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A Wireless Indoor Navigation Aid for Visually Impaired People using UWB Localization Infrastructure and an Original Wayfinding Algorithm

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Abstract. This is the description of a work in progress for the development of a wireless indoor wayfinding system to aid visual impaired people navigating unknown environment with fixed and moving obstacles. Based on a commercial, state of the art Ultra Wideband (UWB) time of flight localization infrastructure, the system can find the best way for connecting a starting and a destination point in an indoor scenario while giving to the vision impaired people the hints to move on the surface avoiding obstacles. A typical example application of the system is for aiding visual impaired people navigate an unknown train station guiding him from descending the train to the bus stop (or taxi stop, or toilettes, or bar, or ticket counter, or other connecting trains, or the like).

The present paper addresses the problem of identifying free paths to navigate into an area full of obstacles. This is the typical situation encountered in robotic guidance or blind people navigation assistance in complex indoor environments. Taking apart the problems of localization and tracking, here we are only concerned about the identification of the optimal path to be followed, given a preexistent binary map of obstacles, to connect the start and destination points in a given area.

Notwithstanding the various algorithms proposed so far, there is still a need for a very fast, robust, scalable and precise technique to be used in real time for the purpose.

The implementation described in the following is made of a series of steps for obtaining the exact path from the preliminary knowledge of the obstacles (recorded as a simple binary map of the floor, clear, walkable, area) and the two positions of start and destination. The binary image of the floor is preliminarily treated with a thinning algorithm for obtaining all the possible paths on the area. The chosen thinning algorithm is the Safe-Point Thinning Algorithm (SPTA), which was custom modified for imposing passing by the start and destination points. Afterwards, the resulting path binary map is heuristically treated for identifying the nodes and connecting arcs and eliminating all the dead-ending branches while saving only the start and destination branches. The resulting graph is then used to feed the Dijkstra algorithm for finding the shortest path between the start and destination nodes.

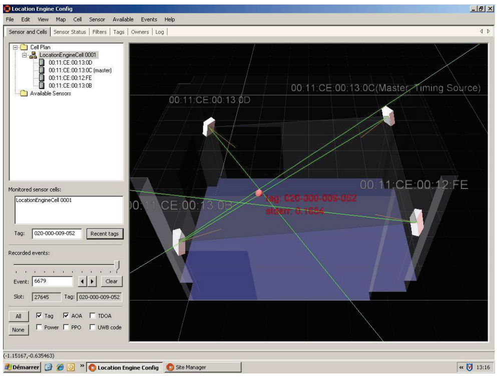

Figure 1. Sensors scenario and schematics of triangulation.

The result is the optimized path to follow for connecting two places in an unfamiliar environment.

In the absence of standard environments able to objectively test the different algorithms, we tested our algorithm with various simulated situations of growing complexity to explore the performances in various cases. The algorithm was implemented in Visual BASIC and proved fast enough for real time use provided the entity to assist in navigation has a normal human speed of movement.

We plan to use this algorithm in the implementation of a commercial navigation assistance system for blind people where localization and tracking will be provided by an UWB real time location system.

Keywords. UWB localization, indoor wayfinding, visual impaired, safe-point thinning algorithm; path planning; indoor navigation; Dijkstra algorithm

1. Brief presentation of the wayfinding algorithm

For robot guidance or blind people navigation in indoor spaces, the main

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problem is, of course, that of finding the optimal path to go from a starting point A to a destination point B, without colliding with any obstacle in between. Thus, the paths have to belong to a "walkable", clear, surface. For such a purpose, the environment's surface has been represented by a binary matrix, where each pixel can only assume two values, one or zero, keeping the information of "walkability" for that pixel. In the first example we used a reference dimension of the pixel as 5cm x 5cm which is one fourth of the space resolution of the UWB localization infrastructure used.

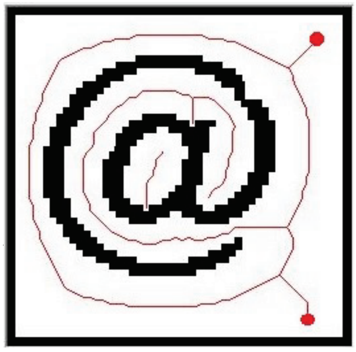

Figure 2. For testing the algorithm, a "test image" has been used. In the image map above, it is supposed that the black pixels are walls on a surface area. Thin lines are the skeleton of the surface, e.g. all the possible paths in the area. Red points are two possible start and ending points of the path to run.

A skeletonizing algorithm seems to be the most suitable way to find secure path. Skeletonizing algorithm's aim is to find out the connected pixels, which are at the maximum possible distance from the obstacles and consequently the most secure path to follow. The principle of our approach is that the skeleton of the binary map of the walkable surface is the sum of all possible trajectories so that, having identified a binary map as the data structure for recording the walkable area of a given surface, we considered a skeletonizing algorithm as the base for finding free paths on the same surface. The map-building skeletonizing is the first critical step in our algorithm. Many algorithms have been proposed to obtain the skeleton extraction from a digital binary picture[1-3].

Figure 3. UBISENSE system employed for tracking and guidance of blind people.

In this paper, an improved method for constructing a topological map is proposed. A local grid map using sensor data is first constructed. From this map, a local topological map is then built using Safe Point Thinning Algorithm (SPTA)[4] further modified to add to the skeleton the paths to the points of interest. Moreover, using SPTA, the skeleton obtained is a single pixel thick line, thus making easy to find the skeleton's nodes. Finally, an algorithm for path finding is applied to the map. Dijkstra algorithm for path finding has been chosen to connect the two points of interest on the arcs identified on the skeleton. For this algorithm's application, it is necessary to define nodes and arcs in the skeleton, and remove the dead-end branches. After such modifications, when Dijkstra algorithm will be applied to the skeleton, the shortest path will be easily found.

Another issue stays lies in the fact that the skeleton may well have "dead-end" paths or not connected arcs (*cul de sac* or blind alley). Such paths could lead the algorithm to fail in the path research. Thus, these regions must be preliminarily deleted from the skeleton map.

2. Results in a prototype implementation

Ultra Wideband (UWB) technology is suitable for realizing powerful and robust 2D and 3D real-time location systems. These systems can deliver very high positional accuracy in traditionally challenging environments at reliability levels unachievable by legacy technologies such as conventional RFID or Wi-Fi. At the Biomedical Laboratory of HEIG-VD, the "UBISENSE 7000 system" has been installed and used for real time tracking which provides a maximum resolution of 0.15 to 0.20 meters. The UBISENSE system is suitable for many applications in the field of home automation for handicapped people but also for sport performance analysis.

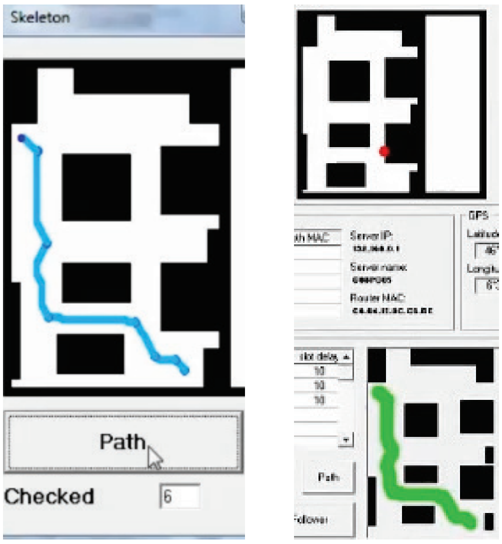

Figure 4. Prototype implementation of the wayfinding algorithm. The map is representing the laboratory with tables and cupboards on the walls. Blue line is automatically generated path from the door to the workshop table. Green line is the way to be run by the visually impaired subject. Red point is the current position of the subject.

In practice the system is composed by two servers and a series of remote devices (embedding UWB tags) worn or carried by the blind persons navigating the area. Further UWB tags can be positioned on mobile (e.g. chairs) or semi-mobile (e.g. doors) objects. The first server is the commercial UBISENSE localization server using four anchors (antennas) with which the exact position of each remote device is detected in real time. This server broadcasts the position of each person to the custom navigation server which has the responsibility of helping person to navigate the area along personalized paths.

Initially the blind people asks the navigation server for the path to the desired destination (out of a series of predefined destinations from the random starting position where the person is presently). The navigation server computes the path using the algorithms explained before (skeletonizing, path finding using Dijkstra algorithm) and sends appropriate information to the remote device for communicating the blind person the right path by comparing in real time the position of the person with the precomputed optimal path (beep or vibrations in the remote devices are coding commands for the blind people to start, stop, turn right, turn left, etc.). Any number of persons can be assisted in the navigation much like an airport control tower assists flying aircrafts.

The algorithm proposed here can also be used as a more generic destination management system for accessing large and complex buildings by anybody using a location based service approach.

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