NAMGIS – A Context-Aware Mobile Web GIS

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Abstract

We present NAMGIS (Nomadic Adaptive Mobile GIS), an open-source location- and context-aware mobile Web GIS especially targeted at small screen and CPU limited handheld devices.

NAMGIS is composed of NAMGIS Core and SAF. NAMGIS Core is the mobile GIS, which builds on top of MapServer and provides an internationalized, context-adaptable Web interface supporting principal GIS functionalities, such as map browsing (e.g. zoom, pan), feature and attribute based queries, layer selection with dynamic legend, scalebar and reference map. SAF (Situation Aware Framework) is the context-aware framework that supports the acquisition and elaboration of context data, including GPS data, used to track the user's position in real time and adapt the contrast/brilliance level of the interface in outdoor scenarios, and RFID (Radio Frequency Identification) data, used to detect the proximity of the user with relevant features equipped with RFID tags (e.g. archaeological finds). These two components can also be used independently and are both released with an open source license (LGPL for SAF, GPL for NAMGIS Core).

NAMGIS is being developed within the ongoing "ArcheoMedSat" Italian research project, aimed at exploiting informative and geomatics technologies to explore archaeological contexts. In this paper, we present the architecture of NAMGIS as well as the preliminary results of an on-field evaluation of NAMGIS within the Comum Oppidum and Meta Sudans Italian archaeological sites.

1 Introduction

This paper describes *NAMGIS*, a context-aware, client-server mobile Web GIS. *Mobile GIS* refers to the access and use of GIS data functions through mobile and wireless devices, such as laptop computers, PDAs and smart phones (Peng et al, 2003). The use of mobile devices, characterized by inferior performances (CPU, memory), connectivity (latency, bandwidth, reliability) and usability (small screen, uncomfortable input controls), limits the functionalities of mobile GIS with respect to traditional GIS. Nevertheless, these systems provide end users with mobility and with a richer experience, by allowing them to explore the representation of a territory while moving in the territory itself (Magni, 2008). Typical mobile GIS users are fieldworkers and

users of location-based services (LBS), i.e. services that provide users with information based on their position; main application fields are car navigation, surveying, disaster management, geosciences and archaeology, while popular proprietary systems are ESRI ArcPad®, MapX® Mobile, MapXtreme® and Autodesk® LocationLogic™. Mobile GIS systems can be realized either as client/server or standalone applications (Brovelli et al, 2008a). Unlike standalone applications, client/server systems like NAMGIS don't suffer from synchronization problems, but they require network connectivity to operate. NAMGIS is a *Web GIS* (Li, 2007), i.e. it retrieves and shows up-to-date information by querying a server and offers a Web interface widely supported by handheld devices. While mobile GIS systems can support editing functionalities for on-field data acquisition, this is not the current focus of NAMGIS.

Context-awareness refers to the ability of a system to dynamically adapt to the context of a user, which comprises all the characteristics of the environment, the device and the user himself which are relevant for the human-computer interaction (Dey, 2000). *Location-awareness* is a particular case of context-awareness that refers to the location of the user. Context-awareness is a natural extension for mobile GIS: by considering the context – and particularly the location – of the user, such a system can provide advanced functionalities (e.g. tracking of user position) and a richer user experience. NAMGIS is a context-aware GIS and exploits the knowledge of the user position to adapt the interface and track the user while he moves on the territory shown by the system; nevertheless, NAMGIS is not restricted to using only location data, but can accommodate and exploit different context sources.

The rest of the paper is organized as follows. Section 2 provides an overview of the NAMGIS architecture and describes the role and data flow among the two main components: SAF, detailed in Section 3, and NAMGIS Core, detailed in Section 4. Section 5 deals with the evaluation of NAMGIS and the two instances of Comum Oppidum and Meta Sudans. Section 6 concludes.

2   Architecture

NAMGIS multi-level and extendible architecture is shown in Figure 1. The system is composed by two main components: *NAMGIS Core*, which provides a complete mobile Web GIS solution, and *SAF* (Situation Aware Framework), which collects location and context information and adapts the user interface by driving and controlling the adaptation capabilities exposed by NAMGIS Core.

A user interacts with the system using a handheld device equipped with a standard Web browser and with sensors that detect the user position and context parameters. The browser is used to access the mobile Web GIS provided by NAMGIS Core. The sensors provide a continuous stream of contextual data and currently consist in a *GPS receiver* and an *RFID (Radio Frequency Identification) reader*: the former provides user's geographical coordinates; the latter detects the proximity of RFID tags deployed in the environment next to relevant POIs (Point Of Interest). Both sensor data and browser requests are intercepted by SAF, which uses the former to assess the context of the user (comprising his location) and, on its bases, manipulates browser requests and resulting responses to adapt the GUI.

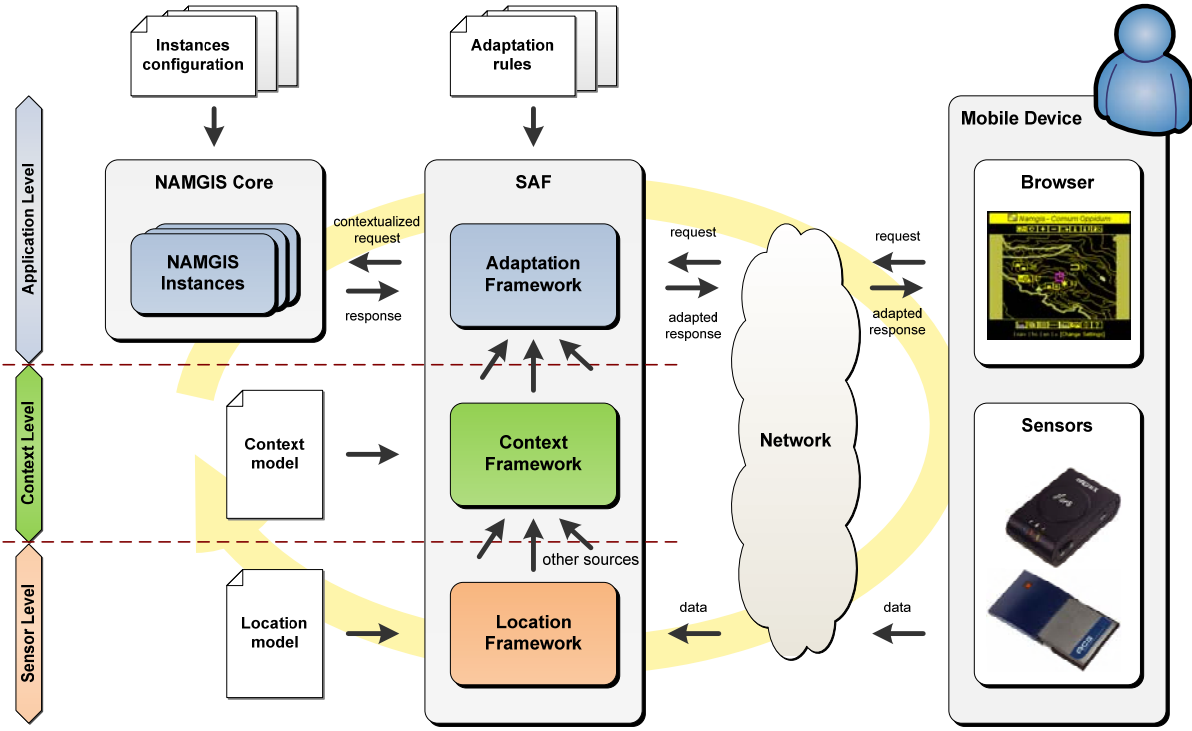SAF and NAMGIS Core are described in more details in the following sections.

Figure 1. NAMGIS architecture.

3 SAF framework

The SAF framework (Situation Aware Framework) provides general-purpose tools and Java libraries to support developers in building location- and context- aware applications.

SAF adopts a MDD (Model Driven Development) approach, consisting in the definition of models describing different components of an application. In SAF, three models are employed; they describe (1) the *environment*, i.e. the physical entities surrounding the user together with their topological relationships; (2) the *context*, i.e. aspects of reality which the application must adapt to; and (3) the *adaptation strategy*, necessary to describe how the system should react when some events occur or when the context changes. As shown in Figure 1, these models are used by three distinct components, corresponding to three logical levels which control and manage informative fluxes coming from sensors and receivers up to the web interface.

The bottom level – the *sensor level* – is managed by the *location framework*, which makes use of the environment (or location) model to estimate the user position starting from the GPS and RFID data received from sensors. The component employs a *hybrid environment model*, which describes both the geometry and the topology of physical entities (Becker et al, 2005). This model allows to compute both the coordinates and the symbolic location of the user, where the latter consists in the identifier of the symbolic location where the user is located in (e.g. a particular office) and of the physical objects near the user. The main topological relation described in the model is the association of an RFID tag to a model feature, which enables the retrieval of nearby features based on the tag detected by an RFID reader. This association is computed by a specific tool, called *RFID-Linker*, according to a semi-automatic process, which tests for the containment of tags in

feature perimeters and asks the user in case of ambiguities, i.e. when there are multiple features a tag can be associated to.

The intermediate level – the *context level* – is handled by the *context framework*, whose aim is to integrate context data (including location data produced by the location framework) coming from different sources, possibly deriving new context information during the process by means of *inference rules*. For example (Brioschi et al, 2006), knowing that a user is at office and the time is a working time, the system could argue that the activity carried on at that moment is a working activity.

The top level – the *application level* – comprises the *adaptation framework*, which uses context data collected and aggregated by the underlying components to adapt the content, layout and presentation of the user interface, according to a set of explicit and implicit *ECA* (Event – Condition – Action) rules. In NAMGIS, this framework is used to control the adaptation capabilities of NAMGIS Core, consisting in contrast adaptation and visualization of user position, and to "push" updated Web pages to the user after a change in its context.
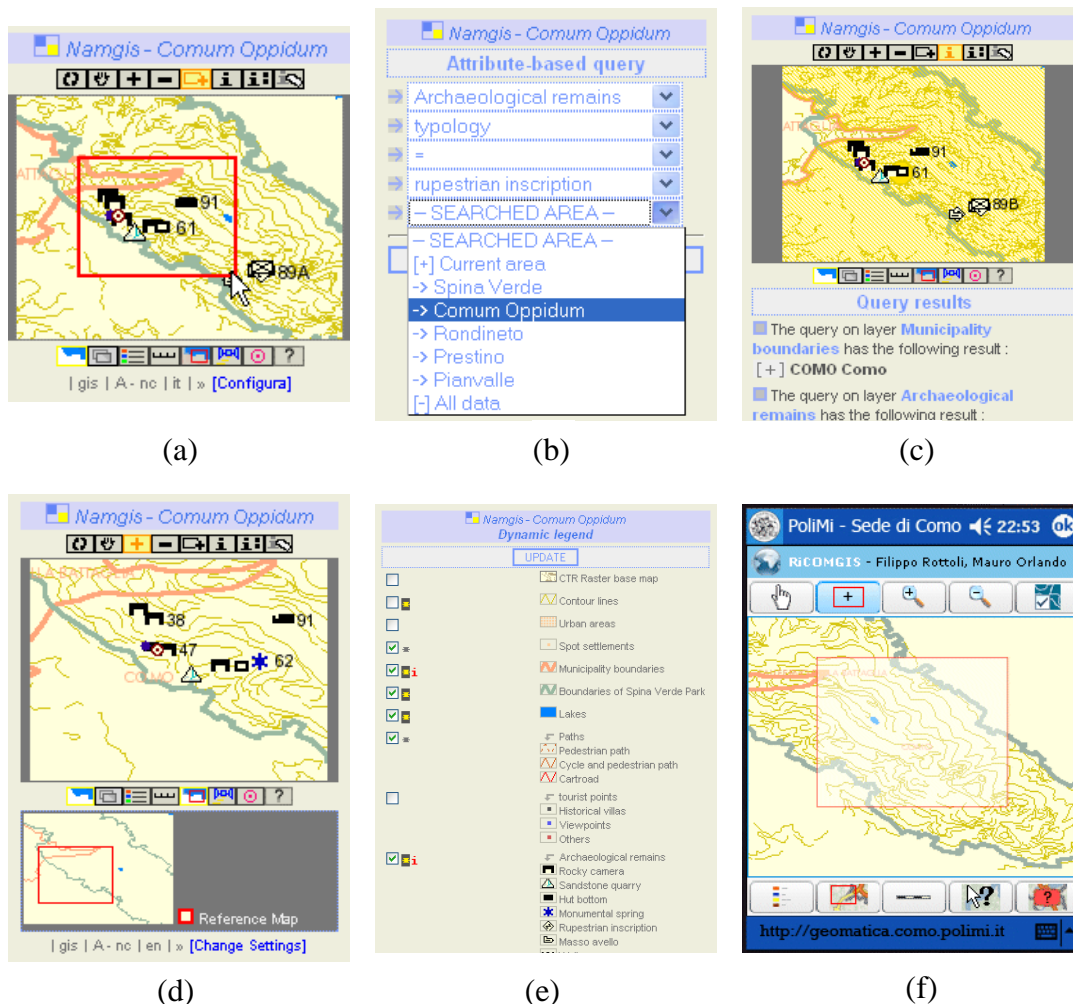

Figure 2. NAMGIS Core GUI: (a) HTML-based GUI showing zoom by rectangle; (b) attribute-based query; (c) results highlighted on the map; (d) reference map; (e) layer management; (f) RiCOMGIS.

4   NAMGIS Core

NAMGIS Core is the mobile Web GIS component of the architecture. It exploits the map generation and manipulation services of MapServer (accessed through Java MapScript) to present the user with a mobile Web GIS interface, especially tailored for the small screen and limited CPU power of handheld devices. NAMGIS Core can be used on its own or combined with SAF (see Section 3) to provide context-awareness functionalities.

NAMGIS Core provides two alternative GUIs. The *main GUI* (Figure 2; a, b, c, d, e) is based on HTML and JavaScript and features small controls, collapsible panels and lightweight graphics and effect to maximize map surface and reduce CPU and bandwidth consumption; this GUI runs on every device equipped with a Web browser and it is stable, internationalized (Italian and English) and largely configurable by users. The other GUI (Figure 2, f) – *RiCOMGIS* (Rich Client Open-source Mobile GIS) provides an alternative Flash-based interface for Namgis Core, based on the Open Source platform OpenLaszlo (Brovelli et al, 2008c); this GUI is more interactive, efficient and responsive, but currently requires high-level handheld clients.

NAMGIS Core supports all the common GIS functionalities (see Figure 2, a, b, c, d, e), including: map browsing (pan, zoom in/out, zoom by rectangle, predefined views, reference map); feature and attribute-based queries with highlight of results on the map; layer selection with dynamic legend; activable scalebar and indication of nominal scale. When coupled with SAF, NAMGIS Core provides also context-awareness features consisting in contrast adaptation and user's position tracking (Figure 3). Through *contrast adaptation*, the environmental light level affects the color theme of text, map and controls: normal contrast for low-to-medium sunlight; high contrast for bright sunlight (note that sunlight level is "inferred" by SAF as a pre-configured function of user's coordinates). *User's position tracking* consists in showing on the map the user location measured by the GPS receiver (see the purple marker on Figure 3), while nearby POIs (point of interest) detected by the RFID reader are highlighted.

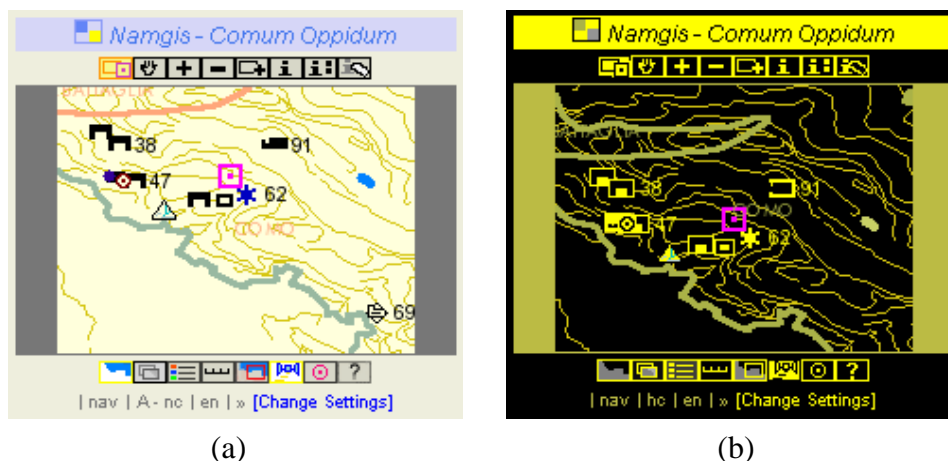(a)   (b)

Figure 3. NAMGIS Core adaptation capabilities: (a) normal contrast; (b) high contrast; user position is shown with a purple square marker.

For usability reasons, position tracking can be switched on/off by the user: if disabled, the system works in *GIS Mode* and all the GIS functionalities are available; if enabled, the system

works in *Navigator Mode*, where the interface is periodically updated to reflect variations in the user position and, because of this, only a subset of GIS functionalities is available. To keep the update process fluid, a *tracking algorithm* is employed to decide whether to update the map, based on: the current map scale (greater than a given max value); the percentage variation of user position with respect to the map width (at least 10%); the accuracy of the GPS receiver (distance covered greater than the accuracy).

NAMGIS Core is implemented as a Java Web application that can manage multiple GIS instances. Each instance is configured by specifying a MapServer mapfile, which defines the layers and the other map resources, and by providing the required fonts, symbols and resources (for normal and high contrast) as well as the data to be used to create the map. NAMGIS Core supports all the vector and the geo-referenced raster formats accepted by MapServer, and can read data both from files and databases. For further details about NAMGIS Core we refer the reader to (Magni, 2008).

5 Evaluation

Two instances of NAMGIS have been developed for two archaeological sites: *Comum Oppidum* in the Northern Italy park of Spina Verde (Figure 4, b), and *Meta Sudans*, located in Rome in the Valley of Coliseum (area of roman Imperial Forums) (Figure 4, c). Several tests have been performed on them, to evaluate both the feasibility of the approach proposed and the user experience of the GUI.

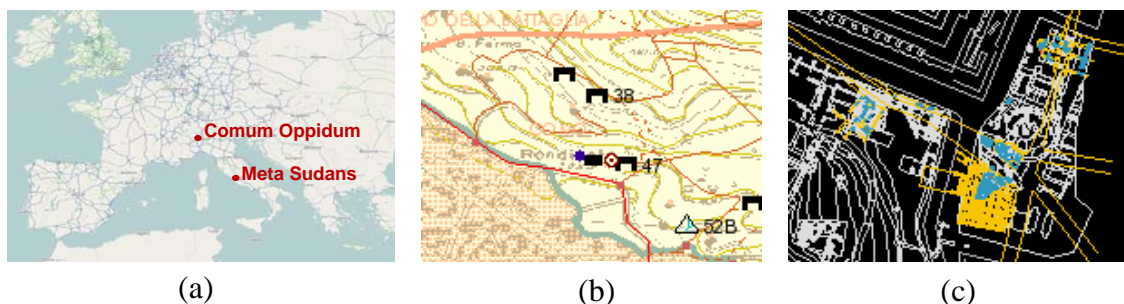(a)   (b)   (c)

Figure 4. The two NAMGIS instances: (a) overview; (b) Comum Oppidum; (c) Meta Sudans

A first set of tests permitted to evaluate the HTML-based user interface using different handheld devices (based on Windows Mobile 2003 and Windows Mobile 5.0) and mobile Web browsers, namely Microsoft Pocket Internet Explorer, Opera Mobile 8.65 and Mozilla Minimo CE 0.2. While these tests showed a satisfactory overall level of usability of the interface and enabled its fine tuning, they also highlighted some issues concerning slow performances (especially on older devices, with more than 20 seconds for each client-server interaction), and limited support of some advanced functionalities (e.g. the zoom by rectangle) due to limited browser support of JavaScript.

A test *in situ* of the Comum Oppidum instance has been performed also, in order to evaluate NAMGIS during use in a real case, where the whole architecture was implemented out-of-office. The area of "Roccione di Prestino", an archaeological point of interest, has been chosen as a use case for tests, and instrumented by deploying RFID tags next to archeological remains and by

installing a local wireless network, powered by solar panels, which allows handheld devices to connect to a server laptop and access the mobile GIS while moving across the archaeological site (Figure 5). The test had good results for connectivity and for providing the service, but confirmed the problems concerning slowness of the HTML-based interface, especially when the user is walking and the GPS position changes more quickly than the page is refreshed by the device (this problem has been partly addressed by the tracking algorithm, see Section 4). Another problem concerns some GPS receivers using a Kalman filter, which causes the estimated position to change in time even if the user is still (Brovelli et al., 2008b).
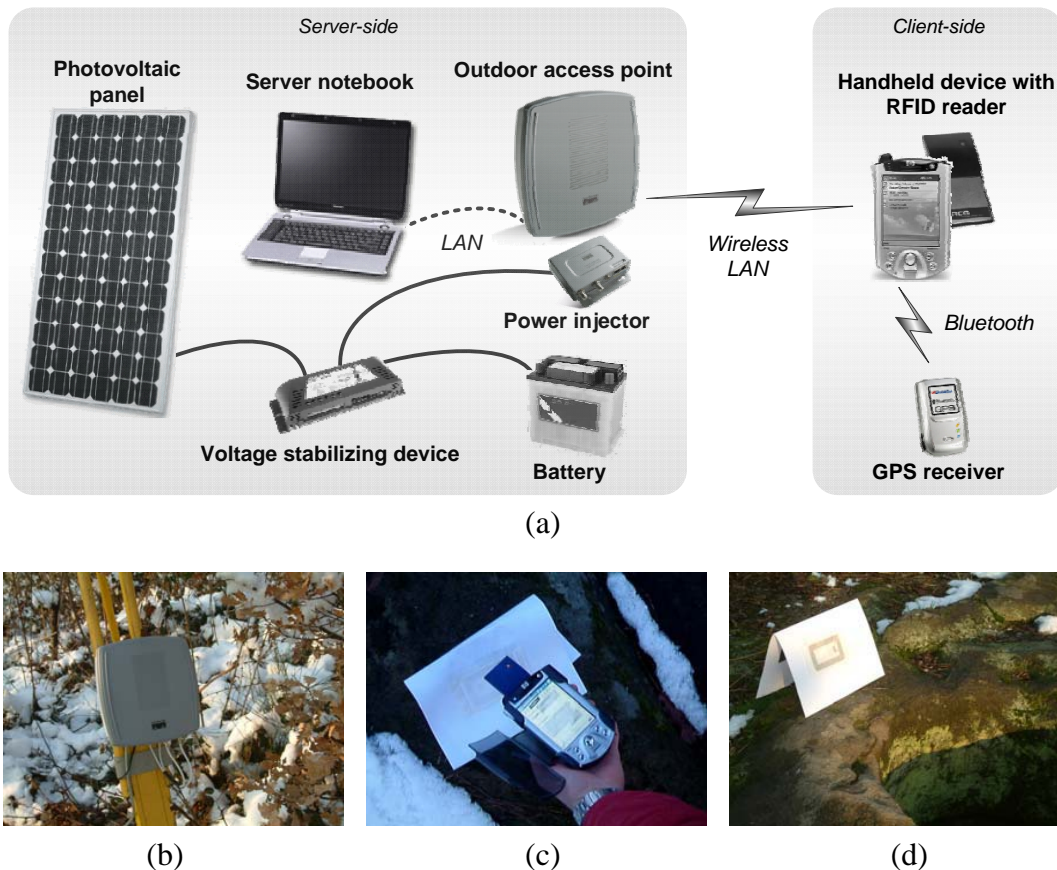

(a)

(b)   (c)   (d)

Figure 5. Test in situ: (a) infrastructure, (b) outdoor access point, (c) PDA with RFID reader, (d) RFID tag identifying an archaeological finds.

6 Conclusions

In this paper we presented NAMGIS, a context-aware mobile GIS targeted at small screen and CPU limited handheld devices. We discussed its architecture and the preliminary test results of the two NAMGIS instances deployed for the Comum Oppidum and Meta Sudans archaeological sites. In the future, we plan to evaluate NAMGIS in different application fields, to improve the GUI using Flash or AJAX in order to address slow performances, and to investigate the design and use of a unique data model based on GML to be shared by both SAF and NAMGIS Core. NAMGIS is open-source software covered by GNU licenses: GPL v3 for NAMGIS core and RFID-Linker, LGPL v3 for the SAF framework. All the software is freely downloaded from http://geomatica.como.polimi.it.

Acknowledgements

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