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POSSIBILITIES FOR SYNCHRONIZING EQUIPMENT USED IN CARTOGRAPHIC DATA COLLECTION

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Abstract: *Technologies for collecting cartographic data using mobile platforms equipped with various types of equipment involve the integration and synchronization of the equipment to ensure that the spatial positioning of the collected data is as precise as possible. This article aims to analyse the possibilities for synchronizing data from a mobile terrestrial laser scanning system with images from a classic digital camera integrated into the system.*

Keywords: GNSS/IMU integration, GNSS time synchronization

1. Analysis of synchronization possibilities

Integrated mobile systems for cartographic data collection usually consist of LiDAR sensors, digital cameras, inertial units, and GNSS equipment. In certain situations, it is necessary to capture digital images with specific characteristics that the already integrated digital cameras cannot fulfil, necessitating the addition of supplementary cameras. Integrating a camera requires connection interfaces to the existing equipment, and finding a solution quickly involves analysing the possibilities of synchronizing images from a classic digital camera with post-processed GNSS/INS and LiDAR data [1]. The study involved using a RIEGL VMX-250 mobile terrestrial laser scanning system to which a digital camera with an image capture rate of 5 images per second was added [2]. The camera was equipped with an IMU device with a 200 Hz frequency and the ability to connect via the NTRIP protocol [3]. Synchronizing the data involves finding the exact time each image was captured. Once the exact time an image was captured is determined, different methods, such as interpolation, can be used to determine the exact spatial position at the moment of capture.

A first approach involves using information on the time the images were taken and the distance travelled from the initialization/start point to determine the distance from the start at which the image was captured, using the linear interpolation method with the following formula:

$$D_{image\ 1} = \left[\frac{(\text{timagine } 1 - \text{t}1) \text{ x } (\text{Dt}2 - \text{Dt}1)}{\text{t}2 - \text{t}1}\right] + D_{t,}$$

where:

- $D_{image\ 1}$- distance at which first image is captured relative to the start point considered as a fixed reference point
- $t_{image\ 1}$- time at which first image was captured
- D_{t1}- distance at t_1 time
- D_{t2}- distance travelled at t_2 time
- t_1- time of the first distance measurement
- t_2- time of the second distance measurement

The linear interpolation method can also be used to determine three-dimensional coordinates (latitude, longitude, and altitude) [4].

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2. Synchronization methods

If it is possible to connect the camera to the existing equipment, synchronization can be achieved using the GNSS equipment's clock [2]. GNSS time-based synchronization involves the following system requirements:

- An external GNSS device capable of setting a data recording rate equal to or greater than the image capture rate. If such equipment is not available, the data recording rate can be increased at the software level through interpolation.
- An IMU device to determine tilt angle values.
- Each captured image can be tagged with the GPS time value recorded by the external GNSS equipment and, where applicable, the tilt angle values resulting from IMU data processing.

Example of synchronized data (GPS time converted to UTC time):

TIMP_UTC	Index_photo	Lat.	Lon.	altitude	distance	heading	pitch	roll
11:27:04 AM	0	44.41893203	26.14122483	105.1468	0	98.13418346	0.17341262	1.57027425
11:27:06 AM	1	44.41891530	26.14128837	105.0655	5.689034	98.09791243	1.06857191	1.35175664
11:27:11 AM	2	44.41889673	26.14136072	104.9490	11.81093	98.56634428	-0.23480297	1.08674738
11:27:13 AM	3	44.41887852	26.14143060	104.7744	17.65284	97.87556132	-0.29983359	1.00492835
11:27:15 AM	4	44.41886030	26.14150326	104.8346	23.70706	97.11280358	-1.03015444	1.01341909
11:27:17 AM	5	44.41884350	26.14157274	104.8099	29.56569	97.57359815	-0.61526019	0.86926516
11:27:19 AM	6	44.41882468	26.14164719	104.7851	35.91683	97.97254672	0.30892136	0.98868712
11:27:21 AM	7	44.41880742	26.14171426	104.7736	41.64665	97.99830639	0.45748789	1.00647901
11:27:23 AM	8	44.41878949	26.14178782	104.6622	47.81847	97.43010930	0.49390837	0.92254194
11:27:24 AM	9	44.41877011	26.14186207	104.5766	54.01335	98.62749901	0.05931530	0.96135580
11:27:25 AM	10	44.41875223	26.14192848	104.5459	59.58081	98.73207054	0.22181137	0.83946674

Correlation-based synchronization

This method is used when the camera cannot connect to an external GNSS device or the GNSS signal is obstructed. It requires:

- Precisely setting the internal clock of the device and synchronizing it with a stable external time measurement device.
- The IMU frequency of the integrated system must be higher than the maximum image capture rate (5 images/second). For the VMX-250 system, the IMU frequency is 200 Hz.
- The IMU of the integrated system is connected to the camera.
- The IMU axes of the integrated system and the camera are oriented in the same directions.

For precise results, image acquisition sessions with a device installed on a terrestrial mobile platform should be conducted under the following conditions:

- The camera is fixed and maintained in a position approximately parallel to the ground.
- The camera is oriented approximately in the direction of movement.
- The axis parallel to the ground presents the largest variation interval.
- The external and internal inertial devices move rigidly so that rotation rates do not depend on the vector between them.

Considering the conditions mentioned, synchronization is best achieved by correlating the rotation rates of the axes parallel to the ground. The actual synchronization calculation requires:

- Estimating the drift between the two clocks.
- Estimating the delay between the two clocks after correcting for drift.
- Interpolating data from the external sensor according to the correspondence between the two clocks.

Usual quartz clock deviations are around 100 ms/hour, or 1.67 ms/minute. If the interval between two consecutive frames is relatively short, the drift between the two clocks can be ignored. If the interval is longer, drift and delay estimation can be achieved by:

- Reducing the speed of the platform carrying the equipment, which reduces the distance and increases frame overlap.
- Detecting matching segments (segments where speed is constant).
- Estimating the delay for each segment.
- Performing a linear regression on the delays.
- Repeating the steps to improve accuracy.

Using the linear regression equation, values for drift and delay for any segment can be obtained. Once these parameters are estimated, linear interpolation can be performed directly using standard software programs.

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3. Precision estimation

In GNSS time-based synchronization, since the calculation uses the distance measured by the GNSS sensor, the main source of error is in finding the mobile platform's position at a given time. Using a high-performance GNSS system, position accuracy can be determined within 10-20 cm in real-time or 3-5 cm after post-processing. In this case, using time synchronization and interpolation, the final precision would be 11-22 cm for real-time measurements and 6-10 cm for post-processing [6].

The previously described correlation-based synchronization procedure involves various assumptions, the impact of which on overall accuracy must be evaluated on a case-by-case basis. The objective parameters that affect synchronization accuracy are:

- IMU Device Performance: For the equipment described earlier, the IMU frequency is 200 Hz; therefore, a correlation precision on the order of 5 milliseconds is expected.
- Motion Characteristics: Motion characteristics impact the correlation result. To achieve good results, at least one of the axes of the IMU devices in the integrated system and the camera should be oriented in the same direction (preferably one of the axes parallel to the ground) and maintain a constant speed over a certain segment of the path.
- Drift: If drift is significant relative to the segmentation used, the quality of delay estimation on each segment could be poor.

4. Conclusions

The synchronization of the equipment used for GIS data collection (GNSS, IMU, LiDAR, digital cameras) within an integrated platform requires a detailed analysis of the technical characteristics to determine if the equipment has common communication protocols that allow for data exchange between them. If there is no common communication protocol between the equipment, synchronization can sometimes be achieved at the software level, using algorithms and techniques to combine and correlate data from the various sources.

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