UPDATING A CENSUS WEB ATLAS IN A GEOSPATIAL DATA INFRASTRUCTURE USING AGENTS AND METADATA

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KEY WORDS: updating, web maps, metadata, geospatial data infrastructure, agents

ABSTRACT

The WWW is an accepted medium to be used for the dissemination and presentation of geo-spatial data. Clearinghouse web sites function as switchboards in a geo-spatial data structure, and are created to function as portals to available geo-spatial data offered by participating (government) organisations. In this process, maps play a prominent role, both as index to available data and as preview on the data to be downloaded. However, maps can still be used in their well-proven role to offer an overview of and increase insight into geo-spatial relations within a particular domain. The interactive and dynamic nature of the WWW guarantees that the map in its established role will be informative and attractive for the new map user.

Irrespective of the modern WWW, some familiar problems such as the currency of maps, remain. How to keep maps up-to-date? In discussions on the WWW, "easy-to-update" is always referred to when one wants to advertise its use. However, if the participating organisations do no have an infrastructure in place to take care of up-dating the data, even the WWW will not help. This paper will focus on a census web atlas. For its contents the atlas depends on the data providers' metadata descriptions to derive the latest data. The solution suggested will not put any burden on the data providers, but assume they are willing to provide access to a sub-set of their data. The solution comprises a design framework for the maps in the census web atlas, and an agent that checks metadata for updates. The paper will use the Province of Overijssel in the Netherlands as a case study, and the results will be extrapolated to non-census applications.

1 INTRODUCTION

Internet is an integral part of today's society. However, its full impact has yet to be understood and will be more drastically than can be currently foreseen. For all traditional activities and new developments around geospatial data the Internet, and more particular the World Wide Web (WWW) will be the vehicle. New products and services are driven by what is called the new economy. An example is delivering geospatial data to mobile devices using wireless application protocols. A geospatial data infrastructure (GDI) could be part of the delivery mechanism. However, the speed of the "new economy" is such that the traditional geospatial data providers will only play a role in this scenario if they can ensure an up-to-date data delivery in an acceptable format. Up-to-date means up-to-date according to internet-time, and this excludes revision cycles of four year or even a month. To be able to fulfil these criteria the internal data streams have to be well organised.
As the WWW is accepted to play a prominent role in the dissemination and presentation of geospatial data, maps have multiple roles to play. They can act in their long established role to present an overview of geospatial relations within a particular domain. This traditional role of presenting has recently been extended. The interactions with maps displayed on the WWW enable users to create different views of a particular dataset, and as such to use the map as a thinking device. Patterns and trends noticed because of these user actions might lead to new ideas and insights. However, within a GDI-environment the map can also be an index to available data or function as a preview of the data to be acquired. In a WWW-environment all these roles converge.

In this paper a census web atlas is presented that exist as an integrated part of a GDI. For its data contents the atlas is dependent on data providers that offer their services via the GDI's clearinghouse. Clearinghouses can be seen a switchboards in the GDI, and in WWW terminology can functions as so-called portals to available geospatial data offered by participating organisations. The data providers inform the users via their product's metadata descriptions. For the visualisation of the data the atlas depends on a so-called design framework. These can be considered prepared map frames that will get shape based on the nature of the data to be visualised. Although called census atlas the idea is not to change the data every ten years but to have data available as they change. The data providers regard the web atlas as useful but is not given priority by They need their energy to make sure their data is indeed up-to-date, and are less willing to spend any additional effort in separate delivery to a web atlas. Especially since it has become practice to keep the data at the data provider's site and not in a centrally manage data warehouse.

The solution suggested would not put any burden on the data providers, but assumes they are willing to provide access to a sub-set of their data. Agents technology, intelligent programmes that can wander the WWW will be used to regularly check the metadata providers offer to the clearinghouse. As soon as changes are observed the relevant data will be downloaded and processed, resulting in an up-to-date map. The paper will use the Province of Overijssel in the Netherlands as a case study and the results will be extrapolated to non-census applications.

2 THE PROBLEM

To produce and manage an up–to–date web atlas in a GDI environment is a complicated process. Many organisational and technical aspects have to be taken into consideration. This requires a strict organisation of rules, policies, standards, design, data flows and so on.

2.1 Having an up–to–date census web atlas

An atlas can be defined as an intentional combination of maps, structured in such a way that given objectives are reached. It informs users on for instance a country's geography, or characteristics with a spatial component. A census atlas holds the results of a census in map form. In many countries a census takes place every ten years, such as the United States. In other countries, such as the Netherlands, they do no longer take place, but a mechanism is in place to ensure census that census data is available anyhow. Putting an atlas on the web gives it potentionally some superb characteristics that deal with actuality and accessibility. In a GDI environment the atlas can become part of the geospatial WWW search engine or even an entrance to geospatial data organised via a clearing house (Kraak, 2000). Examples of atlases existing within a GDI framework are the national atlases of Canada and the United States.

One of the functions of the national atlas of the United States is to be a showcase for the geospatial data collected by Federal agencies (URL 1). Here the web atlas consists of a collection of various thematic map layers that can be combined. Here the clearinghouse and Web atlas co–exists and form as such not a holistic system within the clearinghouse. The national atlas of Canada (URL 2) functions as a data visualisation and exploration component of GDI (Palko, 1999). Here, the set up resembles the configuration given in figure 1. By these examples you can tell that an atlas its function depends on the goals. However, closely related to the goals are the users. Different users require different functionality, and a different interface, and last but not least different map design. But all expect provided data and maps to be up–to–date. How to organise such an atlas without putting to much load on the data providers?

2.2 What is the organisational structure of the census web atlas

To investigate the possibilities of automatically updating web maps in a GDI environment an experimental case is set up. The case evolves around a fictional census web atlas of the province of Overijssel. Assumed initiator of the atlas is the government of the province of Overijssel who utilises the atlas to disseminate spatial data to the general public, as well as to staff working at provincial offices. The latter also requires insight into the available data, possibilities to explore the data and the ability to download the data. The atlas as such, therefore, functions as an index, a visualisation tool, and an exploration tool. During the experiment the contents of the atlas is limited to a few census variables. Participants involved in the experiment are the government of Overijssel, the national bureau of statistics (Statistics Netherlands), and the municipalities located in the province of Overijssel.

What data can be provided by these organisations? The province offers the base map, with municipal boundaries. The national bureau of statistics has available a database with monthly updated population statistics for the municipalities. The municipalities have an elementary municipal administration that holds, among other data the population statistics. These administrations are updated on a daily routine. The national bureau of statistics has privileged access to these administrations. Everyday the national bureau of statistics receives mutations from the municipal administrations, which are carried through in its own database. The provincial government does not have access to these administrations. They gather their information via annual enquiries sent to municipalities and monthly publications originating from the national bureau of statistics (see figure 1 for data flow).

All the data residing in the GDI have a description (metadata) that is available via the national clearinghouse. The composition of metadata variables can be conformed to international standards: European standard CEN/TC 287, international standard ISO TC 211 (Wagner, 1999). The information flow has to be organised to make sure the correct data ends up in the atlas. In this example, only changes to attribute data are discussed, but of course, the geometry of municipal boundaries can change as well. Municipalities can merge, split or exchange area.

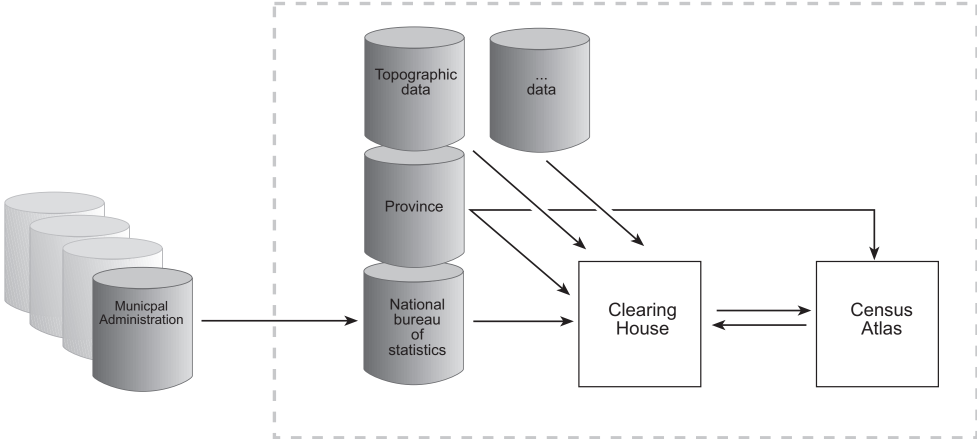

Figure 1 Data flows within the described GDI.

2.3 What is the technical structure of an up–to–date web census atlas?

Similar to organisational constraints of the census web atlas, the technical structure also entails some restrictions due to required functionality in respect to the different user groups, the atlas design guidelines, its user interface and the data processing needed. The WWW itself also has some current limitations.

Regarding the user needs, it is expected the provincial staff require more complex functionality then the citizens. Common functions are zooming, panning, selecting a variable or mapping unit, identifying objects, and creating hardcopy output. Staff members might require more extensive search options because it is likely they will use the data in their own working environment for policy preparation etc. However, both groups benefit from direct links to the GDI. Next, the user should be able to download the desired data. The atlas can also contribute to exploration of population characteristics by providing additional visualisation tools such as re–expression, brushing or animation (for more information on visualisation tools visit URL 3). The user interface for both groups should be well structured and intuitive (Lowe, 1999). The user, both citizen and provincial staff members should be able to adjust the complexity of the interface to their individual needs.

Since the map content is known, the atlas can be fully prepared. Still, the pre-compiled maps require data classification, based on the data characteristic incorporated in the metadata information. Each census map will have its typical design framework. In practice, this means that the map layout elements, such as the location of a title and a legend as well as options for interaction are fixed. New, up-to-date data will only refresh the map itself. For instance, a geographic unit may fall in a different class (choropleth map) or the size of symbol is increased (proportional symbol map) because the new attribute value increased.

The technical structure not only encompasses the functionality of the atlas, but also the contents. For its contents, the atlas depends on data available through the GDI clearinghouse. Since the clearinghouse contains reference to data sets from different data providers, there can be several data providers offering the same data set. This puts up a problem which source the census web atlas should derive its updates from. The different data providers might have different update cycles. This may lead to situations in which one data provider supplies an update to the clearinghouse, but the data are older then those received from another data provider. Taking this into consideration, it is preferable to have but one update source.

Not only the thematic and geometric attributes of an entity change at different times and at different rates, sometimes updates may come available for only few entities during the update-cycle. For example, updated demographic data become available for a limited number of municipalities only. Should the map in the census web atlas incorporate the new data to reflect the latest situation, or is the homogeneity and integrity of the whole map of greater concern? Maps containing data from different updates may confuse readers. This reflection makes an update of the whole data set more favourable over updates of only a few entities. However, situations may come about in which only few entities change their attributes. Should the census web atlas derive the whole data set from the data provider, or only the data from the entities that changed? With regard to bandwidth and WWW traffic, the latter option is more viable.

Users of the web atlas may not only be interested in the present situation, but may want to obtain information on the past or see temporal trends. These requirements make archival of older data sets necessary. These can be stored at the server of the census web atlas. During the set-up of the census web atlas, the practice of storing all data on the atlas server can be pursued, because it contains but few maps and the data providers do not have an archival system in place yet. During this phase, it is necessary for the atlas editorial board to convince their data providers of the need for this archival system. As soon as the census web atlas has been implemented as fully operational, the outdated data sets should be derived from the data providers. On request from the atlas user, the census web atlas then puts a request for these data sets to the data provider and generated the map on the fly.

There are several mechanisms for data providers to deliver update services to the users in the GDI. First, they can send an e-mail message informing them to retrieve the new data sets over the Internet via FTP, or send a CD-ROM with the updated data sets. In a WWW-based GDI, these procedures are insufficient, because of the large number of data sources and users. Furthermore, both the data providers and their clients have to put much effort to effectuate these procedures. Therefore, a more efficient mechanism is required.

3 THE SOLUTION

3.1 Update procedures

To derive up-to-date maps based on the latest geospatial data from data providers in a geospatial data infrastructure (GDI), the census web atlas depends on the data descriptions, the metadata, stored in a clearinghouse. Minimising the efforts, time and money from the part of the data providers whilst ensuring the census web atlas serves the latest data, the atlas itself must have a mechanism to check the metadata at the clearinghouse for the currency of the geospatial data and to retrieve the latest updates from the data providers. When providers update a particular data set, the WWW document that holds the metadata changes too. This change triggers the census web atlas to update that particular data set.

Such a mechanism for checking website contents for its currency is an information agent. These computer systems behave in such a way that, as soon as changes or updates are observed in the site contents at the server of the geospatial data provider, relevant data is uploaded onto the WWW server of the census web atlas and subsequently processed to generate an up-to-date map. Using this mechanism, clients are always assured of the currency of the maps in the census web atlas.

3.1.1 **Metadata.** For efficient searching and accessing geospatial data sets in a GDI, metadata must be available in a clearinghouse. Metadata is the background information describing the content, quality, condition and other appropriate characteristics of the data. It is used to provide documentation of geospatial data such that potential users obtain insight into the “what, who, when, where, why, and how” about the data that they are looking for.

For metadata to be easily understood, queried, and accessed standards must exist. The standards provide a common set of terminology and definitions for the documentation of geospatial data. Metadata standards provide appropriate and adequate information for the design of metadata to be used by different organisations for different purposes. These metadata standards must also describe the temporal attributes of the geospatial data set. In the next paragraph efforts are discussed that address the temporal aspects of metadata database design, with a special focus on the *valid time* attribute, which is most important for temporal queries. The valid time is the time when a fact is true in the modelled reality (Jensen *et al*., 1994).

There are various initiatives around the globe standardising metadata descriptions. The Content Standard for Digital Geospatial Metadata (CSDGM), developed by the US FGDC, provides “Time Period Information” (FGDC, 1998). This section states the temporal information. The “Entity and Attribute Information” refers to this section to store the *valid time* of the data. The European Pre-standard ENV 12657 prepared by the Technical Committee 287 of the European Committee for Standardisation defines a conceptual schema for the minimum set of metadata for geographic datasets (URL 4; CEN/TC 287, 1998a). This metadata standard also supports the storage of *valid time* as it requires the definition of the *temporal extent* and the *period range details* for each entity. This initiative has now been suspended in CEN/TC 287. The result of the work of Technical Committee 211 of the International Standardisation Organisation, ISO/TC 211, on this topic as laid down in IS 19108 Temporal schema, will be considered for implementation as a European Standard (CEN/TC 287, 1998b). This International Standard defines standard concepts needed to describe the temporal characteristics of geographic information, including metadata elements that describe temporal characteristics of data sets (ISO/TC 211, 1999). The Open GIS Consortium (OGC) has started co-operating with ISO/TC211 on standardisation initiatives as well. OGC itself had not developed a temporal schema before.

Taking on one of these standards for describing the metadata, the census web atlas can be updated based on the metadata available at the clearinghouse by means of agent technology. This will be described in the following paragraphs.

3.1.2 **Agent technology**. An (intelligent) agent is a computer system capable of *flexible autonomous* action in order to meet its design objectives. An agent is autonomous because it acts without direct intervention of humans (or other agents) and has control over its own actions and internal state. An agent is flexible, because it is responsive, proactive, and social. The agent perceives its environment and *responds* to changes that occur in it. Moreover, the agent exhibits opportunistic, goal-directed behaviour and takes initiative: it is *proactive*. The agent interacts at its own will with other agents and humans both to complete its own problem solving tasks and to help others with their tasks: it is *social*. Agents also exhibit a number of attributes, the key ones of which are *learning*, *co-operation*, and *mobility* (Software agents: A review, 1997).

Typically, an agent programme, using parameters provided by the user, searches the Internet, gathers information the user is interested in, and presents it to the user on a daily or other periodic basis. On the Internet, the most ubiquitous agents are programmes, also called spiders or crawlers that access WWW sites and gather their contents for search engine indexes. These search engine indexes have the same function as the metadata descriptions in the clearinghouse of a GDI. The agent paradigm therefore is very suitable to adapt to the clearinghouse concept. They have the characteristics needed to support the dynamic service environment of a Geospatial Data Infrastructure: mobility between users and across platforms; autonomy to initiate and perform tasks; representation of their owners' interest across a network; flexibility, responsiveness to the evolving environment and social ability. Agents thus become a fundamental enabling technology for geospatial information brokerage (Foss, 1998).

There are differing perceptions about agents. Relevant to the problem described here are the information agent view and the distributed agent view. An information agent is an intelligent agent, designed to manage, manipulate, or collate information from many distributed sources (Nwana & Ndumu, 1998). Typically, it communicates across a computer network to locate information resources to query or manipulate. A distributed agent (or multi-agent system) is a collective agent at the macro-level, rather than the micro-level (Dale & DeRoure, 1997). The task of a macro-level agent is broken down into smaller sub-tasks. Micro-level agents fulfil together the task of the macro-level agent by co-operating and co-ordinating their activities

In the next paragraph, the attention is drawn to a particular type of information agents that is of use for the problem described previously, namely site watchers. These information agents notify its owner of site updates. To understand the workings of these particular agents, the attention is subsequently drawn to the distributed agent view.

3.1.3 **Site watchers.** Site watchers are information agents that monitor for any updated materials on the Internet on behalf of their owner. These agents notify their owner when a selected site is updated with new or changed information. There are several commercial agents available that take on the role of site watcher, e.g. InformationMiner4U, javElink, and Morning Paper (URL 5, 6 & 7).

These information agents take the overall characteristics of intelligent agents and exploit them for their specific functionality to track changes of WWW documents. Since agents act autonomously and responsively, these site watchers can observe user-defined or self-explored URLs and respond to changes on the WWW without the need for human interaction. Another characteristic of agents is the pro-active behaviour and its mobility. This allows site watchers to explore the WWW looking for new URLs guided by their own opportunistic initiative. The social element of agents makes them interact when they deem appropriate. This enables users to define the URLs that the agents observe and the user-profile that guides the exploratory behaviour of the agents. These characteristics of agent technology make site watchers suitable mechanisms for observation and exploration of data resources and for personalisation of these processes.

Users do not care about the system and processes behind the service delivered by site watchers. They only want to be informed of relevant updates. From their perspective, site watchers have five tasks. First, the site watchers are there for notification: they tell users that something happened. Second, the site watchers give details: they tell all of what changed. Third, the site watchers perform the task of extraction: they tell what is relevant to the users. Fourth, the site watchers perform visualisation: they highlight the changes or display only the latest relevant information. Finally, they have an archival task: they document all changes.

In the context of this paper, the user is not the web audience, but the census web atlas. Whilst the census web atlas is a server to the web audience, it is a client to the clearinghouse at the same time. Push technology brings information on updates from the clearinghouse server to the client, i.e. the census web atlas. Now the relevancy and tasks of site watchers in the context of updating maps in a GDI is clear, it is necessary to take a closer look at their workings, drawing from the distributed agent view.

3.1.4 Distributed agents in a GDI. Site watchers can be thought of as distributed agents. This view on agent technology is very useful, because it abstracts the complex functioning of site watchers. A multi-agent system framework is presented that is comprised of micro-level agents (Dale & DeRoure, 1997). These micro-level agents each perform a smaller task in the framework. Through co-operation and co-ordination of their tasks these micro-level agents fulfil the complex task of a site watcher.

A domain agent supervises the activities that occur within a domain. A domain is a logical boundary delimiting nodes, agents and resources into manageable and distinct entities. The domain agent is the key entity within a domain and is ultimately responsible for ensuring that security is enforces within the domain and that agents can communicate with information resources and other agents. Resources agents exist within a domain to provide a level of abstraction between mobile agents and the information resource to which they provide access. They mediate between access to a particular resource at a local level for an agent. They understand how to interrogate the resource and also understand the permission structures that apply to the resource. Users gain access to these resources by means of mobile agents. These are the components within the framework that migrate between network nodes. They actually hold the user-defined parameters that describe their functionality, in this case site watching. The user interface agents reside within a domain and provide a level of abstraction for the user way from the details of the framework. The user interface agent is a window onto the agents, their status, their results and the mobile agent framework.

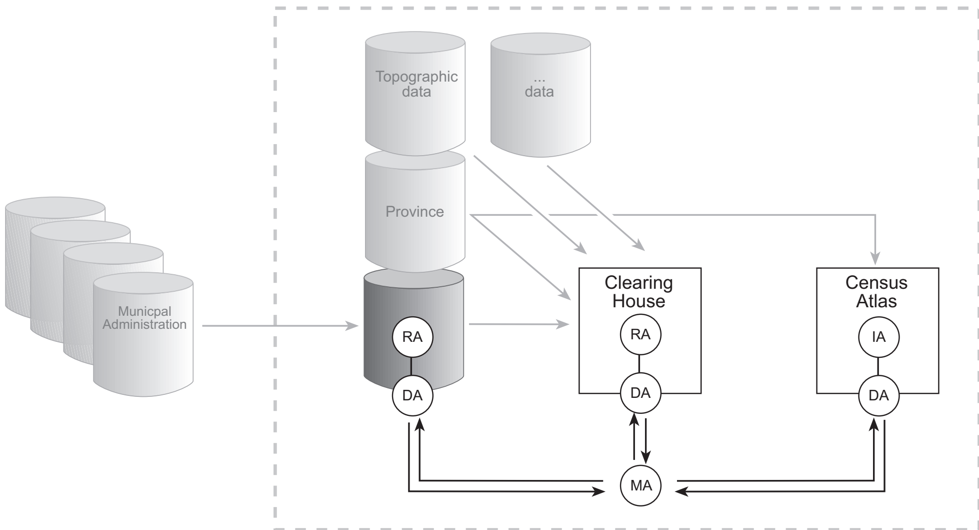

Figure 2 Updating process and web agents.

This framework fits perfectly onto the system architecture of the GDI. The mobile agents migrate through the GDI over the WWW to the clearinghouse and the data providers. When these mobile agents arrive at these nodes, the domain agent checks them for their permission to access the resource. The resource agent on its turn presents the contents of its resource to the mobile agent. In the case of the clearinghouse, the resource agent provides access to the metadata database. The mobile agent checks for the metadata for updates. If it detects an update, it follows the hyperlink in the metadata file to the data provider. In the case of the data provider, the resource agent presents the updated data sets to the mobile agent. Then the mobile agent returns to the census web atlas. The user interface agent is the intermediary to the mobile agent and presents the updated geospatial data sets to the census web atlas in a manageable format for the map generator to produce an updated map. Before this mechanism for metadata based updating can be operational, various technical and organisational requirements have to be met. Although the solution that is presented here is purely technical, the organisational implications have to be considered as well, for the technology to operate effectively.

3.2 The design framework

The census web atlas needs an editorial board, who is responsible for the design framework of the map. Within this design framework special attention goes out to the auto–creating and auto–updating and user interface of the maps.

3.2.1 **Auto–create.** As stated before the nature of the map content is known. Based on this information a map framework can be designed for each topic. In our example it means pre designed maps for topics such as absolute population numbers (resulting in a proportional point symbol map) and population density (resulting in a choropleth map) For each map the location of legend and title is fixed, while the extent of interactivity and dynamics is also determined.

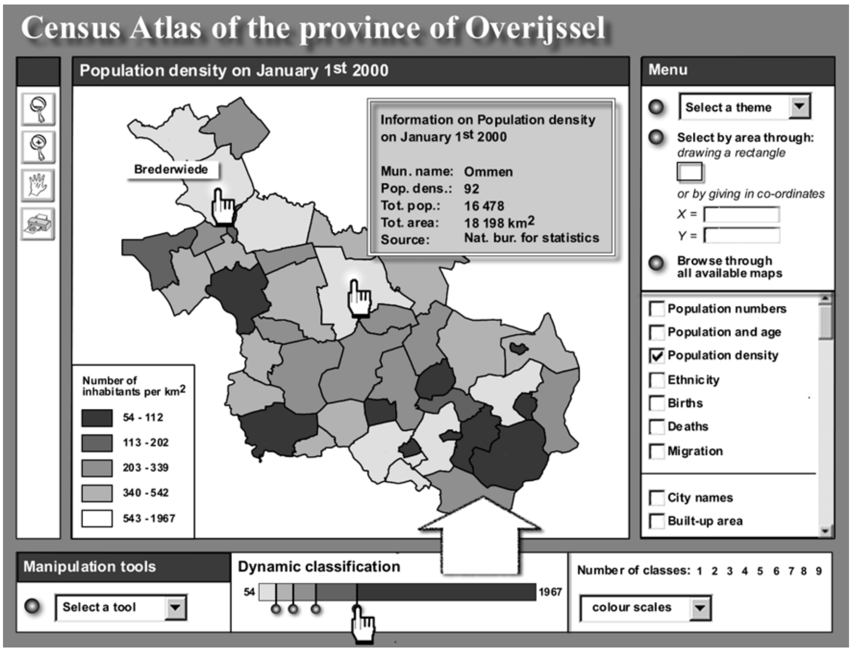

Figure 3. An example of the design framework.

During the experiment we did not concentrate on interactivity and dynamics. Only clicking a municipality results in a pop–up window displaying among other things the exact value of the population density, and the name and total population of that particular municipality. From literature and the WWW more advanced examples are known (Andrienko and Andrienko, 1999 and URL8). Their Descartes system, designed to support visual exploration, shows many examples. Among them the dynamic classification of choropleth maps. Here the user can select the number of classes and choose a colour range, but the option exist to change both on the fly. Also other forms are interactivity could be build into the maps. For

3.2.2 **Auto–update.** Automatically updating of maps is not a problem because the existence of design frameworks. But some problems, already noted in the previous for instance some municipalities have merged or split. In this case a new geometric base file is required. Changes in attribute could lead to non-homogenous maps if for examples the classification system doe not change but one value get and extreme high value resulting in a map that has most municipalities in a single class. These problems can be solved in different ways, but require some cartographic expertise.

3.2.3 User interface. The map interface consists of four panels: menu, map display, map navigation tools and a panel containing manipulation devices (see Figure 3). The menu gives to access all available maps within the atlas. Different selection methods can be applied, for instance choosing a theme via a pull down menu that holds all topics that are offered by data providers within the GDI. When a theme is chosen variables of that theme are given in the scroll menu at the lower right of the image. In figure 3 the variable population density is checked. For orientation purpose the user can also select additional topics such as roads or place names The map display is sensitive to mouse movements. When the cursor is positioned on for example a municipality, this object is highlighted, and a little window pops up displaying the name of that municipality. By clicking on a geographical object a small window is opened displaying more detailed information on that object, for example exact values and source of the data. Further, the map display can be manipulated by the navigation and manipulation tools. The map navigation part contains tools to zoom, pan, print, switch to full extent, or to download data. By first selecting a tool and subsequently clicking in the map display the map is enlarged reduced or moved. The manipulation panel can exist of many functions dependently on the level of the user. For example, dynamic classification, re–expression, dynamic visual comparison, querying, overlay, buffering, time analysis and so on.

4 CONCLUSIONS

The experiment described in this paper demonstrates that it is relatively easy to keep an atlas up to date in the era of geospatial data infrastructures without putting to much burden on data suppliers. A well organised data flow with help of the web agents and visualised according map design frameworks result in a usable census web atlas. It is also another proof of the usefulness of a well functioning clearinghouse within the GDI. The complexity will of course increase if many more data providers get involved, and a permanent editorial board is required if for instance this principle is applied on a national web atlas. The (census) web atlas can also be used as alternative portal to the GDI and other relevant websites since it is easy to created links from the maps to those web sites.

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URL 2 National Atlas of Canada Online. http://atlas.gc.ca/ (28 March 2000)
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URL 4 CEN/TC 287. http://forum.afnor.fr/afnor/WORK/AFNOR/GPN2/Z13C/ (29 March 2000)
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