# Accuracy Assessment of Mobile Mapping System

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## ABSTARCT

The needs of 3-D data have been increasing for various applications like visualization, 3-D modeling, planning and management as well as entertainment. Mobile mapping has become a quick and practical means for acquiring necessary 3-D data for above-mentioned applications. A mobile mapping system mainly consists of two main components, viz. data acquisition devices and positioning devices. The data acquisition devices consist of CCD cameras or/and laser scanners. The positioning devices consist of GPS, INS, Odometer (shaft encoder) and some other referencing devices. The overall accuracy of mobile mapping system depends on the accuracy of positioning devices and their integrated output. Though, GPS is the main input device for the position information, the signal is not available for the computation of position all the times in urban area. The GPS satellites are normally obstructed by high-rise buildings. Thus it is very important to understand the accuracy of such a system in different environments and means to solve such problems. We have developed a mobile mapping system called VLMS (Vehicle-borne Laser Mapping System), which consists of CCD Cameras, Laser scanners, GPS, INS and Odometer. In this paper, we will present and discuss the accuracy of this system with data acquired in different environments (open area, urban area, tunnel, express way etc) by analyzing the data with respect to other existing digital data.

## INTRODUCTION

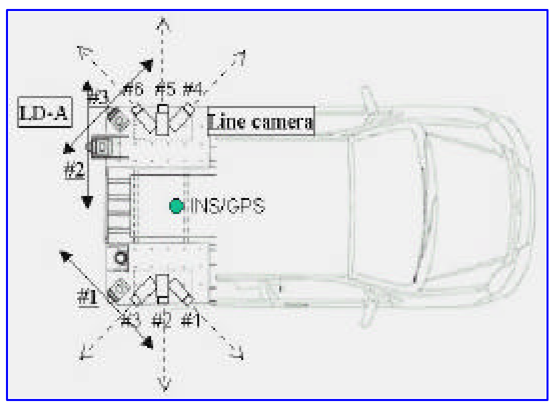


Figure 1: Mobile Mapping Vehicle (VLMS)

Mobile mapping is getting popular due to it's capability of fast data acquisition and acceptable level of accuracy. However, there are issues related with accuracy, continuous operation of the system, speed of operation and location area of operation. Since, a mobile mapping system is based on direct geo-referencing by using GPS and INS, the positioning accuracy becomes a key factor for the successful use of mobile mapping system. A perfect mobile mapping should be able to operate without interruption in urban area where there are dense and high-rise buildings, flyovers and tunnels etc. Frequent stoppage of the vehicle is not possible due to the traffic condition on the road. The system should not disturb other vehicles on the road. Besides, the system should be able to run or operate at various driving speed without general loss of positioning accuracy. In an urban area we encounter lots of obstacles (to GPS signal) like tunnels, bridges, high-rise buildings, flyovers etc. Thus the GPS signal is obstructed quite often and cycle slip is so common that a good accuracy cannot be achieved if the vehicle does not stop for initialization of the system. In order to overcome these problems we have implemented position devices, which is capable of conducting continuous data acquisition in different urban conditions. In this paper, we will present results obtained from the system in different urban area with their accuracy level and means to correct the errors. The accuracy analysis was done by comparing VLMS data with other existing digital maps. We compared VLMS data to multiple sources of digital data from different agencies. VLMS data have good precision since this is primarily based upon the precision of the laser scanners. The precision of laser scanner is 20cm (RMS).

## Hybrid Inertial Survey System (HISS)

The VLMS consists of positioning devices and scanning devices. The positioning devices are GPS, INS, Shaft Encoder (Odometer) and Laser Sensors. GPS is operated in real time differential mode. The differential data from the base station is received by using a mobile phone. The position computation is done using pseudo range estimation, not phase estimation. Shaft Encoder measures the vehicle' s movement (velocity). There are four laser sensors placed beneath the vehicle body. They measure the height from the road surface. If the road surface is perfectly flat and the vehicle is parallel to the road surface, then the distance from the road surface to all the four sensors will be the same. This distance will change when the vehicle accelerates or decelerates or brake is applied. However, this device could not be used successfully in rainy days due to the problem of wrong reflection of laser beams from wet road surface.

The positioning devices on the platform (VLMS) are integrated using Kalman filter. The integration was done by Asia Air Survey. This integrated system is called HISS (Hybrid Inertial Survey System). HISS offers different modes of operation. HISS needs to be initialized before the operation of the vehicle. The initialization must be done where good GPS signal is available. A good GPS signal means at least four satellites that have PDOP value better (less) than four. The initialization process takes about 30 minutes. This process provides initial reference position coordinates in three dimensions to INS and true north direction is also aligned.

## Data Acquisition Procedure

Data acquisition by the survey vehicle (VLMS) are done once the HISS system is initialized. There are two modes of data acquisition in terms of HISS operation modes. The first mode is to initialize the system with good GPS signal first and then use the GPS and INS mode for position and attitude determination. The GPS data are used as long as PDOP is better than four and at least four satellites are visible. If these conditions are not met, then HISS automatically switches to Odometer and INS mode. The system switch back to GPS and INS mode once good GPS signal (PDOP better than four and number of satellites more than four) is available. Thus there will be change of modes between GPS/INS and Odometer/INS depending upon the quality of GPS signal. However, with this mode of operation, we have observed sudden jumps (abrupt change) on position data, especially height component when the system switches from GPS to Odometer or vice-versa. These may be due to time lag (data latency), cycle slips, GPS receiver satellite acquisition time and other factors. Due to this problem, we prefer HISS system to operate in Odometer and INS mode after initialization with GPS and INS mode. This gave rather smooth output, we did not observe sudden jump in data. We have done all data acquisition with this mode of operation.

We have used HISS data to analyze the accuracy of VLMS with respect to the existing digital maps. In order to verify the accuracy of the HISS system, we have acquired HISS data (position and orientation) for one hour in static mode (vehicle not moving). This acquisition was done to see how the HISS data would be affected by the drift error of INS.

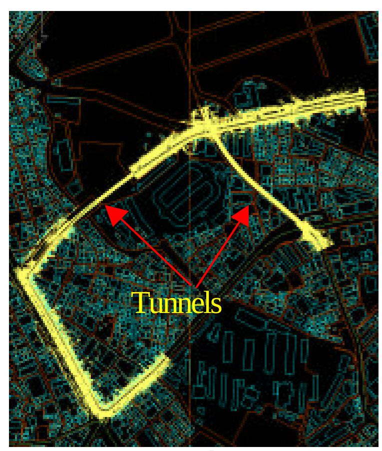
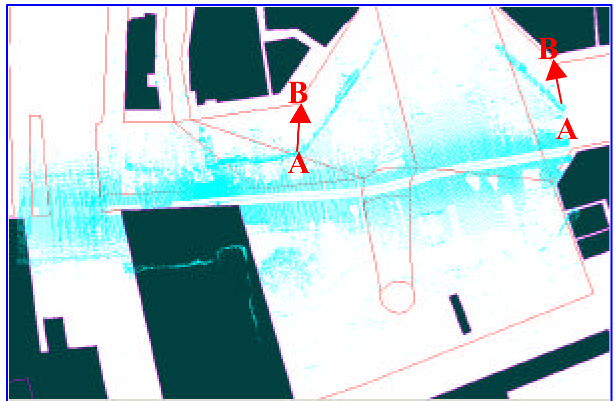


Figure 2: Overlay VLMS data on existing digital data

## Results and Discussions

Figure 2 shows overlay of VLMS data (laser points) over the existing digital map of scale 1:2500 in two dimensions. This data was acquired in a dense area of Tokyo that has tunnels and flyover bridges that obstruct the GPS signals significantly. HISS was initialized with GPS/INS mode and then operated with Odometer/INS mode. The figure and analysis of the data show close match with the existing digital map. We can see that there are no random errors or jumps, which generally happens with GPS data. However, the data have some systematic shift if we look at it closely as shown in figure 3. The laser points at corners A actually belong to corners at B. We have found similar shift in almost all the data. The vehicle was driven at different speed, which varied from normal driving speed in urban area (~30km/hr) to about 80km/hr. In order to correct this shift, we have used affine transformation by selecting the visible corners and other landmarks on the laser data and the reference data. The shift varies from a few meters to about 12 meters. Using this process we can at least correct the horizontal position with respect to the reference data. However, it is still difficult to correct the height data. In our data, we have not corrected the height data and taken the height data from HISS as correct one. There is a possibility to correct the height data using laser data by taking the most upper layer of scan that correspond to the building top edge or near edge. But, it is not guaranteed that the most upper layer of data comes from the building top edge. Sometimes, the laser scanner simply cannot scan the top portion of the building either due the to the range limitation of the scanner or direct fall of sunlight on the laser scanning head. Thus correction of height data is rather complex and still needs lot of work to be done.




The points **A** actually belong to points **B**

Figure 3: Discrepancy between VLMS data and existing digital map

Figure 4 shows the position data observation when the vehicle is kept stationary for one hour. The blue circle shows the data when Odometer data are used. The main function of the Odometer is to feed the Kalman filter that whether the platform is in motion or not. If the vehicle is not moving, the Odometer observed velocity will be near zero value. This indicates that the vehicle is not moving and hence the position of the vehicle must be the same at all times, till the vehicle moves again. Had there been absence of Odometer, HISS system would not have known whether the vehicle is moving or stand still. This is due to the fact that, GPS observation keeps on changing with respect to time, though it is stationary and INS has drift error. If odometer is used, then it sends information to Kalman filter and hence HISS knows whether the vehicle is moving or not. If there is no odometer, then the position computation from the HISS would be as shown by the red curve in figure 4. This data was acquired by VLMS without using the odometer for about one hour. It is clear from these experiments that, we should use the odometer data in HISS so that HISS can know the true vehicle static period and it does not update the position data when the vehicle is not moving.

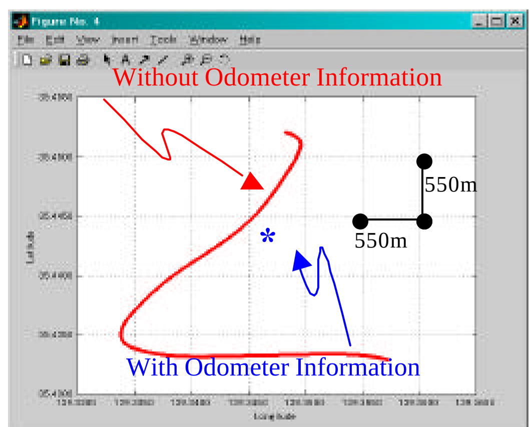



Figure 4: Effect of Odometer on HISS Data

## Conclusions

A mobile mapping system based on direct geo-referencing can produce acceptable accuracy level of a few meters in three dimensions even in urban area provided that the system consists of GPS, INS (medium grade) and Odometer. However, this system will still have systematic shifts. Thus, based upon the application of the acquired data, the position data of the system must be corrected using other external references. This scenario would be different had the survey been conducted in very open area without blockage of GPS signals and good GPS signal availability. Though we can correct the HISS position data with existing external references, it is still difficult to correct height data, as height reference is not available in most of the cases. The VLMS system has quite good relative accuracy (precision) since the data are acquired by laser scanner that has a precision of 20cm (RMS).

Please refer the web site at http://shiba.iis.u-tokyo.ac.jp/member/current/dinesh/research/research.htm for detailed analysis results, figures and power point files.