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Integration of GPS, Digital Imagery and GIS with Census Mapping*

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1. The recent technological developments, including new high-resolution sensors, global positioning systems (GPS), geographical information systems (GIS), Internet and World Wide Web services, are revolutionizing cartography, surveying and mapping in fundamental ways: geographic data is easily collected and combined with a variety of other data in order to create relevant information for spatial analysis and decision making. Geographic information, in its digital form, is indeed exchanged more rapidly, duplicated without alteration, and easily disseminated to end-users.

2. For the past decade, the United Nations Statistics Division (UNSD) has been promoting the development of geographical information systems for population and demographic statistics in developing countries through technical cooperation projects supported by the United Nations Fund for Population Activities (UNFPA), training workshops, and technical publications. However, the statistical community in developing countries has been slow to adopt the use of GIS, partially due to the monetary constraint posed by commercial software and the availability of computers, base maps, satellite imagery, work load, etc.

3. This paper outlines some developments in satellite imagery, GPS and GIS with reference to census mapping activities, and provides some insight on the similarities between a geographic information process and a census mapping process, therefore, it urges for the integration of these geospatial technologies within the census mapping process. It suggests some future actions to undertake in order to help kick-start the development of this field in developing countries.

I. GIS, GPS AND AERIAL AND SATELLITE IMAGERY RECENT TECHNICAL CAPABILITIES

4. The census symposium, held in New York in 2001, provided a comprehensive review of the significant capabilities of GPS, Satellite imagery, GIS and handheld computers, and their relevance to census mapping operations (Dekker, 2001 and Tripathi, 2001s). Hence, our presentation will focus on the recent developments regarding these geospatial technologies, and specifically with regard to their better integration.

5. GPS, remote sensing (including aerial photography) and GIS are technologies that are being increasingly used in the field of data collection, including census mapping operations. Until recently, aerial photography did play a major role in geographic data acquisition in urban areas, and the use of satellite imagery, due to its low resolution, was limited to the study of some phenomena like floods and urban pollution. However, recent satellite imagery is extending its use to urban areas with the increase of its resolution to one-meter (i.e. IKONOS satellite), its high positional accuracy, the revisit frequency of only three days, and its GIS-readiness, despite their relative expensive cost (Montoya, 2002).

6. GPS receivers have become popular and widespread, offering a greater accuracy at a reduced cost (a variety of units less than $500). Indeed, some cost-effective GPS can handle real-time differential correction capable of sharpening accuracy to five meters or better. Furthermore, GPS coordinates (waypoints) can be displayed real-time in a GIS software

(i.e. ArcPad). GIS are becoming more powerful and friendly to use, and GPS more accurate and cost-effective. Both are more integrated, streamlining the acquisition and processing of coordinate data. The future of satellite positioning system looks promising, particularly with the new system under construction, Galileo, the European system dedicated to civil activities.

7. Beside GIS desktop and Internet GIS, Mobile GIS is becoming a reality. GIS software has been tailored to the needs of the field operations, allowing GIS to move from the office to the field. Indeed, improvements in handheld computers and other portable devices, as well as greater accuracy and the reduced cost of GPS units, have made significant contributions to the development of mobile GIS (ArcUser, January-March 2004). With mobile GIS, it is now possible to capture, manipulate, analyze and visualize data in the field in real time, and ground truthing has become possible[1] (see a summary on an interesting example, illustrating how advanced mobile mapping techniques were used to delineate census enumeration areas in Dili metropolis, Timor-Leste).

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8. Furthermore, the combination of digital video (DV), satellite imagery and GPS for the data capture and the input of this data into a GIS for manipulation, analysis and display, is empowering data collection and integration (for ground observations of buildings, GPS can be used in combination with digital video). Indeed, the most significant development in these recent years lies in the better integration of GPS, image processing and GIS systems. Hence, collecting data in the field, and storing it in a geographic database, can obviously improve the efficiency of the census mapping process.

II. GEOGRAPHIC INFORMATION PROCESS

9. The geographic information process consists of three stages: data acquisition, data processing and data dissemination. As illustrated in fig. 1, geospatial technologies are spanning through these three stages: GPS and satellite imagery, among others, are useful tools for geographic data collection; GIS have demonstrated their powerful capacities to enable data integration, analysis, display and dissemination. Hence, remote sensing techniques, GPS and GIS have become ubiquitous in developing policies for integrated management (Laaribi, 2000).

10. Geographic information is about the management of data that are geographically referenced, in order to provide sound information for better decisions. Geographic information is emerging as a fundamental part of the national infrastructure as important as

[1] "As the newest nation of the 21st Century, (East-Timor) faces the challenges of conducting her first population census after independence. This paper reviews the current mapping situation in East-Timor and presents how advanced mobile mapping techniques were used to delineate census enumeration areas in Dili metropolis. The peculiar nature of Dili, where the issue of building ownership and property boundaries remained contentious, coupled with the non-availability of up-to-date cadastral maps; led to a combination of remote sensing and geographic information system techniques being used to map census enumeration areas. QUICKBIRD high-resolution satellite imagery, GPS and an Internet enabled palm-top computer running on windows mobile operating system together with ArcPad 6.0.2 software were used to delineate census enumeration area maps. The methodological steps undertaken for the mobile mapping technique are narrated in this paper and the outcomes of the pilot study are compared with the traditional census enumeration area delineation methods. (Taiwo, 2004)"

physical infrastructure assets such as roads, telecommunications, and other public utilities. Indeed, there is a growing awareness worldwide of the economic importance of geographic information with applications in many sectors (regional planning, land management, environment/natural resources, health care, transportation, urban systems, marketing studies).

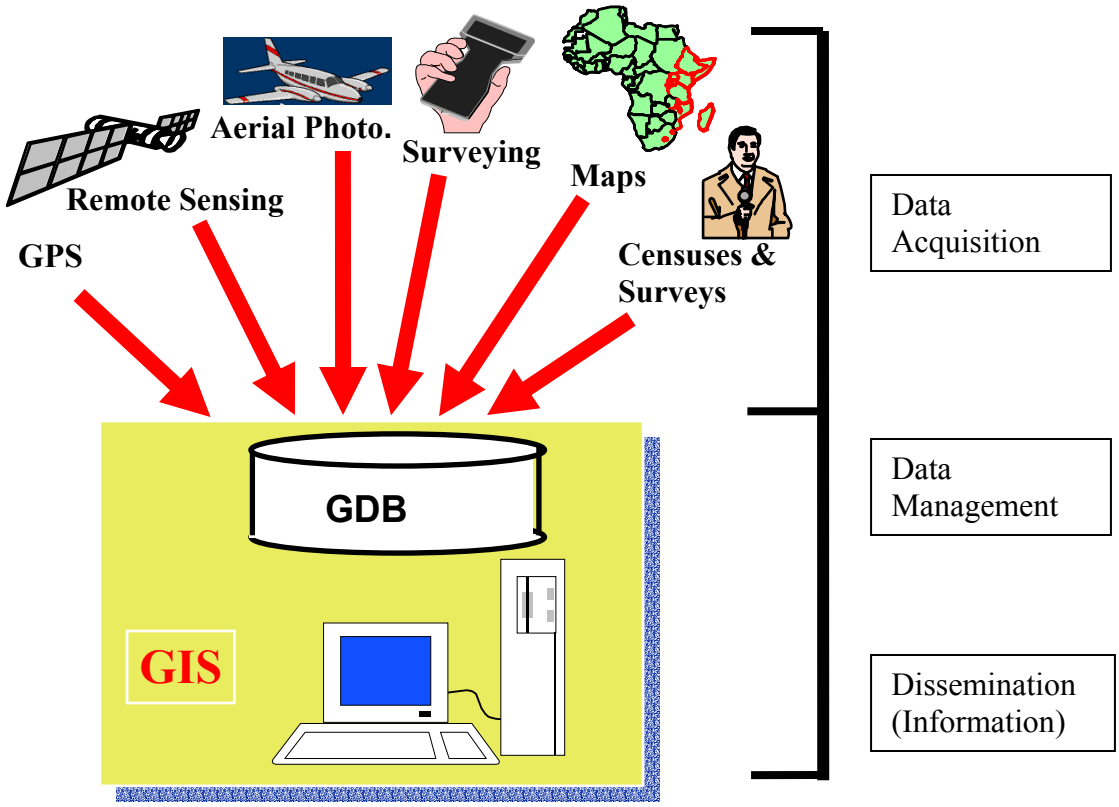

Fig. 1: *Geographic information process*

III. CENSUS MAPPING PROCESS

11. Census mapping operations are an essential component of a Population and Housing Census. As illustrated in fig. 2, census processes entails three stages: pre-census, census and post-census. In the pre-census stage(pre-enumeration), maps ensure consistency and facilitate census operations; in the census stage, maps support data collection and help monitor census activities (during enumeration); in post-census stage, maps make it easier to present, analyze and disseminate census results (post-enumeration) (*Handbook on geographic information systems and digital mapping, 2000*).

12. The traditional role of maps in census and survey operations consists of supporting enumeration and presenting results in cartographic form. However, additional capabilities of GIS, GPS and satellite imagery, such as integrated field data collection, advanced analysis and dissemination of census data, support census activities at all three stages,

proving that census mapping would gain by being a continuous process. Since the census is a process, cost-benefit of census mapping should be therefore considered in this context.

13. Statistical data, including development data, such as economic or health data, concern human activities that are geographically referenced. The geo-coding system, which is a fundamental component in the census enumeration operations, reflects the inherent geographic nature of census data. In other words, it constitutes the reference that gives census units its geographic link. To sustain this link, the coding scheme (meaning that the code is unique, and links between GIS boundaries and tabular census data), should be flexible enough and well structured to incorporate new and future administrative divisions.

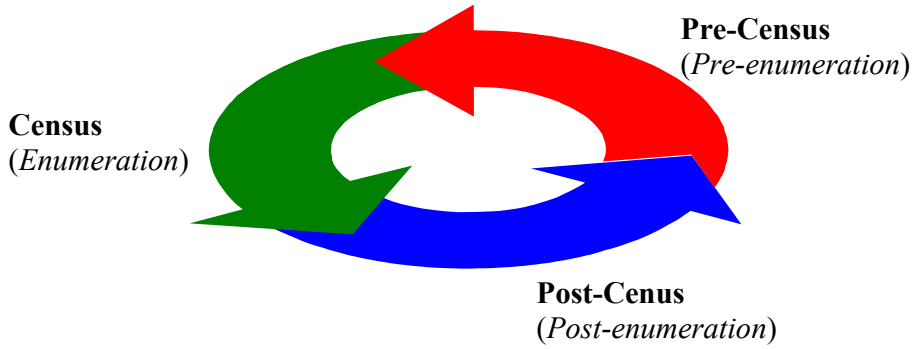

Fig. 2: *Census Process*

IV. STAGES OF INTEGRATION OF GIS WITH THE CENSUS MAPPING PROCESS

14. Our observation is that a census mapping process is akin to a typical geographical information process. There is, therefore, justification for the integration of GIS with census mapping operations at all the stages of the process. In doing so, we go beyond the technological approach to reflect the inherent nature of census mapping activities, which is mainly geographic. Obviously, the integration can be undertaken gradually.

15. Therefore, we advocate a paradigm shift from a traditional mapping approach, which is repeated for every census, to a digital census mapping approach, which is an up-to-date and a continuous approach. We believe that an up-to-date approach will allow census planners to rethink, inter-alia, the periodicity of census taking, the frequency of inter-censal surveys, and eventually the way to conduct census itself (some countries are already reconsidering the way to conduct a whole census countrywide every 10 years).

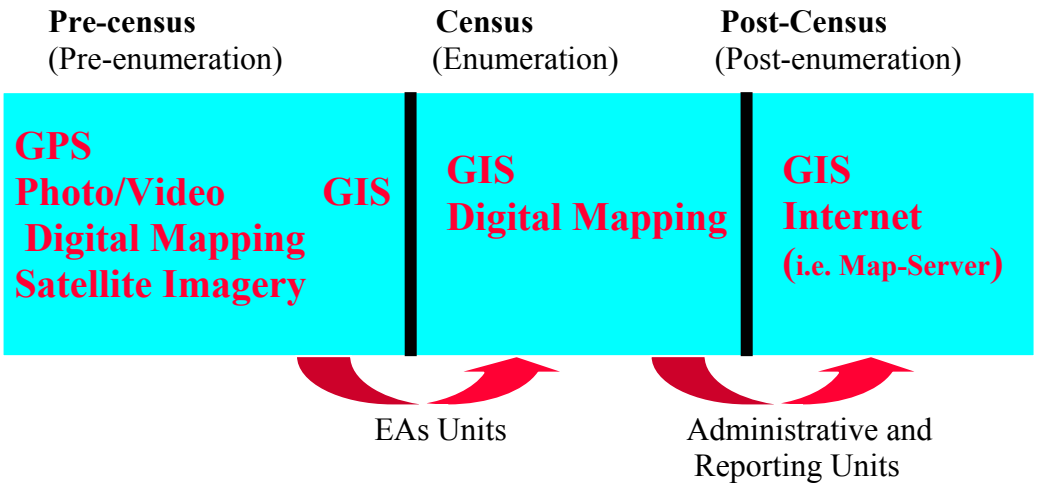

Fig. 3: *GIS with census mapping: stages of integration*

V. SOME CURRENT AND FUTURE ACTIONS TO PROMOTE THE USE OF GEOSPATIAL TECHNOLOGIES WITH CENSUS MAPPING

16. The United Nations Statistics Division succeeded to ensure that the National Statistical Offices (NSOs) of forty developing countries were provided with no-cost versions of commercial GIS software ArcView 3.3, **donated** and distributed by ESRI company, under the Global Map/GSDI Grant Program. Having a commercial software will allow NSOs to explore satellite imagery and GPS use for statistical enumeration activities and further data sharing and collaboration within their government ministries/departments and the private sector.

17. The United Nations Statistics Division published in 2000 a "***Handbook on Geographic Information System and Digital Mapping***", as part of a series of handbooks that have been developed to assist countries in their preparation for the 2000 and future rounds of censuses. This reference document (ST/ESA/STAT/SER.F/79) is a valuable tool for statisticians eager to understand the fundamentals of GIS and their integration within the census mapping process. It provides its readers with many details on the matter, including census mapping processes, digital mapping, GIS technologies and applications, geographic data collection techniques and critical factors for a successful census planning process.

18. While appraising the rich and useful materials provided by the handbook, some managers and planners in National Statistical Offices would like to have specific guidelines, allowing them to better understand how to adapt GIS technologies to census mapping operations and how to cope with organizational and institutional issues in setting up a digital mapping program, including the establishment of a cartographic unit. A recommendation on the establishment of a **Permanent "Cartography & Geographic Information" Unit** within the NSO should be considered.

19. The use of GIS with census mapping is not widely used in developing countries, despite the growing awareness worldwide of the economic importance of geographic information. In order to encourage the use of geospatial technologies in statistical activities, and help NSOs incorporate their statistical data as a fundamental component of the national spatial data infrastructure, the United Nations Statistics Division should consider organizing an **International Conference**, fully dedicated to the topic: "Integration of Geospatial technologies with census mapping for better decisions". Resolutions from the Conference, advocating the use of GIS in census mapping and other statistical activities, would help developing countries in their endeavors.

20. In order to achieve the above stated actions, workshops and technical advisory services would be required during the 2010 round of censuses. However, these actions should be part of a broad vision for the next decade. That's why the UNSD is considering the establishment of a **Group of Experts** to reflect on these important issues of census mapping with GIS and formulate a plan, with the aim to lead the effort to transform census-taking for the 2010 round of censuses, and usher in larger programs.

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