Catching a Dynamic Object in Real Time
“An Application of Mobile Mapping in Real Time”

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Abstract

This paper reports the implementation of a project, which conducted tracking and catching a dynamic object based on mobile mapping principles in real time. The project has aimed to continuously observe a terrain and examine any activity in that area in order to find any unknown object. The project’s cores were emphasised on

- Recognising any objects in a defined terrain.
- Precise positioning and tracking of any object in the terrain.
- Defining the best route from a location to the object.
- Up to date the database and existing map.

To reach Project’s goals, a system was developed based on Real Time Photogrammetric aspects, GIS application, and a developed positioning system. A precise map of the terrain was compiled on PC along a GIS database of the terrain. Consequently, routes and a certain locations’ details and information were constructing the GIS database. The system consisted of two parts of hardware and software. Hardware includes CCD camera, Robot, Infrared Interface, and a PC, and software includes image processing, object detection, and command centre or communication centre, which were developed for this project. Indeed, the system is an ultimate mapping system, which is able to capture, processing, analysing, and compiling data in real time.

Background

Homainejad (1997) was explained a method of dynamic object tracking in real time, which its core was emphasized on Real Time Photogrammetric principles. The method particularly had attempted to define position of a number of points and objects in real time. Indeed, the above method was a Mobile Mapping Practice in real time.

What is Mobile Mapping? Mobile Mapping is the process of map production or updating, which whole or major part of the process is automatically fulfilled and completed along data acquisition. Indeed, Mobile Mapping was or still is the main initiative of all experts in this field. During mapping history, a huge number of tasks have been fulfilled in order to reduce the mapping process and in somehow they succeeded. Homainejad (1997) mentioned a few of such tasks, which attempted to reduce mapping process. With utilization of new techniques and technologies in mapping a new era has been launched, and mapping has eventually been changed from conventional method to automated ages! However, still Mobile Mapping is in its infantile ages, but in general, it has very significantly affected mapping procedures. It needs to develop new methods and avoid merging Mobile Mapping with the conventional method; indeed, it needs courageously to develop and adopt non-conventional methods.

This paper is a report of a project, which was implemented based on Homainejad (1997) method. Aspects of the project were to recognise and locate a dynamic object in a terrain and dispatch a robot to the object and finally capturing the object. A system was developed, included image capturing and acquisition, image processing and object detecting, dada analysing and tracking a dynamic object, positioning, analysing and make a decision, and despatching the order (Figure 1.) The system should be able to implement the above aspects in real time. Indeed, real time practice is the main core of this project and it influences on all developments and processing which were provided for this project.

Therefore, a new method was developed in order to avoid conventional processing and to deploy the whole of process during a real time frame. The method has to be simple, robust, trustable, accurate and precise. In order to meet the simplicity, it needs to avoid a number of processing, which routinely have been utilized by expert in this field such as camera calibration. In addition, a number of scientific rules interfere precise processing in real time such as depth of view. Camera calibration and self-calibration are an important process for a based-photogrammetric project due to reach high precise and robust results. In contrast, camera calibration, specially, self-calibration limits the process of the project and increase the time of processing. Consequently, calibration is an obstacle against real time aspect. In addition, depth of view limits to acquire data from high convergence images. Positioning and navigation are another obstacles, and usually mobile mapping systems have employed GPS and INS to improve positioning and navigation; however, these systems have own limitations and need to carry out some methods in order to reach a precise positioning. For example for reaching a high precise GPS acquisition, DGPS has to be employed. In addition, a least square method needs to apply for reducing errors, which were participating in INS and GPS data. There is a limitation of utilizing GPS inside of building; however, GPS/pseudolite integration method can be employed for open pit constrictions, or recently new GPS receivers is coming in the market with 20 meter indoor precision. Still there are a number of limitations of using positioning and navigation systems for indoor applications.

Hence, a new method of positioning and navigation has been developed and implemented due to reach the real time aspect in this project. The method has to be free of mentioned issues and improves navigation and precise positioning specially in indoor applications. Because the method is still under developing and there is a long way to completion, details cannot be revealed here.

Besides of developing new method for positioning and navigation, a map and GIS of the terrain were compiled and populated in the computer. The map and GIS simplified the image processing as will be explained at the next chapter, and GIS will help to define a best route between the object and the robot. Indeed, a map and GIS of terrain have had a fundamental role in this project and whole of image processing and object extracting rely to them. It is very essential to have a precise map because it affects the precision of whole processing. Next chapters will give an overview of the system and will present results of tests, which were implemented for this project.

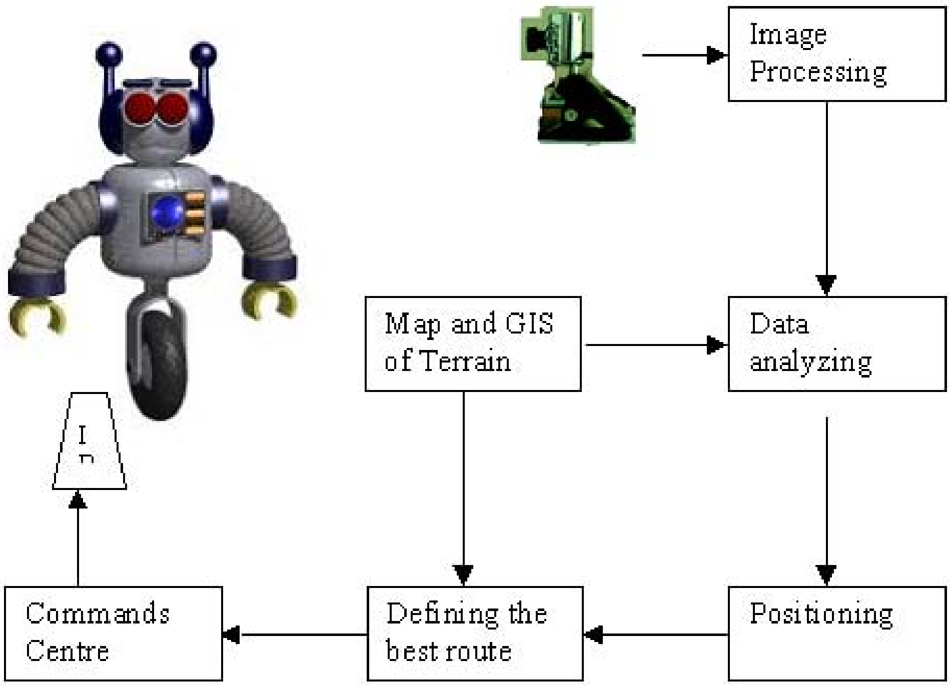

Figure 1. Profiles the whole system processing.

Overview

It needs to mention that this project has been fulfilled in an indoor laboratory; however, the outcomes of a number of tests prove that the system has potential to carry out in outdoor and real world practices. For implementation of the project a terrain has been selected. At the beginning and the first step a precise map and GIS of terrain were initially compiled in the memory to create a database, which the system routinely referred to it. The intensity of the precision and the attributes of objects had significant effect on results of the project. There were several reasons for compiling a precise map and GIS of the terrain in the computer. The reasons can be mentioned such as:

- Indeed, a map of terrain is a reference that spatially matches between captured scenes of the terrain and the terrain. The relationship is more robust if the map is more precise.
- Compiling a map excludes the inevitability of camera self-calibration or in another word; it excludes the necessity of camera calibration.
- Compiling a map from the terrain improves the precisions of images. Indeed, the map improves the precision of outcomes of the system.
- Compiling a map from the terrain gives an identity to images.
- A GIS of the terrain assists to define position of any objects on the terrain precisely and can provide the best route from a specific location to an object.

Camera (cameras) can be set up in a stable position or mounted on the robot. Cameras with stable position were utilized for keeping the terrain under surveillance. In contrast, the camera was mounted on the robot, was only utilized for navigation. In this project mostly cameras with stable positions were employed because it was decided to assess the applicability of utilization of map for assisting the image processing, especially, when images had a very oblique angle.

A system was designed and developed to implement the project aspects. The system includes of two parts of hardware and software. Hardware includes three parts of vision, PC with image grabber, and Robot. Vision and image grabber have had direct link to each other and to a PC, but Robot via an infrared device has a link with the rest of the system. Software was developed for this project includes video and image capturer and grabber, image processing, object detection, positioning the object, analysing and assessing data, and communicating centre. Figure 1 profiles the whole process of the system include both parts of hardware and software.

Vision system, which consists of CCD camera, Frame Grabber, and image processing is able to capture sequence images of multiple cameras semi-simultaneously and compile them in a temporary memory space, and able to process images and populates extracted data in a specific memory. Image processing and object extraction has been implemented according to the method, which was explained by Homainejad (1997) plus a modification. Modification relates to developing and utilizing of positioning system, and assistance of the map of the terrain in image processing.

A positioning system was developed for this project and is called Regional Positioning System (RPS) or Local Positioning System (LPS). As this positioning system is very new and still under developing; therefore, it is not possible to give details about this new system. However, it needs to mention that this positioning system assists the system to provide accurate positions of the robot and the object in the terrain.

The compiled map of the terrain supports the image processing to extract accurate data from sequence images. By assistance of the map, the image processing is able to extract data from, even, a very high convergence images without utilizing camera calibration. In addition, with the assistance the map there is no limitation for setting up cameras and it resolves mostly the effects of depth of view in images. Images can be captured in highly convergence positioning or can be captured in upside down positioning and there is no need for camera calibration. As long as images are matched with the map, the image processing can resolve any issues, which were produced by image distortion and camera.

Once data are extracted and the image processing system recognises an unknown object is in the terrain, the data will be replicated on the map. The reasons for replication are the system can adopt the best route from the location of the robot to the location of the object and updating the map and GIS database. It needs to add, that there is a communication between the robot and the system so that the system is always aware of the location of the robot. It is very important that the system has had knowledge about the location of the robot because the system can define and adopt the best route between the robot and the object. Consequently, the system updates its GIS database. In addition, the route will be defined based on the latest GIS of the terrain. The latest GIS of the terrain has had critical role in this system as it can give any information and details about the terrain. The information can assist the system to provide the best strategy for dispatching the robot towards the object.

Once the above processes were completed and the best route was adopted, the outcome will send to the centre of communication or the command centre. The command centre would select a proper command according to outcomes and delivered the command to the robot via an infrared interface. There were three methods for communications and delivering commands to the robot. One method is to deliver the whole of command to the robot at once. The time delay of communication for this method is very high; specially, when the command is very long. In the second method the command was split to parts and each part was delivered in a certain time, when the robot completed each part of assignment will send a message to the central of command whether it is ready for next assignment. The second method is more applicable than the first method is, but still this method includes time delay.

As real time application is the main core of this project and the system was developed based on this aspect; therefore, a third method was developed due to make a solution for any time delay, which affects to this aspect. If the brain of the robot has had a sufficient space of memory and with a high speed CPU, it is the best method that all commands were compiled on the robot. Consequently, when the system dispatches a command, Robot very quickly respond and follow the order. There is a delay of communication between the system and the robot. This delay always exists and this system is not exceptional. When an order dispatch to the robot there is an I/O delay; specially, the communication between the system and the robot is fulfilled via an infrared device. If commands are bigger, time delay is longer, in contrast if commands are shorter, the time delay is shorter. For reaching to the real time aspect there has to be no time delay for communication. It is very optimistic to say there is no any communication time delay; anyhow, there is a communication time delay in reality. The best way for resolving this issue is to split the commands and store all commands in the robot memory space. Then the system sends a number of codes to the robot and each code refers to a group of commands. Each group of commands imposes the robot to accomplish a defined act or a group of acts. Once the system recognises an object in the terrain, it will defines the position of the object by assisting the map and positioning system. Then, the system will refer to GIS for evaluating the best route from the robot to the object. Eventually, the system reaches to a decision and defines the best route, and the outcome will be sent to centre of communication. In this step, the system chooses a code according to the outcome and transfer to the robot via an infrared interface. Finally, the robot as soon as receives the code and recognises it, follows the order and moves towards the object. The vision system continuously examines the terrain and repositions the object. Once the object will be repositioned, all above process will be repeated and a new code according to new positions of the object and the robot in the terrain will be sent to the robot. Indeed the positions of the robot and the object are continuously updating in the database and the next processing will be fulfilled according to the new positions of the object and the robot.

This method can resolve the time delay of the communication significantly; however, there is still a time delay because of using the infrared transmitter. For minimising the time delay, there are a number of solutions, for example whole of the system is built in the robot and all parts of system has directly link to each other.

Deployment and Outcomes

A number of tests have been accomplished based on the above explanation. As explained, a GIS and a map of the terrain were compiled on the computer. All software of image capturing, image processing, object detection and extraction, and analysing were developed under VC++ especially for this project. Developed commands were stored in the robot's memory space. A CCD camera was set up in a location, which was able to acquire the whole of the terrain. It should be noted, that there is no limitation in the number CCD cameras. The system is able to capture up to 10 CCD cameras, and it is very easily to develop the system, which is able to capture more than 10 CCD cameras as much as necessary. It is possible to use a group of CCD cameras, which each camera can observe a part of the terrain. This method has a number of advantages and has broad applications. For example, if there is a demand for developing the system for a purpose of using in a massive area as large as an industrial area, a city even a country, it can be to utilize a number of CCD cameras along of another sensors to cover the area.

After setting up the CCD camera, the acquired image was replicated in the map. As it was mentioned earlier, there is no limitation for setting up the CCD camera. The CCD camera can be set up in very high convergence position, reverse position, or upright position. A number of tests have been accomplished while the CCD camera was set up in different positions, and results of tests were identical and very precise. Figures 2, 3, 4 illustrate three different images which were acquired from three different positions. Figure 2 demonstrates a high convergence image from the terrain. Figure 3 shows a high convergence and an upside-down image of the terrain, and Figure 4 illustrates an upright image of the terrain. Images of Figures 2, and 3 are very highly distortion images; especially, distortions are worst at the far end sides. The situation is more complex for the image of Figure 4, because the image was acquired while the camera had a high convergence as well as an upside down position. The image of Figure 4 has distortion from centre to sides; however, distortion in the centre of the image is minimum and insignificant. A caution has to be considered about depth of view of images; specially, depth of view for images were illustrated on Figures 2, and 3 are very significant at the far end sides, in compare with the CCD camera principal distance. Indeed, depth of view imposes a limitation in object extraction from convergence images. More details about depth of view can be found at Slama (1980). With compare three images of Figures 3, 4, and 5, it will be realised to extract a high precise data from those images are impossible if conventional methods are employed. In contrast, with utilizing a map and GIS from the terrain the depth of view has no any more effect on the processing. A vast number of tests have been carried out based on different positions of the CCD camera and results of all tests were identical and precise. When the system recognises an object on the terrain, a correct code was selected and sent to the robot via infrared transmitter. In all of tests the system recognised the correct position of the object and selected a correct code to send to the robot. It was very significant result and indicated that a map and a GIS of the terrain how improved the whole of processing. This system is very new and has high potential to develop in order to implement in real life. This system has uncountable applications and any of its applications can assist in any human life aspects.

Figure 2: A convergence images captured by the CCD camera. As it can see the image distortion is increasing from bottom of image to top of image.

Figure 3: A Convergence-Upside-Down image. As it shows the image distortion is increasing from top to bottom.

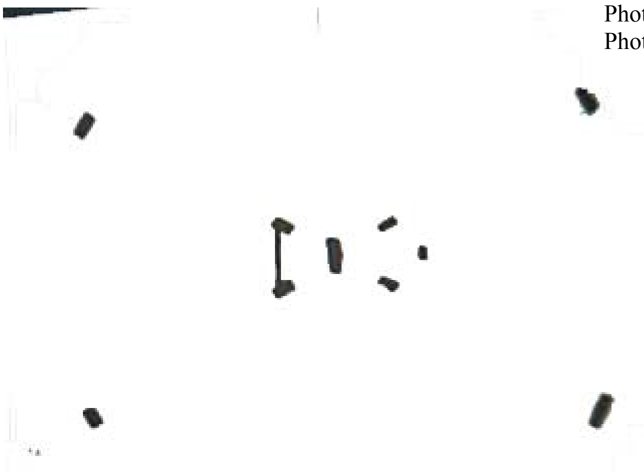

Figure 4: An upright image captured by CCD camera. As it shows the image has distortion from centre of image to sides.

Summery

A project based on application of mobile mapping in real time was implemented and a number of tests were carried out. The core of project was emphasised on real time photogrammetric, and a system based on was developed. The aspects of project were, to detect an object on a terrain from sequence images, to define the position of object, to choose the best route between the robot and the object, to dispatch the robot to the object, and to update the GIS database.
In order to reach above aspects, a map and GIS of terrain were compiled on the computer. The map and the GIS improve image processing and precision of object positioning, as well as reduce the inevitability of camera calibration. With compiling a map and a GIS of terrain, there is no requirement to employ camera calibration and apply a method for reducing depth of view. A number of tests have been fulfilled in order to examine the ability of the system under different situations. In each test, CCD camera was set up in a new position with a new tilt angle with the terrain. Indeed, each test had its individual characters, but results of all tests were similar. It is very significant results that the system accurately recognise the object, and dispatch the robot towards the object. A note should be considered that all images had been acquired from convergence positions. The system is very feasible and has capability to implement in real world where there has enormous applications.

Reference

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