A GENERAL INS/GPS SYSTEM FOR REMOTE SENSING AND GEODESY

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ABSTRACT

Since 1999 the Institute of Geomatics has been involved in research and experimental advanced development in the area of integrated inertial/GPS kinematic positioning, attitude determination and gravity measurement. In this paper, a general description of the related hardware and software systems developed by the Institute is given. The systems deal with inertial/GPS data acquisition and processing. The paper discusses, as well, the current ongoing work on distributing geo-processing systems through the Internet. Considering the remarkable progress in the area of integrated systems for airborne Earth observation made in the last years by commercial integrators, the paper will not describe any particular technical details but the overall concept and the development policies behind the systems.

1 INTRODUCTION

The IG (Institute of Geomatics) is a public consortium between the Generalitat de Catalunya (The autonomous government of Catalonia, Spain) and the UPC (University of Technology of Catalonia) which started actual activities in 1999. The Institute, among other investigations, does research and advanced experimental development in the area of integrated inertial/GPS kinematic positioning, attitude determination and gravity measurement.

The inertial/GPS specific research areas range from testing, evaluating and integrating IMUs (Inertial Measurement Units) and GPS (Global Positioning System) receivers, to the development of algorithms and software, to the analysis of computing modes and paradigms, and to the devise of operational procedures for practical commercial applications. For those purposes it is essential that the IG have full access to open HW and SW systems which allow the rapid implementation and testing of new ideas. The set of the above systems constitutes IG's basic platform for conducting applied research.

The IG is currently building this open platform by combining own resources with those from research and development projects funded by companies and a number of public funding bodies. Since the IG is rather interested in the access to that basic platform than in holding actual IPRs (Intellectual Property Rights) of it, the above policy serves well the Institute needs.

2 ON SYSTEM REQUIREMENTS

The requirements of the experimental systems described in this paper are dictated by customers' needs. However, IG's customers are well aware of the research nature of the Institute and, therefore, in general, we receive reasonable requirements in that they are focused on algorithmic and performance issues once a clear interface (mainly through data and control files) has been agreed. The requirements are usually listed in User Requirements' Documents and translated into SW Specification Documents. Interface Control Documents are used many times, as well, to define the customer inpu/output specifications. Further to these documents and their associated elaboration processes there are the permanent underlying implicit requirements of generality, adaptability and portability as described in (Colomina et al., 1992) in a slightly different context. In the context of inertial/GPS trajectory determination, generality is the power or the potential of mastering a broad range of IMU and GPS receivers; adaptability is the power or the potential to incorporate new ones; and portability is the power to run on different platforms with minor or no changes.

2.1 Special research requirements

In the competitive world of research and development, research organizations will not enjoy the luxury of letting their researchers to develop for her/himselfs. It is too expensive. It takes too long. It is error prone. Moreover, results derived by fresh SW are questionable. On the other hand, large systems tend to be complex, rigid and sometimes slaved to a particular operating system and/or its tools. According to the authors' experience, the best solution to the seemingly conflicting requirements of research and operations is based on the integration of off-the-shelf components and of "home-made" components following a well defined corporate development policy.

In the next section we describe IG's policy for the inertial/GPS platform. We do not claim it is the best policy, but one which seems to work in our particular context.

3 SYSTEM DEVELOPMENT POLICY

Both for the real-time and post-processing modes and both for the pure SW and HW/SW systems, the development is based on the following guidelines:

- the use of the Object Oriented paradigm as described, for instance, in (Meyer.B., 1988) and (Dubois.P.F., 1997) and the use of the most appropriate programming language according to objective (external) factors and subjective (customer and IG internal context) like C++, Java, XML, etc.
- the use of the programme-by-contract paradigm and techniques, through input and output assertions (preconditions and postconditions) in order to describe the behaviour of class methods.
- the use of the LWF (Laboratory-Workshop-Factory) paradigm as described in (Navarro, 1999) and the ECI (Entity-Control-Interface) class classification for the development of class interfaces (Meyer.B., 1988).
- the strict use of language standards and coding written standards.
- the intensive use of exception techniques for the handling of error and extraordinary events and, in general, for code robustness.
- the use of flexible, lightweight software development methodologies and tools tailored to scientific computing and partly based on the XP (eXtreme Programming) methodology as described in (Beck.K., 1999). This includes the "test case" methodology to certificate and formally validate software correctness.

The result of any development for IG's basic inertial/GPS platform should be compliant with the "open-closed" principle as described in (Meyer.B., 1988). In short, this principle asks the sotware to be both "closed" and open. "Closed" in that it is ready for use and open in that it is open to extension.

More detailed related discussions in the area of geodetic and photogrammetric point determination can be found in (Colomina et al., 1992, Colomina, 1999, Colomina, 2001).

4 SYSTEM COMPONENTS

The main components are the data acquisition systems and the data processing systems. They are described in the following sections.

4.1 Data acquisition

The IG has developed, among others, two systems which are of particular interest for trajectory determination, the TAG and the SEIRA systems.

Figure 1: The Litton LN-200 IMU.

4.1.1 The TAG system The TAG (Trajectory, Attitude and Gravity) data acquisition system has been under development since 1999. The system is a fundamental tool for testing sensors and, in general, for conducting experimental observation campaigns in various environments and platforms. Additionally, the system is instrumental in the analysis and/or development of other experimental, more tailored, data acquisition systems because it allows for rapid testing. The same can be stated by the lessons learned by working with TAG.

The logical architecture of TAG is based on the following components and subcomponents:

- CU (Control Unit)
  - GCU (GNSS receivers Control Unit)
  - ICU (IMUs Control Unit)
  - OIU (Operation Interface Unit)
  - *RNU (Real-time Navigation Unit)*
  - TSU (Time Synchronization Unit)
- PU (Power Unit)
  - BPU (Basic Power Unit)
  - UPU (Uninterrupted Power Supply Unit)

In the CU, the RNU is yet to be developed. The system can be operated with or without the UPU.

The different configurations steaming from the above architecture allow the system to be operated

In its current status the system includes an internal Novatel GPS L1/L2 receiver board, a lightweight/tactical 1 deg/h Litton LN-200 IMU (figure 1), and CPU, communications' and time synchronization boards.

4.1.2 The SEIRA system The SEIRA (Image Exploitation System, Rapid and Airborne) is a cooperative international (Brazil and Spain) industrial project (StereoCarto and AeroCarta companies) whose research partners are the IG and the Departament of Cartography (Presidente Prudente Campus, SP, Brazil) of the UNESP (São Paulo State

University). The goal of SEIRA is to investigate the integration of lightweight photogrammetric and remote sensing data collection and fast processing for applications where the two keywords are “fast” and “lightweight.” The SEIRA concept was ready as soon as 1997 although it had to await the availability of funds for its realization.

IG task within SEIRA is to investigate very fast direct sensor orientation at high and medium accuracy levels. (We point out that there is more to SEIRA than just inertial/GPS integration since rapid mapping requires rapid assisted image interpretation with image processing techniques and rapid geo-information compilation.) The first IG’s subtask in SEIRA was to integrate an experimental data acquisition system with an IMU, a GPS receiver and a small format digital frame camera. If we describe system components according to section 4.1.1, the SEIRA data acquisition system includes a GCU, an ICU, a TSU and a BPU. (Unless a closed loop synchronization between the GPS receiver, the IMU and the camera is desired, modern digital cameras have their own means to synchronize to GPS time and, therefore, most current digital cameras can be GPS time synchronized at no additional cost.).

If funding permits, in a second stage, fast direct sensor orientation will be addressed. Here, the main limiting factor is GPS performance as discussed in (Colomina, 1999, Colomina, 2001) since it is always possible to compute a real-time inertial/GPS navigation solution (Kalman-filtered) or a “rapid” inertial/GPS trajectory solution (filtered and smoothed). In that hypothesis, a precise absolute GPS trajectory will have a small impact on the quality of attitude; however, the position information is much more sensitive. In this stage two lines of research will be pursued. First, the suitability of IGS (International GPS Service) GPS satellites’ ultra-rapid orbit and clock-correction information will be investigated. Secondly, the current realistic performance of single receiver positioning (Bisnath et al., 2002, Han et al., 2001, Ovstedal, 1999) and the future situation with modernized GPS (McDonald, 2001, Fontana et al., 2001) and Galileo (Benedicto and Ludwig, 2001).

4.2 Data processing

In this context, data processing refers to the real-time and post-processing of inertial (time tagged angular velocities and linear accelerations), GPS (phases and unambiguous ranges) raw data and their integration. So far, the GPS processing capability is left to the GPS receivers real-time navigation solutions or to the post-processing available — commercially or institutionally— SW packages. The inertial real-time capability is not yet developed though planned (see section 4.1.1). The inertial/GPS post-processing capability is currently being developed within the frame of the GAST-1 project. (Inertial trajectory prediction and integrated inertial/GPS IMU calibration and trajectory filtering is a well known topic which can be found in many publications such as (Savage, 1998a, Savage, 1998b, Scherzinger, 1997, Schwarz and Wei, 1995).)

4.2.1 The GAST-1 SW system GAST (Airborne Gravity as a Substitute of Terrestrial gravity measurements) is a long term cooperative research and development project between IG and ICC (Institute of Cartography of Catalonia). Its long term goal is the development of tools for airborne gravity field observation and modeling. This results in research, development and testing activities. GAST-1 (phase 1 of GAST) deals with the development of the basic inertial trajectory ($t\Omega$ and $tPV\Omega$) determination modules and of the integration modules with GPS trajectories (tPV). The inertial/GPS integration is realized in the usual way by calibrating the IMU systematic errors through a loosely coupled decentralized Kalman filter and fixed interval smoothing. Careful numerical integration of the SDE (Stochastic Differential Equations) for the prediction of the inertial trajectories and of the use of SRF (Square Root Filtering) techniques are the main algorithmic features of the system. The components of GAST-1 and their function are summarized in table 1

Probably, the most interesting features of GAST-1 are related to its SW architecture and development methodology. The architecture recognizes that inertial SW is IMU-dependent and, therefore, allows for an easy procedure to change the IMU model.

5 WEBTOP COMPUTING

Internet distributed computing is one alternative to the current dominant practice of local computing. Internet computing requires both general computer/network systems and specific domain knowledge. Getting legacy SW to run in the Internet is possible and, sometimes, the optimal — or even, the only— solution under time or budget restrictions. However, optimal performance and maintenance are achieved through distributed architectures whose design requires a multidisciplinary team with intimate knowledge of the application domain. The application’s domain knowledge is necessary to define the building components of the distributed application in a proper way. Typical components of geo-applications are georeference frame servers. geoid servers, coordinate transformation servers, elevation data servers, etc.

WebTop computing is a particular case of Internet computing where the user interface is offered in a www page.

WebTopGPS is a project and system currently being developed by the IG and GeoNumerics. The system lets GPS data sets to be remotely processed following the general scheme in figure 2. Through WebTopGPS the IG is gaining practical experience in the construction of geodetic and remote sensing distributed components accessible as system geo-services through servlets. The resulting set of services will serve both educational, research and even production needs like those described in (Navarro, 2000).

We note here that the LWF/ECI paradigms and the XML (eXtensible Markup Language) are powerful tools and that there is a gap in the programming language technologies: scientific developers are longing for a language which has the rigor and simplicity of Java and that is as performant as FORTRAN or C.

Module	Function
`W_navigator`	$t\Omega^1$ inertial determination
`I_navigator`	$tPV\Omega^2$ inertial determination
`I_PV_navigator`	$tPV\Omega$ combined inertial/GPS determination (navigation solution)
`I_PV_T_server`	$tPV\Omega$ combined inertial/GPS determination (trajectory smoothed solution)

[1] $t\Omega$ stands for time tagged attitude parameters.
[2] $tPV\Omega$ stands for time tagged position, velocity and attitude parameters.

Table 1: GAST-1 main modules.

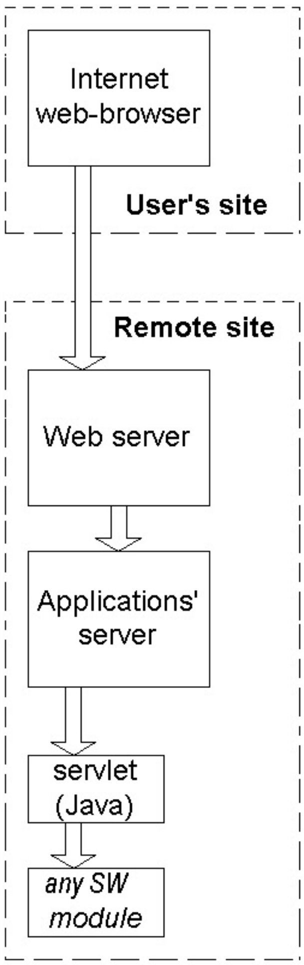

Figure 2: Schematic process flow of WebTop computing.

6 CONCLUSIONS

In this short paper, the general features of IG's basic platform for conducting applied research in the area of inertial/GPS trajectory determination for geomatic applications have been introduced. In addition, the strategy for having access to the platform rather than owning it and the development policies have been described. In future papers the authors will focus on the details and performance of each particular system.

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The IG does not intend to compete with existing or future commercial inertial/GPS systems with the developments described in this paper.

REFERENCES

Beck.K., 1999. Extreme programming explained: embrace change. Addison-Wesley.

Benedicto, J. and Ludwig, D., 2001. Galileo defined: proposed architecture and sercices. GPS World 12(9), pp. 46–49.

Bisnath, S., Beran, T. and Langley, R., 2002. Precise platform positioning with a single GPS receiver. GPS World 13(4), pp. 42–48.

Colomina, I., 1999. GPS, INS and Aerial Triangulation: what is the best way for the operational determination of photogrammetric image orientation? In: International Archives of Photogrammetry and Remote Sensing, ISPRS Conference *Automatic Extraction of GIS Objects from Digital Imagery*, Vol. 32, München, pp. 121–130.

Colomina, I., 2001. Modern sensor orientation technologies & procedures. In: Proceedings of the OEEPE Workshop “Integrated Sensor Orientation”, Hannover, Germany.

Colomina, I., Navarro, J. and Térmens, A., 1992. GeoTeX: a general point determination system. In: International Archives of Photogrammetry and Remote Sensing, Vol. 29-B3, International Society for Photogrammetry and Remote Sensing, pp. 656–664.

Dubois.P.F., 1997. Object technology for scientific computing. The object-oriented series, Prentice Hall, Upper Saddle River, NJ.

Fontana, R., Cheung, W. and Stansell, T., 2001. The modernized L2 civil signal. GPS World 12(9), pp. 28–34.

Han, S., Kwon, H. and Jekeli, C., 2001. Accurate absolute GPS positioning through satellite clock correction estimation. Journal of Geodesy 75(1), pp. 33–43.

McDonald, K., 2001. The future of GNSS: new capabilities, performance and issues. In: Proceedings of the *KIS’2001 Symposium*, Department of Geomatics Engineering, University of Calgary, Calgary, Alberta, Canada.

Meyer.B., 1988. Object oriented software construction. Prentice Hall, Hemel Hempstead, UK.

Navarro, J., 1999. Object-oriented technologies and beyond for software generation and integration in Geomatics. PhD thesis, The University of the Balearic Islands, Palma de Mallorca.

Navarro, J., 2000. The visual factory suite: facing evolving mass production in spatial data processing environments. In: Proceedings of the XIX ISPRS Congress, Amsterdam.

Ovstedal, O., 1999. Absolute positioning with GPS - an accurate alternative. In: Proceedings of the ION GPS 99, Nashville, TN, pp. 2055–2059.

Savage, P., 1998a. Strapdown inertial navigation integration algorithm design - part 1: attitude algorithms. Journal of Guidance, Control and Dynamics 21(1), pp. 19–28.

Savage, P., 1998b. Strapdown inertial navigation integration algorithm design - part 2: velocity and position algorithms. Journal of Guidance, Control and Dynamics 21(2), pp. 208–221.

Scherzinger, B., 1997. A position and orientation postprocessing software package for inertial/GPS integration (POSPROC). In: Proceedings of the KISS’97 Symposium, Calgary, pp. 197–204.

Schwarz, K. and Wei, M., 1995. Inertial geodesy and INS/GPS integration. Department of Geomatics Engineering, University of Calgary, Calgary, Alberta, Canada. Partial lecture notes for ENGO623.