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[POSTER] Road Maintenance MR System Using LRF and PDR

Ching-Tzun Chang* — National Institute of Advanced Industrial Science and Technology

Ryosuke Ichikari* — National Institute of Advanced Industrial Science and Technology

Koji Makita* — Canon, Inc.

Takashi Okuma* — National Institute of Advanced Industrial Science and Technology

Takeshi Kurata* — National Institute of Advanced Industrial Science and Technology

Abstract

We have been developing a mixed reality system to support road maintenance using overlaid visual aids. Such a system requires a positioning method that can provide sub-meter accuracy and function even if the appearance of the road surface changes significantly caused by many factors such as construction phase, time and weather. Therefore, we are developing a real-time worker positioning method that can be applied to these situation by integrating laser range finder (LRF) and pedestrian dead-reckoning (PDR) data. In the field, multiple workers move around the workspace. Therefore, it is necessary to determine corresponding pairs of PDR-based and LRF-based trajectories by identifying similar trajectories. In this study, we propose a method to calculate the similarity between trajectories and a procedure to integrate corresponding pairs of trajectories to acquire the position and movement direction of a worker.

Keywords: Mixed reality, geographic information systems.

Index Terms: [Human-centered computing]: Interaction paradigms - Mixed / augmented reality

1 Introduction

Maintenance services are important for public infrastructure such as roads, bridges, and tunnels. Activities related to maintenance are highly dependent on labor, and efficient connection innovations are expected to reduce the time required to perform the work and train new workers.

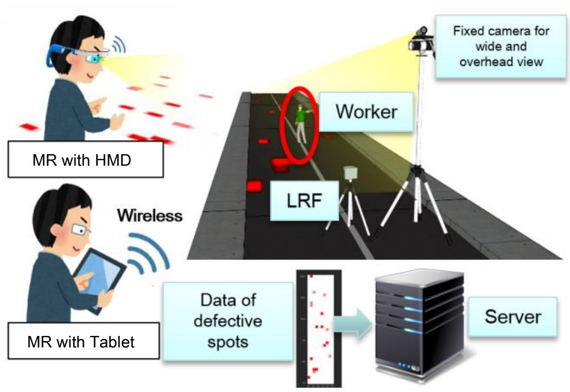


Figure 1: System overview

"Checking defective spots" and "road repair" are the main activities in road maintenance. Defective spots are usually recorded with maps and pictures of the road. Workers refer to these maps and pictures to find the locations of the defective spots. However, the search can take considerable time because the location environment is frequently changed by premaintenance activities such as the elimination of surface asphalt.

In a previous study, we reported the development of RoadMR, a prototype system that uses mixed reality (MR) to support road maintenance [1]. An overview of the RoadMR system applied to visualize defective spots is shown in Figure 1. Workers can check defective spots using a head-mounted display (HMD) and hand-held device.

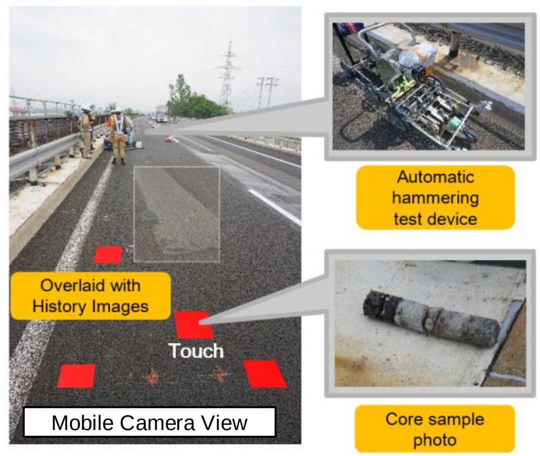
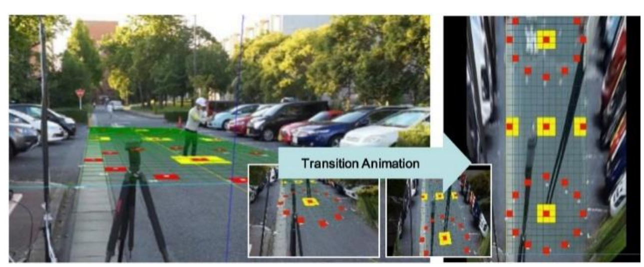


Figure 2: Related photos and information are displayed when user touches the visual indicators

Figure 2 shows a mobile camera view of RoadMR. Workers can interact with visual indicators of a defective spot and view history images and other information.

RoadMR provided three perspectives: egocentric, ego-impression, and exocentric, i.e., MR with mobile camera view (Figure 2), MR with fixed camera view (Figure 3A), and MR with pseudo overhead view (Figure 3B). Workers can choose an appropriate viewpoint to identify the position of defective spots. In addition, a transition animation is shown when a worker changes the viewpoint.



(A) Fixed Camera View (B) Overhead View

Figure 3: MR viewpoints

*keishun-chou@aist.go.jp, r.ichikari@aist.go.jp, makita.koji@canon.co.jp, takashi-okuma@aist.go.jp and t.kurata@aist.go.jp.

In several MR maintenance support systems, GPS is used to estimate the position of the user. However, GPS positioning errors can be greater than 10 m depending on the number and position of receiver satellites. In addition, GPS does not function in occluded environments such as areas under bridges and in tunnels.

Vision-based tracking has been used to obtain user positions. Vision-based positioning errors are centric meter. However, vision-based camera tracking is not effective for homogeneous textures (e.g., most road surfaces) and performs poorly when the appearance of recognition targets has changed. Road surfaces are completely different in each construction phase, and the appearance of a road surface will be affected by time and weather. These factors indicate that vision-based positioning is unsuitable for an MR road maintenance system.

To overcome the limitations of GPS and vision-based camera tracking in our first prototype system, a worker's current position is manually estimated by human–computer interaction. Camera parameters (i.e., position and orientation) are semi-automatically adjusted by built-in sensors (accelerometer, gyroscope, and geomagnetic sensor). Workers touch the grounding point of their feet in the displayed camera image to estimate their position each time they move.

In the next step, we used laser range finders (LRFs) to obtain the worker's position in real time. We designed a system to analyze scan data from an LRF sensor (Figure 4A) and calculate a worker's current position in real time (Figure 4B). LRF can detect a worker's position within 20 cm, which is an acceptable error range for use in a road maintenance MR system.

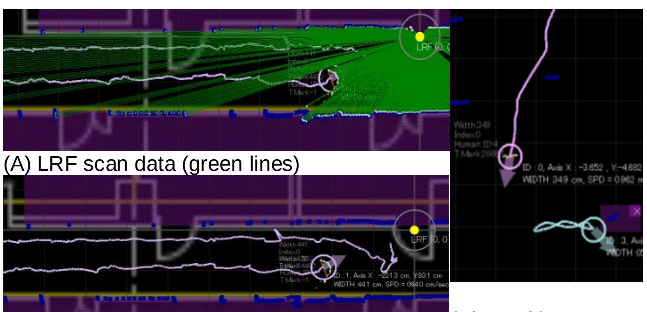


Figure 4: LRF scan data and analyzed trajectories

However, LRF cannot obtain a unique ID for tracked people. Therefore, the system does not recognize which worker is operating the RoadMR system if multiple people are moving in the detection area (Figure 4C). Many other positioning methods such as pedestrian dead reckoning (PDR) can specify a unique ID for all tracked candidates. However, the accuracy and error range of PDR-based trajectories are insufficient to display MR visual indicators in our proposed system. PDR errors depend on the distance walked after initialization. The error range in a road maintenance system should be less than 25 cm.

To overcome these problems, we propose a method to integrate an LRF-based trajectory and a PDR-based trajectory that incorporates their advantageous characteristics, i.e., low error and unique ID. Specifically, we implemented a method to calculate the similarity between the trajectories and then specify an ID to LRF trajectories from the paired PDR trajectory.

The objective is to obtain the worker's position in real time by integrating LRF and PDR. We designed and implemented a system to analyze scan data from LRF sensors and calculate the trajectories of tracked people. PDR is used to obtain a unique worker ID. Therefore, it is necessary to calculate the similarity between LRF-based and PDR-based trajectories to find corresponding pairs.

The proposed calculation method uses common feature values to verify the correspondence between multiple trajectories by a numerical indicator. We used relative feature values (e.g., speed and angular velocity) and absolute feature values (e.g., position and absolute angle) to compare trajectories (Figure 6). These feature values are selected considering the characteristics of LRF and PDR (Figure 5).

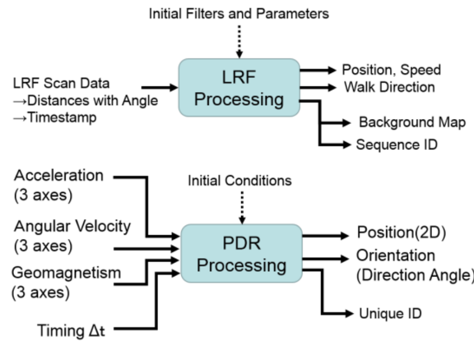


Figure 5: Characteristics of LRFs and PDR

One PDR trajectory is compared with one or multiple LRF trajectories (Figure 6). All LRF trajectories are compared with a PDR trajectory to obtain a similarity score. The LRF trajectory with the best similarity score is considered a paired trajectory of a PDR trajectory. A corresponding pair indicates that the two trajectories originated from the same worker.

Figure 6: Comparison of tracked trajectories

After determining a corresponded pair, our next goal was to integrate these two trajectories considering their characteristics. In this case, a unique ID of a tracked worker and their body orientation in a time series were determined by PDR, and the positions were determined by LRF.

2 Conclusion

We propose a method to calculate the similarity between trajectories that can determine the correspondence between multiple trajectories. We also propose a method to integrate a pair of corresponding trajectories.

To realize our final objective—developing a real-time positioning method for an MR road maintenance system—we plan to improve the accuracy of corresponding pair identification and integrate online trajectories.

References

[1] K. Makita et al, "A Fundamental Study of an Augmented Reality System for Road Maintenance Services", IDW '14, DES3/VHF5-5L, 2014.