Ambient Assisted Route Planner Based on XML Files with Accessibility Information

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***Abstract*—** This work introduces an Ambient Assisted Route Planner (A2RP) aimed for providing route planning in unknown indoor environments. System was first designed as an assistive mobility aid to be used by intelligent powered wheelchairs, although it can be suitable also for other autonomous mobile robotics systems, non-automated mobility device users or pedestrians. A2RP system is based on a set of XML description files that can be retrieved from the internet. These files contain all the information needed to access public or private buildings: floor maps, accessibility information, available routes and calibration landmarks. XML description files must be created, located and maintained in an internet server specially dedicated for this purpose. This paper presents description files structure and the associated software applications: a visual editor to build and maintain XML accessibility information files and a navigation setup program to be run on board of the intelligent wheelchair processor.

***Keywords*—** Route planning, navigation maps, accessibility, assisted mobility, intelligent wheelchair.

I. INTRODUCTION

For people with some kind of locomotion disability some tasks and situations of everyday life can have physical constrains sometimes impossible to overcome for them. In this case manual or powered wheelchairs are standard devices that help them to increase their locomotion ability and quality of life.

But it is very difficult for a wheelchair user to make a plan to move in a place never visited before. These difficulties are mainly due to the lack of accessibility information [1] ensuring that there is a possible way for a wheelchair to go from an entry point to the desired location in the building.

For outdoor navigation a common solution [2, 3, and 4] is the use of high precision systems and databases like GPS (Global Positioning System) and GIS (Geographic Information System). This is intended to provide a navigation system to wheelchair users that could display, in real time, accessibility information that allows a safe motion between locations in open environments.

But indoor environments are not suitable for GPS positioning information. Several works in literature use mobile robotics techniques and advanced sensors (video cameras, laser range finders) in order to determine wheelchair location and the creation of maps of the environment, using SLAM techniques (Simultaneous Localization and Mapping).

Other research lines propose the development of Smart Spaces [5 and 6], in which some of the system sensing and processing capabilities have been installed over the environment itself, making easier the tasks of route planning and navigation inside it.

In [7] is proposed a navigation system that models the environment in a hierarchically structured tree using the architectural features of the building. In this work, navigation uses odometry based on optical encoders coupled to wheelchair's motors. Wheelchair position calibration is based on video cameras and visual landmarks placed in doors and halls.

Reference [8] proposes a small area autonomous navigation system for a wheelchair using technologies applied to AGV (Automatic Guided Vehicles) and maps fetched from a local server. The location system of the wheelchair is based on an external radio system and the route planning algorithm is left to the local server.

In [6] is presented a navigation method for service mobile robots in indoor environments. It uses XML (eXtensible Markup Language) semantic maps and sensors placed in the smart space for robot location. Maps simplify routing tasks, describing the features of the multiple cells, their connection points and the location sensors in each one.

The work presented here is part of a research project that aims to develop a simple and efficient tool for the retrieval of accessibility information of public or private buildings (hospitals, shopping centers, airports, etc.) to help the navigation of an autonomous wheelchair in these kinds of indoor environments.

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The accessibility information of a particular building will be provided by an Internet Service (IS). Administrators of buildings and public places will store in servers of this IS the accessibility information in the form of XML files; these files should contain the description of floor maps, access points, places of interest and optimal routes for a wheelchair to move inside the building. Wheelchair route is estimated using dead reckoning, where actual position and path can be corrected by means of visual marks placed on the ceiling at certain locations.

Many of the related works present solutions for autonomous navigation of a wheelchair in indoor environments. But none of them establish a complete structure where the environment itself helps to find the route to any place of interest on any floor of the building from any point within it or even from an external sidewalk. This is the aim of the Ambient Assisted Route Planner (A2RP) and its associated advanced wheelchair navigation system.

This work presents the definition of the A2RP system architecture for buildings with several floors. It presents an editor for XML files containing metric maps and accessibility information. It also shows a control program for a wheelchair to fetch these files from the server using a cell phone. With the maps and accessibility information retrieved from the XML files it controls the wheelchair for autonomous navigation within the building.

II. Wheelchair Indoor Navigation System Architecture

Fig. 1 shows the main components and functions of the Ambient Assisted Route Planner (A2RP) and wheelchair indoor navigation system.

In the top left corner it is shown an internet server, dedicated to the storage of the XML files containing the maps and accessibility information. Creation, maintenance and updating of this information can be done off-line, even in a different location (in top right corner of Fig. 1). At the bottom the embedded control system onboard the wheelchair is shown.

System behavior is as follows: when approaching to a certain location of interest, wheelchair controller send to the internet server its geographical position (obtained from a GPS) using a mobile phone or any similar device. Then it gets the information from registered buildings in the nearby. User selects the desired building to go and gets its XML files with the maps and accessibility information to be used by the navigation system.

Selection of the location to be visited may be done by a menu system or directly pointing to a position on a floor map. This is made using the appropriate Human Machine Interface (HMI), depending on user profile. Fig. 1 shows a head mouse as input device; it uses accelerometers to detect command actions made with specific head movements.

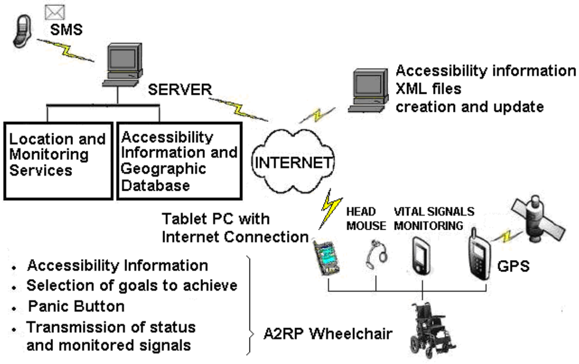

Fig. 1. Architecture of the indoor wheelchair navigation system.

Communication and positioning structures of navigation system can also be used for remote monitoring of biological signals and location of wheelchair users, opening a broad range of possible health care services.

A. Maps and accessibility information modeling in XML Files

Building maps and accessibility information should include the existing locations to be visited, the best entry point, the best path from this entry to an elevator that reaches the desired floor (if needed) and then the best path to go to the desired place. These paths must be achieved by a wheelchair so they can not have stairs, narrow corridors or passages, and doors difficult to open. This information is included in a set of XML building description files.

These files describe the ways to access the building, the position of its entries (suitable to a wheelchair) the map of each floor with the location of lifts, doors and places of public access. They also define landmarks for wheelchair position calibration and a set of optimum routes, free from physical barriers, from each landmark to all of its neighbors.

In the proposed architecture, a building to be visited is considered as having a ground floor, *n* floors and *k* basements, defined by XML files with the formats described in following sections.

- File type: **Building.xml**

This file (Fig. 2) defines the number of floors and basements of the building; the position in UTM coordinates of the map of access to it; the location and orientation of the ground floor on the map of

```
<?xml version="1.0" encoding="utf-8"?>
<Building Floor="3" Underground="0">
  <Position Latitude="4484900.73" Longitude="470228.70"/>
  <Orientation X="14170" Y="3080" Tilt="0.8605253" />
  <AcessLimits X="0" Y="0" Width="27347" Height="27347"/>
  <Limits X="357" Y="85" Width="12716" Height="13447"/>
  <Lift Name="ELEV1" Floors="All"/>
        : : :
  <Lift Name="ELEV7" Floors="0,1,2"/>
</Building>
```

Fig. 2. XML file with the basic parameters of a building.

```xml
<?xml version="1.0" encoding="utf-8"?>
<Floor0>
  <Rectangle X="3774" Y="255"
    Width="2533" Height="2380" Color="-1"/>
    : : :
  <Rectangle X="3774" Y="2669"
    Width="2516" Height="374" Color="-1"/>
  <Line X1="2975" Y1="13430" X2="340" Y2="13430"/>
    : : :
  <Line X1="9690" Y1="3043" X2="10523" Y2="2227"/>
  <Ellipse X="4148" Y="4216"
    Width="5202" Height="5236" Color="-1"/>
      : : :
  <Ellipse X="11730" Y="8024"
    Width="986" Height="1037" Color="-1"/>
  <Polygon NVertices="4" X0="580" Y0="4842"
    X1="1303" Y1="3917" X2="2546" Y2="5329"
    X3="1353" Y3="6489" Color="-1" />
  <Door Name="DOOR1" X1="4803" Y1="11256"
    X2="4803" Y2="11427"/>
    : : :
  <Door Name="DOOR2" X1="4799" Y1="12036"
    X2="4799" Y2="12204"/>
  <Landmark Name="CIR01" Tipo="Circulation"
    X1="3120" Y1="7331" X2="3320" Y2="7531"
    Xo1="3220" Yo1="7331" Xo2="3220" Yo2="7531"/>
    : : :
  <Landmark Name="ELEV1" Tipo="Lift"
    X1="3505" Y1="7206" X2="3705" Y2="7406"
    Xo1="3505" Yo1="7306" Xo2="3705" Yo2="7306"/>
</Floor0>
```

Fig. 3. Floor's xml file describing map of the floor.

access and the limits of the ground floor map in order to establish its initial scale on the wheelchair computer screen. In this example the coordinates are given in centimeters. The file also defines the existing lifts and their connectivity (which floors can be reached with them).

- File type: **Floor.xml**

These files define the map of each floor including doors and position calibration marks (or landmarks) for paths to be made by the wheelchair.

If a building has *n* floors and *k* basements with possible locations to be visited by a wheelchair we have a total of $(n + k + 2)$ files with this structure. A file for each floor and basement, a file for the ground floor and a file for the building access map. Fig. 3 shows the main fields of the XML floor files.

In this Fig. 3, a first set of lines represents the scale vector map of the floor and may be defined by geometric figures like lines, rectangles, ellipses and polygons; floor's reference is always considered to be in the top left corner of picture.

Next lines encode doors in corridors and rooms of places to be visited in the building. Last lines of file represent positions and orientations of the calibration points (landmarks) of floor paths; these landmarks can define different behaviors that are coded in a type field; there are: landmarks of circulation, landmarks of access to the building and landmarks of floor's elevators.

- File type: **InfoFloor.xml**

For each XML floor file there is another XML file with the accessibility information of that floor. Fig. 4 shows the format of the fields of the accessibility information.

```xml
<?xml version="1.0" encoding="utf-8"?>
<InfoFloor0>
 <Sector Name="DEPARTAMENTO 1">
   <Local Name="XEROX">
     <Source Name="CIR07" Distance="3114">
       &lt;Segment Name="Landmark" NameLandmark="CIR07"/>
                      : : :
       &lt;Segment Name="Line" X1="8429" Y1="1816"
        X2="9270" Y2="1867" Angle="0"/>
     </Source>
     <Source Name="CIR06" Distance="3279">
       &lt;Segment Name="Landmark" NameLandmark="CIR06" />
                      : : :
       &lt;Segment Name="Line" X1="8413" Y1="1715" X2="9220"
        Y2="1732" Angle="0"/>
     </Source>
   </Local>
   <Local Name="SECRETARIA">
     <Source Name="CIR202" Distance="0">
       &lt;Segment Name="Door" NameDoor="DOOR1"
        NameCorridor="CORR1"/>
     </Source>
   </Local>
  </Sector>
  <Route Begin="CIR02" End="ENT01" Distance="2862">
    &lt;Segment Name="Line" X1="3084" Y1="6471"
     X2="3051" Y2="6943" Angle="0"/>
    &lt;Segment Name="Line" X1="3051" Y1="6943"
     X2="663" Y2="6893" Angle="0"/>
  </Route>
                      : : :
  <Route Begin="ENT01" End="ELEV2" Distance="3346">
    &lt;Segment Name="Line" X1="663" Y1="6893"
     X2="3101" Y2="6926" Angle="0"/>
    &lt;Segment Name="Line" X1="3101" Y1="6590"
     X2="3673" Y2="6573" Angle="0"/>
  </Route>
  <Corridor Name="CORR1" Begin="CORR1" End=""
   X1="5034" Y1="10993" X2="5017" Y2="12893" Angle="0"/>
</InfoFloor0>
```

Fig. 4. XML file structure of the floor accessibility information

This file defines all building sectors in the floor and the rooms or locals of each one of the sectors that could be visited. For each one of the defined locals there is one or more *sources* that are a close landmark that can have a path from it to those locals. For each *source* is defined a path connecting the landmark to the concerned place. In Fig. 4, a first set of lines, limited by `<Sector>` tag, shows the structure of definition of these rooms and paths in the XML file. The path from a landmark to a room can be defined as a sequence of straight lines or as a door associated with a corridor.

Then, lines delimited with `<Route>` tag show the fields of definition of the routes linking the landmarks with its neighbors. These routes are outlined following the best and free of obstacles path to a wheelchair. Its length should not be very long, allowing the path position control to be performed using the signals coming from the optical encoders of the wheelchair.

Final lines of Fig. 4 show an example of the corridor definition on a floor (`<Corridor>` tag). The corridor is defined by a landmark and a line segment or two landmarks and a line segment (an existing route) linking the two landmarks. With the definition of doors associated to these corridors, the path of a landmark until the door can be generated automatically by the intersection of two straight lines.

B. Wheelchair route planning

Fig. 5 shows a diagram of the accessibility information structure described in the defined XML

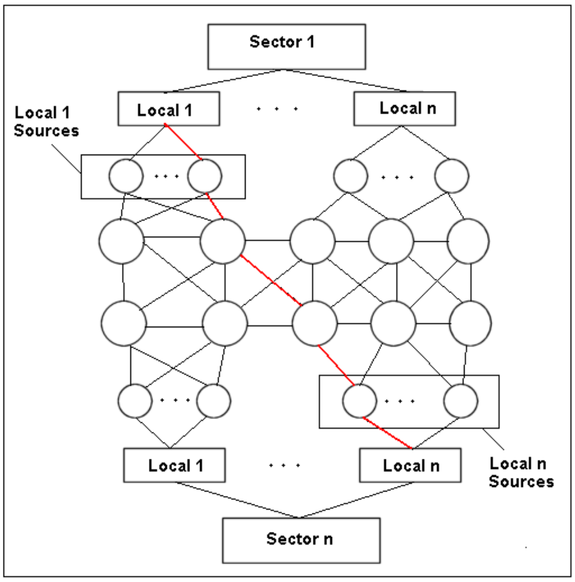

Fig. 5. Sector, locals and landmark tree for path planning.

files. Places of interest are stored as sectors. Each sector can have multiple locals and each local can be accessed by a number of sources, which are marks of navigation, represented by circles in Fig. 5. The lines connecting the circles represent the routes defined between landmarks and its neighbors. The lines connecting the sources to the locals are paths to reach the local from the source.

The algorithm to plan the best route to go to another location takes into account the lower length path, using a variation of Dijkstra's algorithm [9] from all the existing routes in the XML file. All possible routes, using all possible sources, are analyzed, and the shortest path is chosen as the optimal one. If the destination is on the same floor that the wheelchair is, the direct path is found. If the destination is on another floor, the route is split first to get to the closest elevator that goes to both floors and then out of the elevator to the destination on the other floor, reaching the desired location.

Once the route has been defined, control program commands the wheelchair to follow a set of straight and circular paths in each route section. Wheelchair relative position is determined integrating motor encoders pulses (Dead Reckoning) between calibration landmarks. When the wheelchair reaches a landmark, absolute position and orientation information can be retrieved from them [7] using a video camera pointing to the ceiling. This information is used to correct dead reckoning estimations.

Autonomous navigation can be overridden at any time by user actions (i.e. with the joystick) or by the detection of an obstacle in the path.

In case of a change in the existing routes, either by a placement of a fixed obstacle in the way, as a kiosk in a mall, or a defective elevator or automatic door, building administrators must edit the affected route and send this modification to the server in a new XML file containing the change.

III. RESULTS

This work is under development at the Electronics Department of the University of Alcalá (Spain) in the framework of EINTA research project (Smart Spaces in Assistive Technology) granted from CAPES (Brasil) and Ministerio de Educación (Spain).

A. Prototype of A2RP Wheelchair

It has been built a wheelchair prototype (Fig. 6) equipped with an intelligent distributed control architecture. It has got a set of nodes interconnected by a CAN bus (Control Area Network) formed by several LPC2194 ARM micro-controllers (NXP Semiconductors) and an embedded PC.

The computer has got a touch screen display and internet wireless connection. It also manages other devices like a cell phone, a GPS, a video camera to the calibration of wheelchair position and special HMI, like a head mouse using accelerometers.

ARM processors implements several functions in a modular concept: system behavior depends on number and nature of installed nodes. A minimum system needs only two nodes: a power control, in charge of both motors driving and control; and an intelligent input device with different programmable behaviors coming from a standard joystick to a blow sensor drive mode. Actual prototype has got a third node in charge of safety devices based on ultrasonic sensors and accelerometers.

In manual mode there are three ways to control the wheelchair:

- Standard joystick.
- Blowing drive, using a linear flow sensor device to control speed and direction of the wheelchair.
- A head mouse based on accelerometers that implements joystick like commands for speed and direction control with head movements.

In automatic modes, HMI devices can be used to make path corrections and other safety related issues.

Fig. 6. General view of the prototype of A2RP wheelchair.

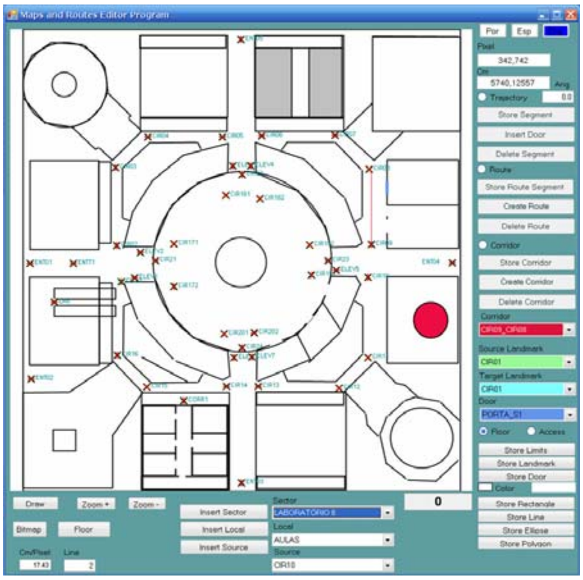

Fig. 7. Screenshot of the accessibility information XML editor.

B. System software components

Fig. 7 shows a screenshot of the developed accessibility information XML files editor. This tool allows the creation of vector maps for each of the building floors and the accessibility information (sectors, local, sources, routes and paths between locals and sources) for route and path planning.

Fig. 8 shows a picture of a georeferenced map of the Escuela Politécnica building of the University of Alcalá (UAH, Spain). This building was used as an example for the creation of XML maps in the editor and to make the geographic position of the ground floor and the building accesses, along with their entries accessible to a wheelchair.

Fig. 9 shows the screen of the navigation setup program onboard of the wheelchair. In the case shown in this figure, user has selected the

Fig. 8. Edition of building geographic position information.

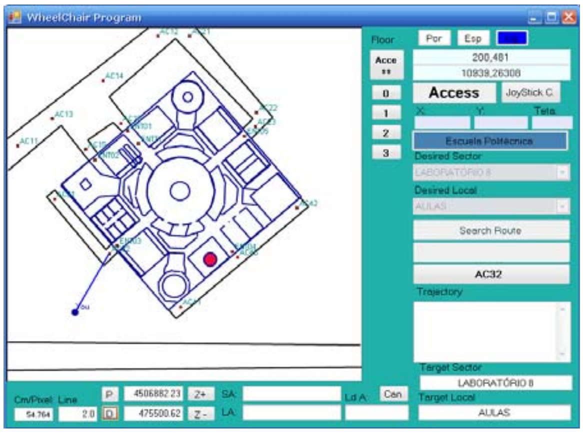

Fig. 9. User position from the closest access entry to the building.

Polytechnic School building. Once fetched the accessibility information from the XML files, it will be available the geographic positioning screen of the building ground floor, along with the current position of the wheelchair and the nearest building access. The desired location can be chosen by touching the screen or by using the head mouse. Next, computer generates the path planning.

Fig. 10 shows an example path from the nearest entry (number 03) to the desired location, passing through each one of the existing landmarks for calibration.

In this screen of control program user can navigate in several ways: selecting the desired sector and location in the combo boxes; using the touch screen; or with other HMI devices, like the head mouse. If user can identify desired locations directly on the map he can select it directly by pointing the desired destination. This screen also allows the change of the building floor to perform the navigation between places in different floors.

Wheelchair control program executes planned routes to marked destination using line segments and landmarks checkpoints.

User can change scale of graphics to see small details of it. Fig. 11 shows a zoom screen of an actual run of the example shown in Fig. 10. It has been added a detail of an interesting section of this run in order to improve its visibility. Planned route is

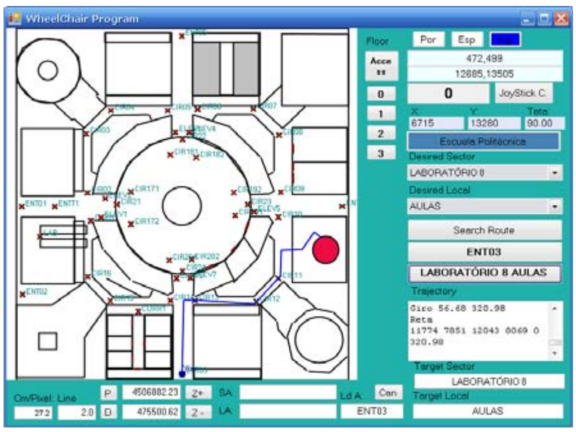

Fig. 10. Path generated from entry 03 to the desired location.

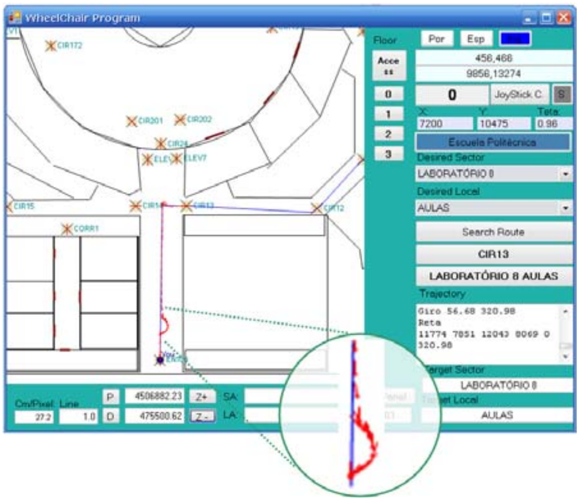

Fig. 11. User zoom screen and a detail of an actual run: planned route (shown in blue) and executed path (superimposed, in red).

drawn with straight segments (in blue). Actual path has been superimposed to planned one using red directional marks. Executed path is located between the first landmark and the following one.

In automatic mode the HMI (in this prototype, the joystick and/or the head mouse) may be used to make minor corrections of the trajectory, control its speed or to temporary set a manual mode control to avoid obstacles. An example of this behavior is illustrated in the deviation shown in the beginning of the executed path (detailed view in circular area at the bottom of Fig. 11) to the right side of the planned one.

Currently the project is in the final stage of integrating the video camera and the ceiling landmarks to make the automatic position correction of the wheelchair.

IV. Conclusions

This paper has proposed an Ambient Assisted Route Planner (A2RP), as part of a wheelchair indoor navigation system based on XML files that store building accessibility information. These files are retrieved from an internet server specifically created for this purpose. It was also presented an editor of the XML files and the navigation setup program onboard the wheelchair to follow the desired routes.

Unlike other works the proposed system does not need a structure of high cost equipments in the building. Only the placement of calibration marks on the ceiling on special points is enough to allow the indoor navigation of the wheelchair.

Equipments needed for the autonomous navigation with this system are not complex and most of them are already available in the wheelchair with an external navigation system, such as GPS and cell phone for internet access.

It's important to note that in the proposed system wheelchair user always has the control of his vehicle, even in automatic mode. Minor corrections can be done by pulling the joystick to control the speed; strong actions on the same device force a temporary exit from the automatic mode for safety reasons, to avoid obstacles or persons in the path.

The blowing sensor and the head mouse make possible the full use of the system even to persons with severe mobility restrictions, so they can have only the ability to blow or move their heads.

The proposed system can also be used by other kind of users, as the accessibility information may also be presented on the screen of a hand computer and provide the best route to a traditional wheelchair user or pedestrian.

Acknowledgments

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References

[1] D. Ding, B. Parmanto, H.A. Karimi, D. Roongpiboonsopit, G. Pramana, T. Conahan, and P. Kasemsuppakorn, "Design Considerations for a Personalized Wheelchair Navigation System," *Engineering in Medicine and Biology Society, EMBS 2007, 29th Annual International Conference of the IEEE,* pp. 4790 – 4793.

[2] M. Kurihara, H. Nonaka, and T. Yoshikawa, "Use of highly accurate GPS in network-based barrier-free street map creation system," *IEEE International Conference on Systems, Man and Cybernetics*, Vol. 2, pp.1169 – 1173. 2004.

[3] O. Matsumoto, K. Komoriya, T. Hatase, H. Nishimura, H. Tsutomu and N. Hideki, "Autonomous Traveling Control of the TAO Intelligent Wheelchair," *IEEE/RSJ International Conference on Intelligent Robots and Systems*, pp. 4322 – 4327. 2006.

[4] W. Yi-Hui, L. Bing-Yuh, C. Heng-Yin, O. Yao, L. Jin-shin, K. Te-Son and C. Fok-Ching, "The Development of M3S-Based GPS Navchair and Tele-Monitor System," *IEEE-EMBS 2005, 27th Annual International Conference of the Engineering in Medicine and Biology Society*, pp. 4052 – 4055. 2005.

[5] J. C. Garcia, M. Marrón, M. Mazo, and J. Ureña, "Positioning and localization system for autonomous wheelchairs," *IECON'02 IEEE 2002 28th Annual Conference of the Industrial Electronics Society*, Vol. 2, pp. 1555 – 1560. 2002.

[6] P. Jae-Han, B. Seung-Ho, and B. Moon-Hong, "An Intelligent Navigation Method for Services Robots in the Smart Environment," *International Conference on Control, Automation and Systems*, Seoul, pp.494-497. 2007.

[7] M. Marrón, and J. C. Garcia, "Sistema de navegación autónoma en entornos interiores estructurados," *TELEC`02 International Conference*, pp.1-4. 2002.

[8] H. Chuan-heng, L. Ming-long, S. Yuan-Chung and L. Feipei, "A design of small-area automatic wheelchair," *IEEE International Conference on Networking, Sensing and Control*, Vol. 2, pp. 1341 – 1345. 2004.

[9] E. W. Dijkstra, "A note on two problems in conexion with graphs," *Numerische Mathematik*, pp.269-271. 1959