Augmented reality based indoor positioning navigation tool

Article · September 2011

DOI: 10.1109/ICOS.2011.6079276

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Abstract— **Indoor positioning has gained popularity recently due to its potential to be used in the increasing complexity of indoor environment. Unfortunately GPS signals are restricted to outdoor purposes. The main objective of this work is to design a new method to develop indoor positioning navigation system without using wireless technology through image processing. Apart from that, the work also aims to develop an interactive indoor navigation system. Augmented reality is being used to superimpose the directional signage on the real view of the indoor environment in 3D form. Along with the 3D guides, voice guidance will be output from the system to assist users in identifying their locations easily. Overall, the scope of study involves research on augmented reality, audio API, and other additional techniques that can improve the program in computing the route. The idea of this work can be broadly applied to mobile devices such as mobile phones and PDA as an added indoor navigation functionality without the use of GPS and wireless communication. The proposed system has been tested at the ground floor of the Information Resource Centre (IRC) in Universiti Teknologi PETRONAS and the results show the flexibility of the system in navigating 12 locations and ability to handle up to 30 possible routes.**

Keywords- augmented reality, video, positioning

I. INTRODUCTION

Experiments have revealed that Global Positioning System (GPS) is not suitable for enclosed areas due to the satellite signals being attenuated higher than 1dB per meter of structure [1]. Currently the solutions to achieve indoor positioning are through wireless technologies such as GSM, WLAN, Bluetooth, Infrared, and RFID. However comparison among the positioning technologies [2] does not show the most feasible solution as is shown in Table 1. Indoor positioning based on wireless technology is highly dependent on the availability of the connection in the building. Most of the common navigation guidance in indoor environment still rely on the non-interactive signage and floor plan or map around the building.

TABLE 1: Comparison among heterogeneous positioning technologies [2]

	GPS	GSM	WLAN	Bluetooth	Infrared	RFID
Range	Wide area	Wide area	Micro area	Micro area	Pico area	Pico area
Accuracy	No signal	Low	Low	Low	High	High
Signal Error Rate	No signal	Low	Mid	Low	Lowest	Lowest

Augmented Reality (AR) is used to superimpose computer-generated graphics on the real view of the user to create the effect of mixture of virtual and reality. AR technology has been invented since 1950s' and for the last few years it has been explored rapidly in more domestic fields such as gaming fields and personal research projects from previous industrial application e.g. medical visualization, industrial manufacturing, military aircraft navigation and others [3]. The motivation force behind the technology is the enhancement of the visual effect that could assist users in presuming certain object more easily. Therefore the interactive 3D image being superimposed on the real scene may improve the efficiency in training based application such as assisting doctors in surgery demonstration, robotic design and others.

The basic working of the ARtoolkit (open source augmented reality software) is to display a virtual object (VRML model) on the detected marker. ARtoolkit has been used in this work to display directional information in 3D format to deepen user's perception in recognizing the route for the destination.

II. LITERATURE REVIEW

A. ARtoolkit

ARtoolkit is an open source software library for developer to develop AR applications. ARtoolkit was formerly developed by Dr. Hirokazu Kato and supported by Human Interface Technology Laboratory (HIT Lab) at the University of Washington, HIT Lab NZ at the University of Canterbury, New Zealand [4], and ARToolworks, Inc, Seattle. In general ARtoolkit is used to overlay a predesigned 3D object on the detected marker.

The great part of ARtoolkit is that it is able to precisely real-time track the view point of the user by using computer vision techniques to calculate the camera position and orientation relative to the marker orientation so that the virtual object that rendered on top of the marker appears always aligned with the marker. The rendering from ARtoolkit provides smooth animation of 3D object. First a frame from the video stream is grabbed from the web cam. The image will be converted into binary image (black and white) based on the threshold value which is the technique of binarization and thresholding [7-8]. Next the program will look for square regions by using image labeling technique where those connected components and the size which is almost to accommodate a fiduciary marker will be extracted. After that, the outlines of the contours that can fit four line segments will be recognized as square regions. The corner will then be detected from the mentioned contour. The square region can be in any orientations therefore it must be normalized to the initial orientation when the marker is trained. The pattern inside the normalized square region will then be compared with the pre-trained markers which have been stored as binary data. If there is a match, the confidence value, which is the percentage of matching, will be computed.

When there is a marker detected, the position and orientation of the marker relative to the camera will be computed. After the view point is computed, OpenGL API will be used to overlay the VRML model on the marker based on the computed view point (camera's coordinates). As a result, the virtual object will appear exactly aligned with the marker and the same process is repeated for real time processing.

B. Analysis of ARtoolkit's Accuracy

The performance of ARtoolkit plays an important role in determining the performance of the entire indoor positioning system as the 3D arrows and all navigation guides are dependent on the detection input from ARtoolkit. The subsequence modules in the program are more stable than the detection module of ARtoolkit.

The performance of ARtoolkit can be evaluated from its ability of detecting a marker and the tracking accuracy upon the detection of marker. Confidence value that represents the matching percentage of the detected marker with the pre-trained marker will be calculated by ARtoolkit once it detects a marker.

The accuracy of ARtoolkit to detect a marker is highly dependent on the lighting condition from where it detects the marker. If the lighting condition is similar to the lighting condition where the marker is trained then the threshold value is appropriate for easy detection of the marker. Nevertheless, the threshold value is adjustable to suit different lighting condition in the indoor environment.

On the other hand, the tracking accuracy of the ARtoolkit upon the detection is shown in Figure 1. The experiment [9] is carried out with the conditions that a 55mmx55mm marker is being fixed at x- and z-directions while changing y-direction (20cm to 100cm) from the camera. The camera used is a web cam with resolution 640 x 490 pixels and frame rate of 15 is used as the configuration of this project.

The result shows that the systematic error of ARtoolkit to continuously track a marker is low for the estimated distance from 20cm up to 70cm from the camera to the marker. This is considered acceptable as the expected working range from the marker to the user will be fixed within the mentioned range.

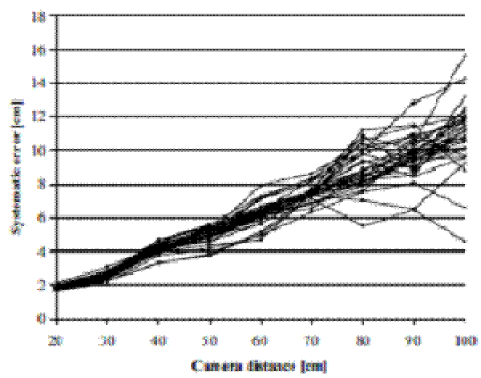

Figure 1: Plot of systematic error of ARtoolkit at different camera distance [9]

C. OpenAL

OpenAL [5] is a 3D audio API that is used to handle audio in cross-plattform application. It enables the developer to set the position and velocity of the source and listener to achieve the 3D audio effect. The OpenAL algorithm has been used in the audio module (Figure 2) to play the WAV files that correspond to the detected location. OpenAL SDK for windows has to be installed before it is applied in the program.

III. METHODOLOGY

A complete set of hardware and software needed for this project includes a computing device (e.g. laptop which also acts as the displaying device) with ARtoolkit software installed and a USB web cam installed to face the front view. The overview of the work can be seen in Figure 2 that consists of several blocks of module, each dedicated with certain functionality to form an indoor positioning system. The web cam would continuously be capturing the live view frames and send to the computing device. The marker recognition module in ARtoolkit will process the frame and recognize it if there is at least one trained marker (pattern). If no marker is detected then the displaying devices (laptop) will only shows live image captured from web cam. However if marker is detected, the identified marker ID will be input to the route planner module then the module will compute the route connecting the current location (based on current detected marker) and the desired destination (based on the location input by the user at the beginning of the program). Once the route is identified the information will be passed to rendering module from the ARtoolkit to render the corresponding 3D virtual image on the detected marker. The audio module will output the voice guidance that corresponds to the route.

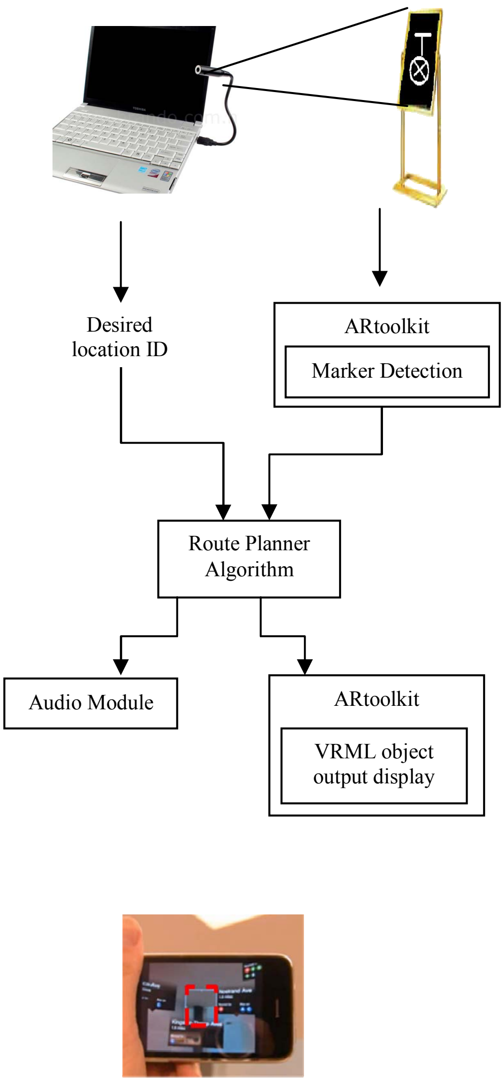

Figure 2: Project Overview Working Flow

A. ARtoolkit: Camera Initialization

First a connected camera is being detected for camera setup. The parameters of the camera are loaded from the camera parameter file that is obtained from camera calibration process. Figure 3 shows the window prompt that asks the user to confirm several common setting of the camera. The output size determines the size of the output console window.

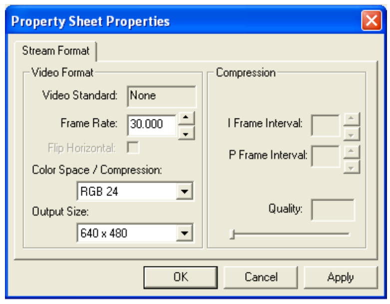

Figure 3: Camera parameter setting window

B. ARtoolkit: Load all the markers

The markers [6] have to follow certain criterias such as being black and white, rectangular and its dimensions must follow those shown in Figure 4 to be recognized. Trained markers are kept in the database as binary data and they must be listed out in object_data_vrml file located in data directory. The program continues by loading marker pattern file to load those markers and their assigned VRML models (virtual objects) once for validation purpose. The program will be halted if any error is found in identifying marker or locating the VRML model.

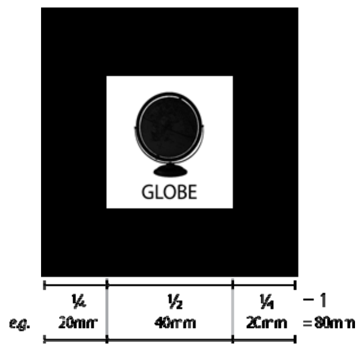

Figure 4: Marker dimensions [6]

C. ARtoolkit: Frame acquisition

OpenGL will be initialized at this section to load a window from GLUT. ARtoolkit video capture will interact with the windows graphic display API. After a frame is grabbed from the camera it will be output at the window loaded. A timer is set to keep track of the frame rates that are determined by the user at the initialization stage.

D. ARtoolkit: Real-time tracking

ARtoolkit will load multiple pattern files based on the saved list to detect if at least one marker is detected from the live view. The program can detect and handle more than one marker at a time. The result from the pattern recognition function is the number of the marker detected, the recognition confidence value and the VRML model ID to be displayed. If there is no marker detected the process proceeds to grab a new frame, otherwise it will go to the rendering process.

E. ARtoolkit: VRML model rendering

Before the OpenGL and GLUT libraries are used in the VRML model rendering, the camera transformation matrix which corresponds to the position and orientation of camera viewpoint is used as input to the 3D rendering module. As a result the virtual object would be drawn exactly to align with the orientation of the detected marker. The result is shown in Figure 5.

Figure 5: VRML model superimposed on marker

F. Route Planner Module

This module will receive the destination input by the user at the beginning of the program. The location will be converted into the location ID for ease of processing. When the user moves to the new location the web cam will continue to capture a new frame. Once a marker at that particular location is detected, the route planner module will compute the link between the current location and the destination. The route is based on the matrix which is pre-programmed. The matrix relates the route between the two locations. The route planner is based on simple pre-calculated paths. In order to automate the routing planning, future work may incorporate algorithms such as Djikstra's shortest path or Bellman-Ford.

G. Audio Module

OpenAL is the audio API used in the application to play the sound tracks. The number of sources used depends on the need of the application, for example the number of check points or depth of the information required. For this work, the number of sound track is the same as the number of navigation checkpoints. The audio module will render the WAV file once the route is defined by the route planner module.

IV. RESULTS AND DISCUSSION

For performance evaluation, the project had been tested at the ground floor in the Information Resource Center (IRC) of Universiti Teknologi PETRONAS.

For pre-processing phase, a floor plan of the targeted indoor environment was obtained as is shown in Figure 9 and a matrix connecting the route between the checkpoints in the map used as an input to the system can be seen in Table 2 and Table 3. The route planner module would look for the route from lookup table based on the detected location ID and the destination location input from the user.

Figure 6 shows the marker being placed at check point 3 in IRC. The user is equipped with a laptop and web cam. The web cam captures the live video of the condition in IRC when the user walks in IRC. The program is started when a user inputs a destination (Basement) at the initialization phase. Figure 7 shows the program recognizing the marker when the user reach checkpoint 3 and the route planner module computes the route from checkpoint 3 to basement. Figure 8 shows the updated map display with the route suggested by the route planner module.

Figure 6: Marker placed in IRC

Figure 7: Directional Guidance on Top of Marker

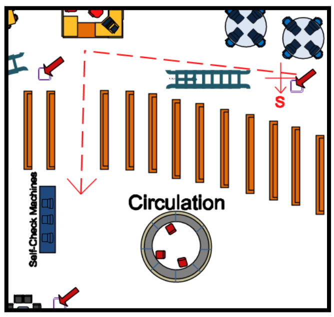

Figure 8: Updated Map with current route

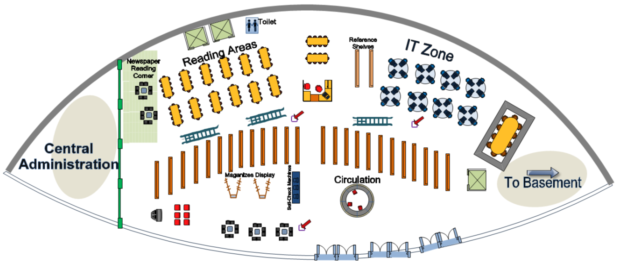

Figure 9: Floor Plan of IRC

TABLE 2 : Lookup Table

	Check Point 1	VRML ID	Check Point 2	VRML ID	Check Point 3	VRML ID
Entrance	0 (S)	5	1 (S)	9	3, 1 (S)	15
Circulation	0 (N)	0	1 (S)	9	3, 1 (S)	15
Magazine Display	1 (N)	1	1, 3 (S)	11	3, 1, 3 (S)	17
Self-check Machines	0 (N)	0	1, 3 (S)	11	3, 1(S)	15
Reading Areas	1, 2 (N)	2	2 (N)	7	2 (N)	13
Reference Shelves	1, 3 (N)	3	3 (N)	8	0 (N)	12
IT Zone	1, 3 (N)	3	3 (N)	8	0 (N)	12
To Basement	3 (N)	4	1, 2 (S)	10	3, 1, 2 (S)	16
Lift	3 (N)	4	1, 2 (S)	10	3, 1, 2 (S)	16
Newspaper Reading Corner	1, 2 (N)	2	2 (N)	7	2 (N)	13
Toilet	1 (N)	1	1 (N)	6	2 (N)	13
Discussion Rooms	1, 3 (N)	3	3 (N)	8	3 (N)	14

TABLE 3 : Indicator of Codes

Code	Indication
0	Exactly at that point
1	Go straight
2	Turn Left
3	Turn Right
N	Direction shown with respect to North indicated in the map
S	Direction shown with respect to South indicated in the map

V. CONCLUSION

The indoor positioning system based on augmented reality aims to deepen a user's perception in perceiving the information conveyed from the map and to ease the user in identifying the route that leads to the destination. The proposed system has been tested in IRC, and it has shown its flexibility in working as indoor positioning to navigate twelve locations which handles more than thirty possible routes. However, there is still room for improvement in terms of the system's flexibility in handling more complicated indoor layout before it can be applied as an alternative to the current indoor navigation solutions.

For future enhancement, more research may be focused on improving the intelligence of the route planner such as shortest-distance-route computation and alternative routes based on the criteria input from the user. For example, a user may prefer to choose routes that are concentrated with restaurants in the shopping mall. However, it is very dependent on the application. Therefore, the flexibility of the system is very important.

The concept of this work shows its potential for future development as it incorporates visual technology in designing the indoor positioning technology, which is also a rapidly growing technology.

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