and science. The recent development in research areas such as computer science, robotics, Artificial Intelligence, or sensor technology allows to significantly broaden the range of possible applications that support handicapped or elderly people in their daily lives.

Rehabilitation robots, such as smart wheelchairs, will play an important role. By compensating for the specific impairments of each individual, rehabilitation robots enable handicapped people to live more independent and mobile than they could before. Powered wheelchair is a necessary locomotive system to provide mobility aid for these people with motor disabilities. However, it is still difficult to drive a conventional powered wheelchair for the severely-handicapped people who have spinal cord injury at the cervical, quadriplegia, tremors, and so forth. Consequently, an intelligent wheelchair that can ensure an autonomous navigation will certainly make life easier and better for people with wide ranging impairments by minimizing the cognitive and physical requirements of operating a power wheelchair. An autonomous robotic wheelchair is a mobile machine capable of autonomous operation in a structured and/or unstructured environment. One of the most desirable characteristics of a robotic wheelchair is the flexibility and the adaptability. These two features can be ensured by a vision system and generally, a feedback of other types of sensory information. It is known that most current robotic wheelchairs have limited capabilities to perform tasks of ‘intelligent thinking’ type. However, recent modern intelligent robotic wheelchairs are able to employ 2-D or 3-D worlds of a vision system to assist various tasks such as visual navigation, obstacle avoidance etc..

We will focus in this paper on intelligent wheelchair robots by summarizing the requirements of a smart wheelchair with regard to the human-machine interface, the technical equipment, functionality, and the safety aspects. The main objective is to develop a mobile system which supports elderly and disabled persons in every-day-life activities. They should be able to navigate through narrow areas and open doors, to press switches, and to pick up and handle objects. The variety of possible users should range from persons, who are unable to walk to people with severe disabilities like upper-limb impairments or even paraplegia.

Using a commercial powered wheelchair, we equipped it with a set of sensors such as a camera and infrared sensors, we developed a neuro-fuzzy control system to tackle various problems encountered during autonomous navigation. We enabled the system to perceive the environment and memorizing routes and frequently used objects to better adapt itself to the environment changes. The interpretation of the wheelchair environment was not efficient without developing a knowledge base upon which the system may resolve complex situations the wheelchair encounter during the navigation.

The paper is organized as follows: sections 2 and 3 discuss the state of art of the intelligent wheelchair developments and the environment where they act in. Sections 4 give a brief description of the wheelchair hardware. Section 5 introduces the knowledge base that was integrated in the navigation system. Finally, section 6 and 7 details the resulting navigation procedure of our intelligent wheelchair and a conclusion with a planned future work on the wheelchair.

2. State of the Art

Many groups simply use the standard joystick as input devices and provide no special output device apart from simple displays. Some groups (RobChair, SIAMO) employ speech recognition systems to enable the user to issue commands by voice. In the Wheelesley project, the human operator controls the wheelchair by choosing high-level commands via a graphical user interface on a notebook [1]. The SIAMO project provides even more input devices: Apart from joystick control, switches and a voice recognition system they offer a blow control and a facility which enables the user to instruct the wheelchair by head movements, using a CCD micro camera mounted in front of the user in order to track his or her face [2]. In order to control the wheelchair, the human operator has to use a four component control panel as human-machine interface to choose a motion, a direction, the placement of the most important object close to the wheelchair, and a distance or speed. The experimental platform of the FRIEND project is equipped with a control-PC and a robotic arm structure, the MANUS manipulator. The main topics of the project are the control of the manipulator and its human-machine interface [3]. The INRO as well as the RobChair project employ a radio link from the wheelchair to a remote station for various tele-operation purposes [4].

Despite of the convincing progress the smart wheelchair community made within its ten years of existence, there is still a lot of work to do before such devices can be commercially available. The research wheelchairs are not yet robust enough to operate for a long time in the house of a handicapped person. In order to increase the acceptance in the potential buyers’ mind as well as to ease to certification by the administration, the safety issue has to be examined more thoroughly [5]. Nevertheless, the chances to provide a useful tool to significantly improve the quality of life of many people are quite realistic.

Current smart wheelchair research projects range in their applications, capabilities and use of sensors. Some projects focus on users with cognitive impairments. The simplest typically employ bumpers and sonar for collision avoidance and sometimes follow lines [6], [7], and select a safe driving direction using joystick input and sonar readings, but often cannot navigate doorways. Some achieve better navigation by employing a laser rangefinder and IR sensors for obstacle-avoidance, wall-following and three-point turns [8]. Many approaches specialize in safe navigation of highly dynamic environments, such as subway stations [9]. Some systems perform landmark-based navigation and employ visual behaviours for greater autonomy [10], but do not provide a manipulator.

Current approaches employ a variety of interface methods, such as touch-screen or voice recognition interfaces [11], [12]. Others detect eye movements via eye trackers either to guide the wheelchair directly with the direction of gaze [13], or to select menu items on a display [14]. Facial expressions, mimic and gesture recognition have also been used to as input [15]. Additionally, “sip and puff” devices and single switches that are common in rehabilitation technology have also been used for smart wheelchairs [16].

To accomplish an autonomous behaviour of a robotic wheelchair an efficient cooperation is necessary between the navigator,which does all the planning and the control functions, the sensing system available, and finally the mechanical structure of the wheelchair itself including the actuation. The three parts are linked together in a closed loop as illustrated in figure 1.

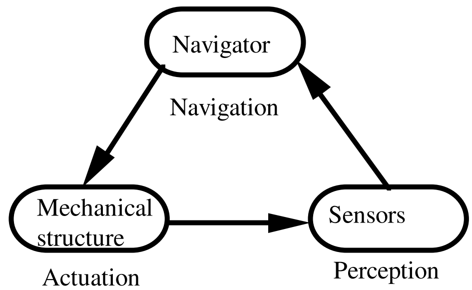


Figure 1. cooperating elements

It is clear that different sensors provide different kinds of information and no sensor works perfectly in all real-world applications [17]. How to effectively utilize the positive side of each sensor and avoid its negative side becomes critical for the deployment of mobile wheelchairs in the real world. To reach this goal, sensor technology and data fusion algorithms have been a hot research topic and played a key role in the acquisition of more accurate and reliable information for the last two decades. However, there are a number of open problems in both sensor technology and multi-sensor data fusion algorithms that remain to be answered.

3. Characterization of the Environment

Due to the fact that the employed wheelchair has to be classified as a safety critical system, because it shares its workspace at least with its operator, actions have to be taken in order to prevent human beings from any harm. As a result on software side, any driving command with respect to the current obstacle situation should be efficiently analysed. It can then be decided whether the given command is to be forwarded to the actuators or to be replaced by a necessary deceleration manoeuvre [18].

Our environment is full with visual cues intended to guide human navigation. For example, there are building directories at entrances and room numbers next to doors. By developing a robot wheelchair system that can interpret these cues, we should create a more robust and more usable system. We classify the major features of the urban environment (relevant for safety) in which we want the wheelchair to function . Based on this set of features the system can classify parts of the world as being [19]:

*1. **Obstacles**.*

*2. **Hazard**: overhangs, drop offs, steep inclines, and very rough surfaces.*

*3. **Caution areas**: inclines, narrow regions, and rough surfaces.*

*4. **Unknown areas**: regions with insufficient data.*

*5. **Safe areas**: the surfaces over which a wheelchair can travel.*

We only consider environments where the travel surfaces are not inclined. This is mostly true of indoor office environments and many outdoor places as well. Therefore inclines are considered as hazards. Furthermore, only fixed obstacles are considered, and rough surfaces are ignored [20].

4. Wheelchair Hardware

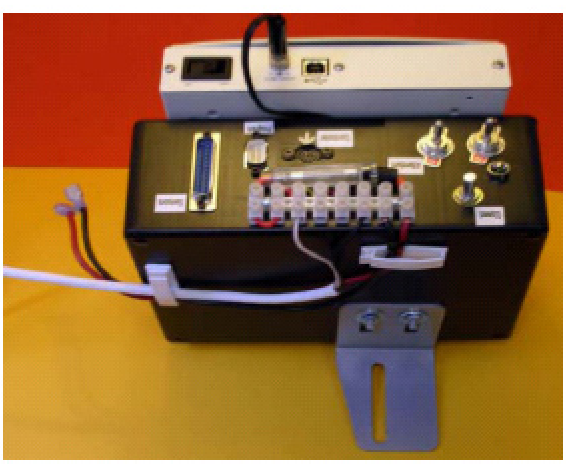
The starting point was a commercial electric wheelchair that complied with the basic ergonomic requirements and also with the mobility of the users. The experimental wheelchair system is based on Invacare Pronto M71 Power Wheelchair with Sip-N-Puf Digital Interface. The Invacare Pronto M71 power wheelchair with SureStep is easy to use and maintain. It offers excellent maneuverability and true-mid-wheel-drive performance in a compact, electric wheelchair design. With its innovative SureStep technology, the Pronto M71 electric wheelchair drives smoothly over transitions and thresholds up to two inches while maintaining stability [21]. We equipped our experiemntal wheelchair with the following hardware components as shown on figure 2:

1. An onboard Basic Stamp II controller is installed for motion control of two differentially driven wheels.

Figure 2. Experimental wheelchair

2. A computational ressource: PC installed onboard (laptop: SONY Intel Centrino 2.2, 1GB RAM, WIN Vista tablet with 3 USB ports), which is connected to the DSP motion controller via a USB link.
3. A touch screen LCD display for providing command and visual feedback.
4. A 24 volts battery to provide power for the DSP controller, the PC and drive motors.
5. A local joystick controller is connected to an A/D converter of the BS2 based controller.
6. 8 ultrasonic range sensors at a height of 80cm for obstacle avoidance.
7. 8 infrared range sensors at a height of 80cm for obstacle avoidance.
8. A Logitech 4000 Pro Webcam is equipped for vision control and environment perception.

Power for the sensors is drawn from the wheelchair batteries. A voltage regulator that supplies 5 V to the infrared sensors and another voltage regulator that supplies 12 V to the sonar sensors convert the 24 V from the batteries. The intelligent wheelchair control box is "inserted" into the control system between the user's input device and the wheelchair's motor controller (see Figure 3).



a) Control box

b) control box connections

Figure 3. Wheelchair control box

The control box is designed to accept signals from an input device (such as a joystick or attendant control) and present the user's input to the wheelchair's proprietary control electronics. Normally, the input device is plugged directly into the interface module. When the wheelchair system is installed, however, both the input device and the interface module are plugged into the smart wheelchair system. Note the presence of the max speed potentiometer whose function is to set a maximum speed by hardware, which the wheelchair cannot exceeds [22]. The wheelchair system reads the signal from the input device and sends a revised signal to the wheelchair's motor controller. The motor controller then treats the revised signal as if it came directly from the input device. Under most circumstances, the revised joystick signal is identical to the original signal but, if an obstacle is detected, the system alters the joystick signal to avoid collisions. The BASIC Stamp used in our smart wheelchair system has been programmed using the Parallax BASIC Stamp editor/ development system version 2.2.5. All modifications to the existing programming should be done using that development system by simply connecting the laptop to the programming connector on the wheelchair system control box using a serial programming cable.

4.1 Camera

Considering our application of computer vision to detect obstacles and landmarks from a semi-structured environment, We decided to go with a medium end camera which is easy to interface and has application interface libraries easily available. Finally, it was a Logitech QuickCam Pro-4000 color camera, which is easy to interface using Intel OpenCV (Intel's Open Source for computer vision application). OpenCV has the necessary functions which will help us a lot in developing our mentioned application. The camera, Logitech® QuickCam® Pro 4000, is mounted in front of the vehicle capturing the front view as shown on Figure 4. The 160 x 120 32-bit RGB image is updated and saved in memory at the rate of 10 frames per second. The camera is connected to the PC through a USB (Universal Serial Bus) port and used mainly for recognizing a path in the hallway and static objects in the environment [23].

Figure 4. Camera setup on the wheelchair

4.2 Infrared and sonar sensors

In this experiment, eight sonars, eight infrared (IR) sensors, and a single web camera are used and gather information about the environment. Figure 2.5 depicts the arrangement of sensors installed on the wheelchair. The IR sensors (evolution robotics IR sensor pack) enclose the rectangular wheelchair fairly evenly for 360° of coverage as shown in Figure 5. According to the sensor specifications, objects within a distance between 15 cm and 100 cm should reliably be acquired in reasonable ambient lighting conditions. Behaviors such as collision detection and obstacle avoidance are designed to perform actions based on the information given by these sensors.

Figure 5. Sensors mounted on our wheelchair

Figure 6. Sensor modules each consisting of 1 sonar and 1 infrared

The smart wheelchair system uses sonar, infrared, and camera, because each sensor has different strengths and weaknesses. In keeping with our goal of producing a system that was both modular and configurable, one sonar and one infrared sensor were housed together in an 8.5 × 5.5 × 4.0 cm box (shown on Figure 6), which we referred to as a "sensor module." eight sensor modules were mounted on the wheelchair or wheelchair lap tray with the use of Velcro or duct tape.

4.3 Touch screen

Once the autonomous navigation is initiated by the user, the interface displays to the user a map of the environment where he is moving. In this mode the user has to specify his motion intentions just by pointing to the destination on the map through the touch screen.

4.4 Bumpers

Due to the conic field of the range finders, small objects on the floor may not be detected correctly to be avoided. In this case the bumpers which are small contact switches play a safety role by stopping the wheelchair once the contact is done.

4.5 Localization sensors
The wheelchair cannot execute any navigation command issued by the user unless it knows exactly its current location before heading to the destination. This is accomplished by the localization sensors which are simply network wireless sensors delivering in real time the position of the wheelchair in its environment.

5. Knowledge Base

We developed a navigation system with two-level control: high-level control and low-level control. The low-level control system consists of the neuro-fuzzy network controller and an encoder, which provides odometric information. The high-level system performs map building and path planning tasks. This system contains the sensor interpretation, the sensor data fusion, the map building and the path planning blocks. All the modules are designed based on fuzzy logic [24]. The principal task of the knowledge based system is the ensuring of a reliable perception, so that efficient autonomous navigation can be guaranteed. Perception robustness depends essentially upon the reliability of the road edge detection algorithm. This is why the road edge detection algorithm in our vision system uses two independent image data representations. The first is the result of several image processing operations, and the second is a scene prediction generated from a memorized world map. Scene prediction based on the map data is completely independent of the principal causes for the erroneous selection of road edges. The vision system consists of several modules each ensuring a specific task involved in the autonomous navigation activity. The flow of data and control between the different modules which ensure the navigation task is shown in figure 3.

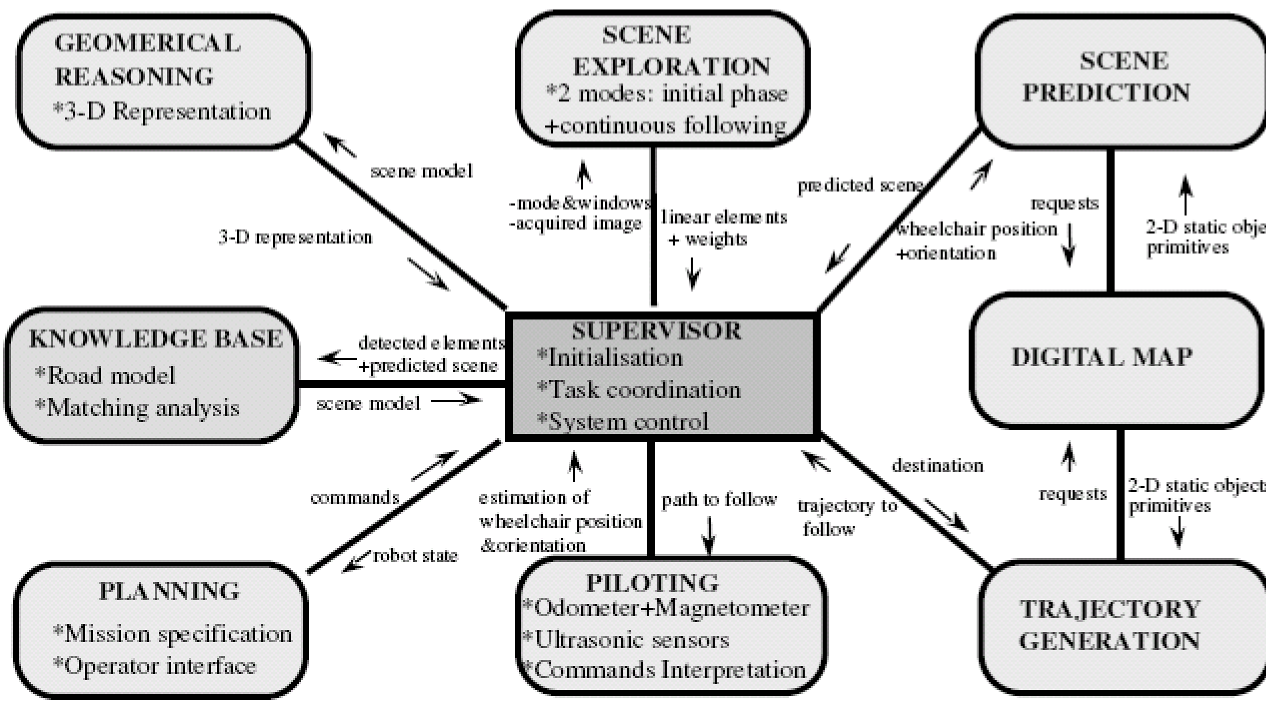


Figure 7. Architecture of the knowledge based system

Most of the processsing time is spent with the scene exploration module which is based on the Hough transform to extract the dominant sraight features. This module operates in two modes: the initial phase which includes all the processings applied to the first image acquired in order to initiate the navigation, and the continuous following mode which handles the processing of subsequent images taken at the end of each blind distance. In order to rely less on visual data, a digital map of the environment has been established, and a corresponding algorithm is used to make a scene prediction based on the wheelchair position provided by the localization system. The predicted scene is used to validate the objects detected by the knowledge base. This knowledge base uses the acquired and predicted data to construct a scene model which is the main product of the vision system. This model is used by the geometrical reasoning module in order to obtain a 3-D interpretation necessary to the pilot module. Moreover, a simple trajectory algorithm is used to break the path down into segments which are transmitted to the pilot module one after the other. Generally, without prior detailed knowledge of the environment, the system may not be able to determine its absolute world position during the initial phase. To overcome this problem, the vision system should search for those elements useful for wheelchair localization with respect to the road edges. This is performed only during the initial phase, and requires a tremendous processing time. Once these elements are localized, the vision system can predict their position with a certain degree of precision in the next acquired images. Thus the execution time is considerably reduced by focusing the analysis on a visual field portion estimated sufficient to maintain navigation. This way of processing is particularly efficient when computing resources are limited, which is often the case. Hence to exhibit a desired behavior, the robotic wheelchair should explore the software and hardware capabilities in a predefined order. At the level of the vision system, this order is well established since the architecture structure is modular, allowing a specific function to be added or deleted easily.

To simplify the task during the initial phase, the wheelchair should be placed at approximately the center of the road and oriented according to the direction it is to take. Once the road following task is triggered by the operator, the supervisor resets the system software and hardware, and informs the planning level about the actual state of the wheelchair in order for this to send the first command of the preset command sequence. Traditionally, the first command to initiate the navigation is: find the path. Therefore, the supervisor selects the initial phase mode, triggers the image acquisition process and transmits the first image taken to the exploitation module. The latter processes the entire image seeking for linear elements based on the Sobel gradient orientation. Using the Hough transform, a parametric descrition is associated to each linear element detected, and a weight indicating its degree of linearity.Up to now the wheelchair is still immobile in a position supposed known by the system. having the coordinates of this position and the wheelchair orientation, the supervisor initiates the scene prediction algorithm. The data concerning the static objects in front of the wheelchair are back-projected onto the image plane, taking into account the camera model and the wheelchair-camera configuration. The predicted image reflects the approximate position of the objects and the road edges. It is then transmitted with the linear elements and their weights to the knowledge base. At this level , a reasoning is performed on the compatibility between the linear features provided by the Hough transform and the characteristics shown by the predicted scene.

Once the path edges have been selected, the knowledge base establishes the scene model and sends it to the supervisor. This model describes the road shape and constitutes the final output of the vision system after each acquisition. It contains a record of the position and the orientation of the wheelchair with respect to the road.

After the supervisor has been informed of the scene model, it asks the geometrical reasoning module for a 3-D intrpretation of this model. The interpretation consists of a conversion of the model parameters into physical world parameters by perspective transformation. This transformation takes an infinite number of solutions, so certain constraints concerning the terrain flatness and road edges continuity are required. The resulting representation and data provided by the pilot module, allow a periodic localization of the wheelchair. As the wheelchair is localized with respect to the path, the supervisor indicates to the trajectory generator the destination to be reached, so that the road state on the map and the region to be traversed with a minimum of hazard can be examined. Relying on the characteristics of this region, the trajectory generator breaks down the path linking the wheelchair to its destination into a set of segments. The first segment is selected by the supervisor and then sent to the pilot module which interprets it into movement commands. These commands are decoded and used by the locomotion system which causes the wheelchair to start moving. Periodically, the pilot module informs the supervisor about the distance travelled. Once the first segment is completed, the supervisor asks for a new frame and switches to the continuous following mode. During this mode , the supervisor starts by specifying the current position and orientation of the wheelchair to the scene predictor. Subsequently, this makes a scene preediction and computes the position of the windows through which the the road edges are supposed to enter the lower part of the image. Consequently, the processing at the level of the scene exploitation module will be limited to a set of windows, thus considerably reducing the processing time. The initial windows are placed in such a way to include a maximum of the road edge length. However, we notice that the success of the subsequent window positioning depends heavily on the previous results. Processing in this mode ends once the last window reaches the top of a predefined search zone. The Hough transform is then again used to parametrize the road edges detected through the linking of the set of segments found in each window. Following this structure, the supervisor repeats the same procedure until the wheelchair reaches its final destination, or meets an unkown situation and asks for help, or is ordered to stop.

6. Navigation Procedure

Environmental models can be known beforehand, but gradual changes deteriorate their usability. A better approach is to maintain the scene model directly by using the images taken by the camera. Therefore an image base is used to efficiently describe the robot workspace. The database consists of a set of images $I = \{I_1, \ldots, I_n\}$ of the environment taken at various poses $P = \{P_1, \ldots, P_n\}$ where $P_i = (x_i, y_i, \theta_i)$ in a relative coordinate reference frame F with respect to an initial camera position. These locations are the initial reference locations which the wheelchair refers to for locating itself in the environment. The corresponding images are called reference images. These images should sufficiently sample the entire workspace. These

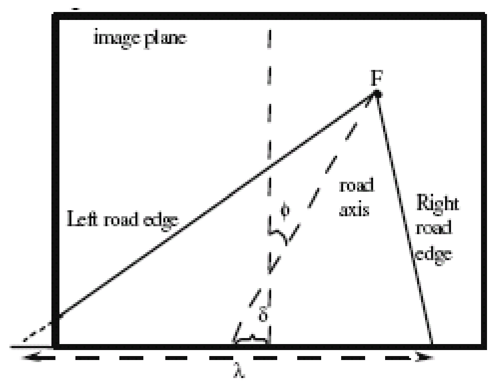


Figure 8. The Scene Model Parameters

images are input to the scene exploration module which will output a scene model composed of a right and a left road edge may be described by four parameters M_s (F,φ,δ,λ) as shown figure 8.

a. The vanishing point F: this point is determined by the intersection of two segments. It may be inside or outside the image plane depending on the robot-camera configuration.

b. Orientation error φ: the orientation error f is the angle between the road axis and the vertical axis of the image plane.

c. Shift error δ: this shift in pixels is measured at the bottom of the image plane between the image vertical axis and the road axis

d. The path width λ: this quantity in pixels measured at the bottom of the image plane allows

Moreover, since the scene model Ms (F,φ,δ,λ) is to be exploited by the locomotion system of the wheelchair, the scene model parameters {θ,δ,λ} should be expressed in the world coordinates system. Consequently, from the scene model the geometrical reasoning module determines the physical quantities {Θ,Δ,Λ} in the physical world coordinates system. For this, the geometrical reasoning module considers the following coordinate system shown by Figure 9.

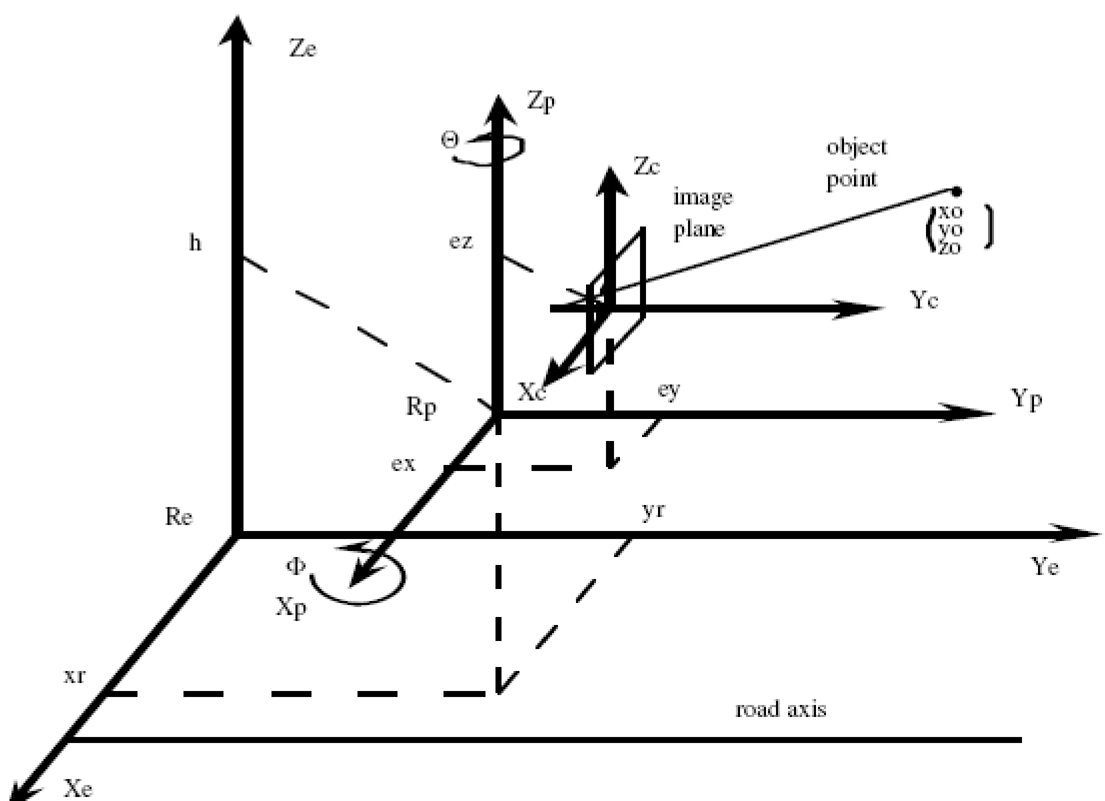


Figure 9. environment coordinate system

R_e represents the environment coordinate system, R_p represents the platform system. The quantities xr and yr are provided by the localization system and give the wheelchair's position within the environment coordinate system (the position of the platform frame with respect to the whelchair frame is known). The camera position is given by (e_x, e_y, e_z). For the sake of simplicity, we suppose that the image plane (X_c, Y_c) is parallel to the platform plane (X_p, Y_p) . The center is at (0,-*f*,0) in the camera frame, where *f* is the focal length of the camera. Using the mapping matrices from one frame to another, we may find the image of any object point $M(x_o, y_o, z_o)$ on the image plane. The image point coordinates (x_i, z_i) are given by the following expressions:

$$x_i = f\frac{x_o\cos(\Theta) - y_o\sin(\Theta) + A}{x_o\sin(\Theta)\cos(\Phi) + y_o\cos(\Theta)\cos(\Phi) - z_o\sin(\Phi) + B + f} \tag{1}$$

$$z_i = f\frac{x_o\sin(\Theta)\sin(\Phi) + y_o\cos(\Theta)\sin(\Phi) + z_o\cos(\Phi) + C}{x_o\sin(\Theta)\cos(\Phi) + y_o\cos(\Theta)\cos(\Phi) - z_o\sin(\Phi) + B + f} \tag{2}$$

with: Θ the rotation around the Z_p axis, Φ the rotation around the X_p axis. and:

$$A=-x_r\cos(\Theta)+yr\sin(\Theta)-e_x$$
$$B=-x_r\sin(\Theta)\cos(\Phi)-y_r\cos(\Theta)\cos(\Phi)+h\sin(\Phi)-e_y$$
$$C=x_r\sin(\Theta)\sin(\Phi)-y_r\cos(\Theta)\cos(\Phi)-h\cos(\Phi)+e_z$$

To interpret the meaning of the scene, we should study their properties and their relations with the outer world. This requires the passage from a 2-D image plane to a 3-D environment reference frame. This approach is an ill-posed problem in artificial vision since it requires the introduction of a certain constraints in order to get a unique solution. In our case the constraints concern the route structure and are as follow:

- the wheelchair is moving on a flat terrain,

- the road is made up of two locally parallel edges,

- the road edges are continuous in the image plane, which implies their continuity in the physical world.

Note that the last constraint makes the prediction of a missing edge possible. Taking into account the previous assumptions made on the corridor structure, in order to obtain the following relations between {θ,δ,λ} and respectively {Θ,Δ,Λ}:

$$\begin{aligned}\tan(\frac{\pi}{2}-\theta) &= \frac{[h-(e_y-f)\sin(\Phi)+e_z\cos(\Phi)]\cos(\Theta)}{(1-\cos(\Phi))e_x\cos(\Phi)+[h\sin(\Theta)-e_y+f]\sin(\Theta)},\\ \Lambda &= \frac{[h-(e_y-f)\sin(\Phi)+e_z\cos(\Phi)]\cos(\Theta)}{f\sin(\Phi)+zi_{\max}\cos^2(\Theta)}\cos(\Phi)\lambda,\end{aligned} \tag{3}$$

and finally:

$$\Delta = \frac{D}{f\sin(\Theta)+zi_{\max}\cos^2(\Theta)}\cos(\Phi) - x_r - e_x$$

The navigation method in this prototype uses a localized planning algorithm which takes into consideration the topology of the environment when moving the wheelchair. More specifically, given a starting point s and a goal point t, the planner moves the wheelchair towards the direction that minimizes the Euclidean distance between these two points. The algorithm computes in real-time a set of optimal paths for reaching the destination.

The system is designed to provide a collision-free path configuration for the wheelchair to navigate from point to point autonomously and to choose the best behavior to execute the motion functions. First, the system is initialized with a predefined map of the environments then it will extract the geometric features of the environment and transform them to a convenient graph representation as shown by the Figure 10.

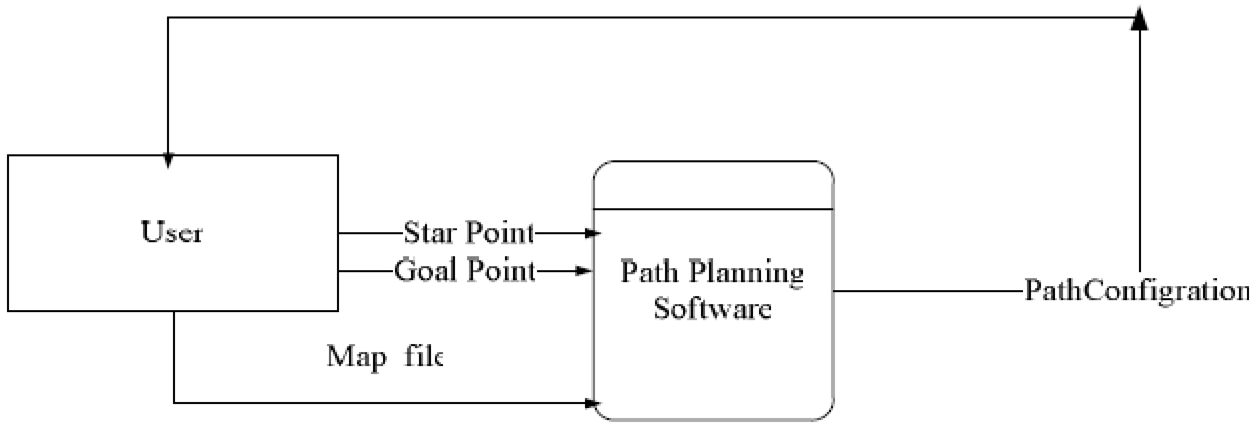
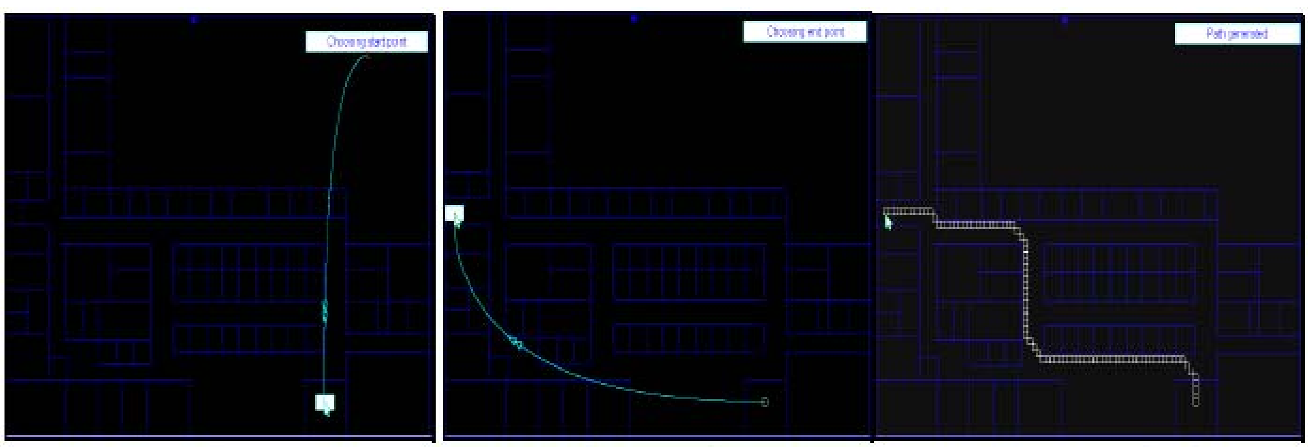


Figure 10. Path Planning system Overview

Then the interface displays the map and wait for the user to input the start and goal positions via the touchscreen. Afterwars, the user input the positions and the system determines a free path between the actual position and the destination as shown on figure 11.



Choosing a Start point — Choosing a destination point — Generated Path

Figure 11. Path generation example

7. Conclusion and Future Work

The planned application of this work is to build an autonomous robotic wheelchair which can navigate and explore urban environments in interaction with its human user. The main contribution in this work is the introduction of a knowledge base. The proposed method enables to decrease the failure rate of detection of road edges in the navigation of autonomous robotic wheelchair in an unstructured environment using a vision system, infrared and sonar sensors. This constitutes an efficient aid for the self-localization of a wheelchair within its environment and a particularily significant strengthening in difficult situations , such as partial path edge concealment, high contrast, or dazzling, which represent considerable problems for the effective functioning of artificial vision systems.

There are many ways in which this work can be extended. In the short term, future work will consist of speeding up the system and auto calibrating the sensors. For calibration we intend to use techniques that take advantage of multiple sensors to auto-calibrate the sensors against each other. Another extension to this work will include using additional visual cues for safety such as color. As a long term extension, we plan to incorporate a robotic arm onboard so that the user might command the robot to open a door to a room, go to a table and pick up a few toys on top of it. Accordingly, the arm control system must detect the door handle, grasp it accurately it so that it can be turned, maneuver so that the door is opened, navigate the doorway, identify the table location and navigate the room towards it while avoiding people or other obstacles. Moreover, based on visual feddback, the system should identify the objects to be picked up and, grasp and manipulate them. It must do so safely and without unnecessary motion, while monitoring for failures and recover from them sensibly, without excessive user intervention. Finally, we plan to extend the work to environments where travel surfaces are non-level.

8. Acknowledgements

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References

[1] Mazo, M. and Research Group of the SIAMO Project (2001). An integral system for assited mobility, IEEE Robotics and Automation Magazine pp. 46–56.

[2] Bailey, Matt ., Chanler, Andrew., Maxwell, Bruce ., Micire, Mark., Tsui, Katherine.,Yanco, Holly . (2007). Development of Vision-Based Navigation for a Robotic Wheelchair, In: Proceedings of the 2007 IEEE 10th International Conference on Rehabilitation Robotics, June 12-15, Noordwijk, The Netherlands

[3] Simpson, R., LoPresti, E., Hayashi, S., Nourbakhsh, I., Miller, D. (2004). The Smart Wheelchair Component System, Journal of Rehabilitation Research & Development, 41 (3B) 429–442.

[4] Zeng, Q., Burdet, E., Rebsamen, B., Teo, C. L. (2008). A collaborative wheelchair system, IEEE Transactions on Neural Systems and Rehabilitation, 16 (2) 161–170.

[5] Tsui, K.M., Yanco, H.A., Kontak, D., Beliveau, L.(2008). Development and evaluation of a flexible interface for a wheelchair mounted robotic arm, In: Proceedings of the Third Annual ACM/IEEE Conference on Human-Robot Interaction, Amsterdam, The Netherlands.

[6] Nesbit, P.D. (2002). Assessment and training of Children for Powered Mobility in the UK.” Technology and Disability 14, p. 173-182, IOS Press.

[7] Levine, S.P., Bell, D.A., Jaros, L.A., Simpson, R.C., Koren, Y., Borenstein, J. (1999). The NavChair Assistive Wheelchair Navigation System, IEEE Transactions on Rehabilitation Engineering, 7 (4) 443-451.

[8] Rao, R. S., Conn, K., Jung, S. H., Katupitiya, J., Kientz, T., Kumar, V., Ostrowski, J., Patel, S., Taylor, C. J. (2002). Human Robot Interaction: Application to Smart Wheelchairs, In: IEEE International Conference on Robotics and Automation 2002, Washington, D.C.

[9] Lankenau, A. Meyer, O., Krieg-Bruckner, B (1998) Safety in Robotics: the Bremen Autonomous Wheelchair, In: Proc. of the 5th Int. Workshop on Advanced Motion Control.

[10] Gomi, T., Ide K (2006). The Development of an Intelligent Wheelchair, In: Proceedings of IVS’96, Tokyo, Japan.

[11] Bley, F., Rous, M., Canzler, U., Kraiss, K.-F. (2004). Supervised navigation and manipulation for impaired wheelchair users, In: Proc. IEEE International Conference on Systems, Man and Cybernetics: Impacts of Emerging Cybernetics and Human-Machine Systems, p. 2790–2796. The Hague, IEEE Systems, Man& Cybernetics Society, October.

[12] Argyros, A., Georgiadis, P., Trahanias, P., Tsakiris, D. (2002). Semi-autonomous navigation of a robotic wheelchair. Journal of Intelligent and Robotic Systems, 34. 315–329.

[13] Crisman, J. D., Cleary, M. E., Rojas, J. C. (1998). The deictically controlled wheelchair, Image and Vision Computing, 16 (4) 235–249, March.

[14] Bien, Z., Chung, M.-J., Chang, P.-H., D.-S. K. et al. (2004). Integration of a rehabilitation robotic system (KARES II) with human-friendly man-machine interaction units, Autonomous Robots, 16. 165–191.

[15] Kuno, Y., Shimada, N., Shirai, Y (2003). Look where you’re going: A robotic wheelchair based on the integration of human and environmental observations. IEEE Robotics and Automation, 10 (1) 26–34.

[16] Mazo, M. et al. (2001). An integral system for assisted mobility, IEEE Robotics and Automation Magazine, 46–56, March.

[17] Talukder, A., Goldberg, S., Matthies, L., Ansar, A (2003). Real-time detection of moving objects in a dynamic sene from moving robotic vehicles, In: Proc. of Int. Conf. Intelligent Robotics and systems, p. 1308-1313.

[18] Wei, Y. (2004). Vision-based human-robot interaction and navigation of intelligent service robots, PhD Thesis, Institute of Automation, Chinese Academy of Sciences, Beijing, China.

[19] Felzer, T., Freisleben, B (2002). HaWCoS: The “handsfree” wheelchair control system, In: Proc. 5th Int. ACM Conf. on Assistive Technologies, Edinburgh, Scotland, p. 127-134.

[20] Ono, Y., Uchiyama, H.,Potter, W (2004). A robotic wheelchair for corridor navigation: A multi-agent approach, In: Proc. ACMSE’04. ACM Press, p. 379–384.