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Options and recommandations related to further development of an Espon Cartographic Language

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To cite this version:

Paule-Annick Davoine, Hélène Mathian, Cécile Saint-Marc, Christine Zanin, Nicolas Lambert. Options and recommandations related to further development of an Espon Cartographic Language. [Technical Report] 5, UMS Riate; UMR Géographie-Cités; Laboratoire d'Informatique de Grenoble. 2013, pp.80. hal-01383440

HAL Id: hal-01383440

https://inria.hal.science/hal-01383440v1

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ESPON CARTOGRAPHIC LANGUAGE

Options and recommendations related to further development of an ESPON Cartographic Language

Dec 2013

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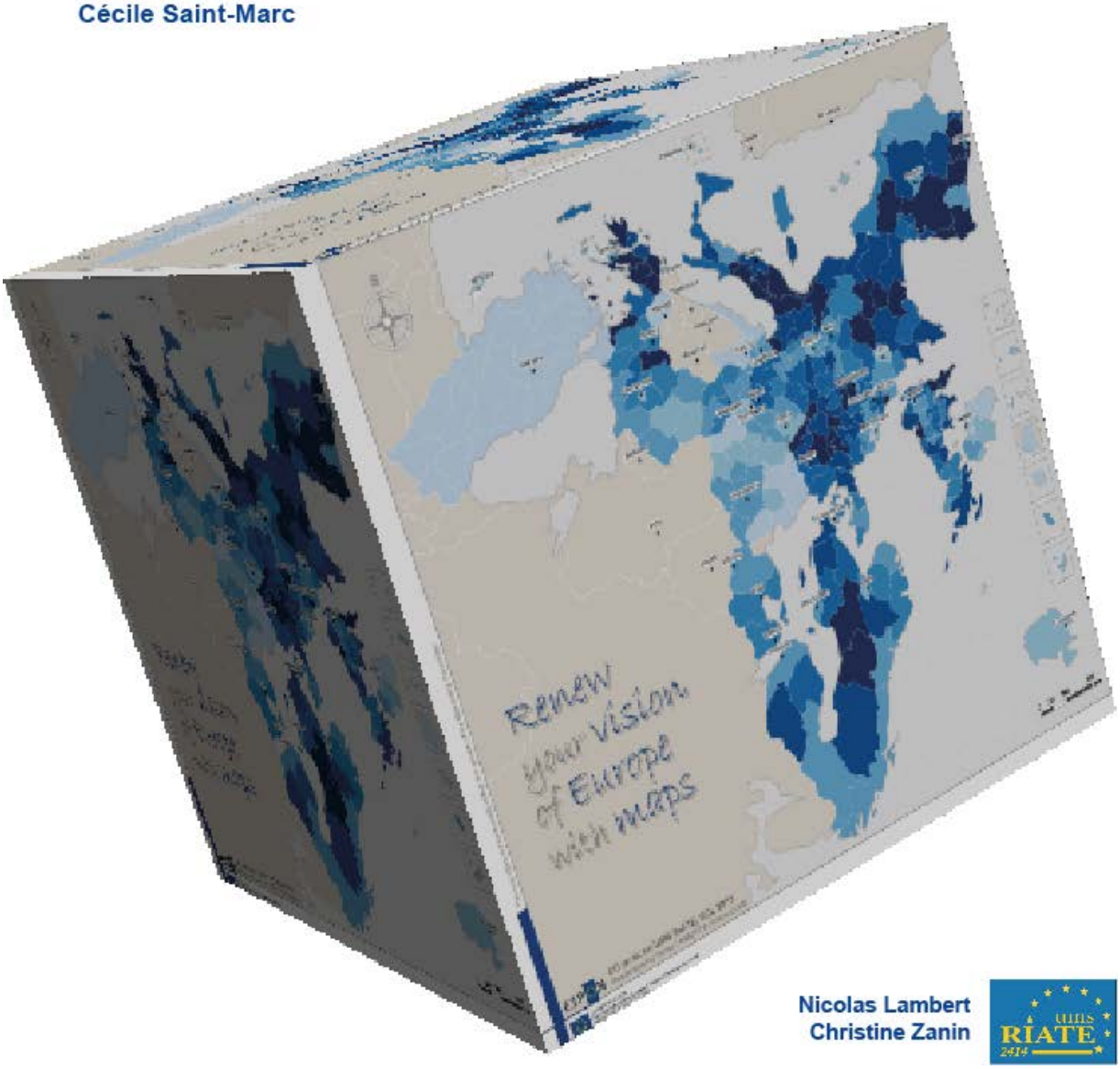

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This report is task 5 of ESPON ECL Project. 2013

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"The word geovisualisation ...is slowly becoming a synonym for mapping",
Menno-Jan Kraak (2008)

"La carte est un écheveau de temporalités ",
G. Palsky (2004)

INTRODUCTION

As it was shown in Task 3, recent technological advances have contributed to the development of interactive cartographic environments, among which electronic atlases are the most representative. These atlases have the capability to integrate a diversity of maps. They enable the user to have different levels of use, from the classic visualization of maps, to the exploration of geographical data, stored in databases. Visualization of data can be done with a gradual approach, from a global vision to a detailed reading. Electronic atlases enable the user to create his own maps, depending on his needs and his cognitive scheme, through on-demand maps. They also enable to associate some forms of graphic and cartographic representations, to explore data on several points of view.

These tools are attractive by their design, their ergonomics, their easy access (sometimes only by appearances), but the diversity of their functions, enabled by recent developments in informatics, can lead them to be very complex to use and less effective. The conception of such environments can raise some issues:

- problems of ergonomics and of functional specifications in their uses. The functions to consider are not the same according to the type of cartographic application to develop, that themselves depend on the users' aims.
- Problems of cartographic constructions. Indeed, with such environments, maps become interactive, animated, dynamic or multimedia. These new forms of maps can trouble the user and lead to a less legible cartographic message.

In this Task, our aim is to identify good practices, as well in the development of interactive cartographic environments such as atlases, as in innovative cartographic constructions. Our proposals target several levels:

- The level of applications themselves: which functionalities have to be use, for what applications and what objectives?
- The level of cartographic representations, meaning the possibilities to introduce elements of animation and interactivity in maps, depending on data and objectives: what innovations for which representation?

To achieve such aims, we use two types of resources:

- a collection of interactive atlases, considered as the most representative of the diversity in european statistical atlases, which we have analyzed and compared.
- the collection of maps presented in Task 4, that we propose to enrich with functions of interaction and animation.

The first part of Task 5 deals with recommendations, coming from a comparative analysis of european statistical atlases. These recommendations depend on the type of environment to be made (environment of visualization, analysis or exploration), and on the desired interactivity level.

The second part deals with recommendations to create interactive and animated maps. They are illustrated by concrete proposals, in the form of summary datasheet.

The final part deals with a comparison of computer tools that can be used to make innovative cartographic applications.

Part 1

Review of European territorial atlases

1.1. Methodology

In task 3 we set out to describe the innovations encountered in the environments for dynamic cartography in the wide sense, providing illustrations in the form of examples of maps. Here we intend to start from particular usage of these environments in territorial atlases, so as to derive recommendations that are more specific to cartographic production in ESPON projects. We analysed around a dozen statistical atlases. Thus the review presented here is representative of the diversity observed. It is based on European productions, and presents maps developed in national and international settings (Table 1).

Level of production and representation	Institution
International, Europe	Regional Policy – InfoRegio, European Environment Agency, Eurostat
National, Europe	Statistik Austria, Hungarian Central Statistical Office, Statistics Netherland
National, country	Ireland AIRO/CSO, Statistics Lithuania, Slovenia statistical office, Statistics Sweden, United Kingdom National Statistics Atlas statistique de la Suisse

Table 1: Environments analysed

The websites were then analysed for the characteristics of their main functionalities, summed up in the following six dimensions:

- type of the atlas : publication of interactive maps, interactive cartography environments
- interactivity with the data and intelligent interfaces,
- potential for analyses required for synthesis,
- potential for original cartographic representations and re-expressions,
- adaptability ,
- technologies used.

This inventory enables presentation of the following:

- firstly an overview of the functionalities that make up the strengths of these atlases, and also a review of their shortcomings. Details on these advantages and drawbacks of each atlas are given in the annexes.

- secondly a list of recommendations concerning the above characteristics for the development of innovating interactive cartography.

1.2. An atlas or a geo-catalogue?

A catalogue is, according to the Larousse definition, "a list of documents [items] classified according to a determined order to facilitate searches". When the items are documents concerning spatial data, the term geo-catalogue is used. This is an information system on a website enabling individuals or organisations to access spatial productions issued by administrations, collectives or any other body generating spatial data. It may also be possible to share the data (geographical information in raster or matrix form, cartographic documents, geo-referenced documents, satellite images). A geo-catalogue can also provide links with other spatial data catalogues. It complies with ISO and OGC standards of interoperability. A cartographic atlas for its part is defined as "an ordered ensemble made up solely or mainly of geographical or historical maps" (Larousse). Generally speaking, an atlas is a collection of maps designed to represent a given space and to cover one or several themes.

Following the European Directive 2007/2/CE dated March 14th 2007, known as the INSPIRE directive, geo-catalogues have developed considerably in recent years. The INSPIRE directive aims to establish a geographical information infrastructure within the European community to foster environmental protection. What this directive refers to as a geographical information infrastructure is in fact a set of services available via Internet on the various websites of the different protagonists, enabling the diffusion and sharing of geographical data. These "infrastructures" which take the form of geo-catalogues, provide information on the data they present in the form of metadata: description of the data, production characteristics, and modes of use. In some cases it provides the option of accessing the data-set, but does not provide any cartographic representation (Figure 1). These tools are generally based on the use of an interactive map that facilitates searches and spatial selection of the data. The result of the selection is displayed in the form of a descriptive page presenting the data corresponding to the selection criteria, sometimes accompanied by a graphic or cartographic vignette enabling the visualisation of the data. Thus these tools are not cartographic atlases, and fall outside the scope of this study.

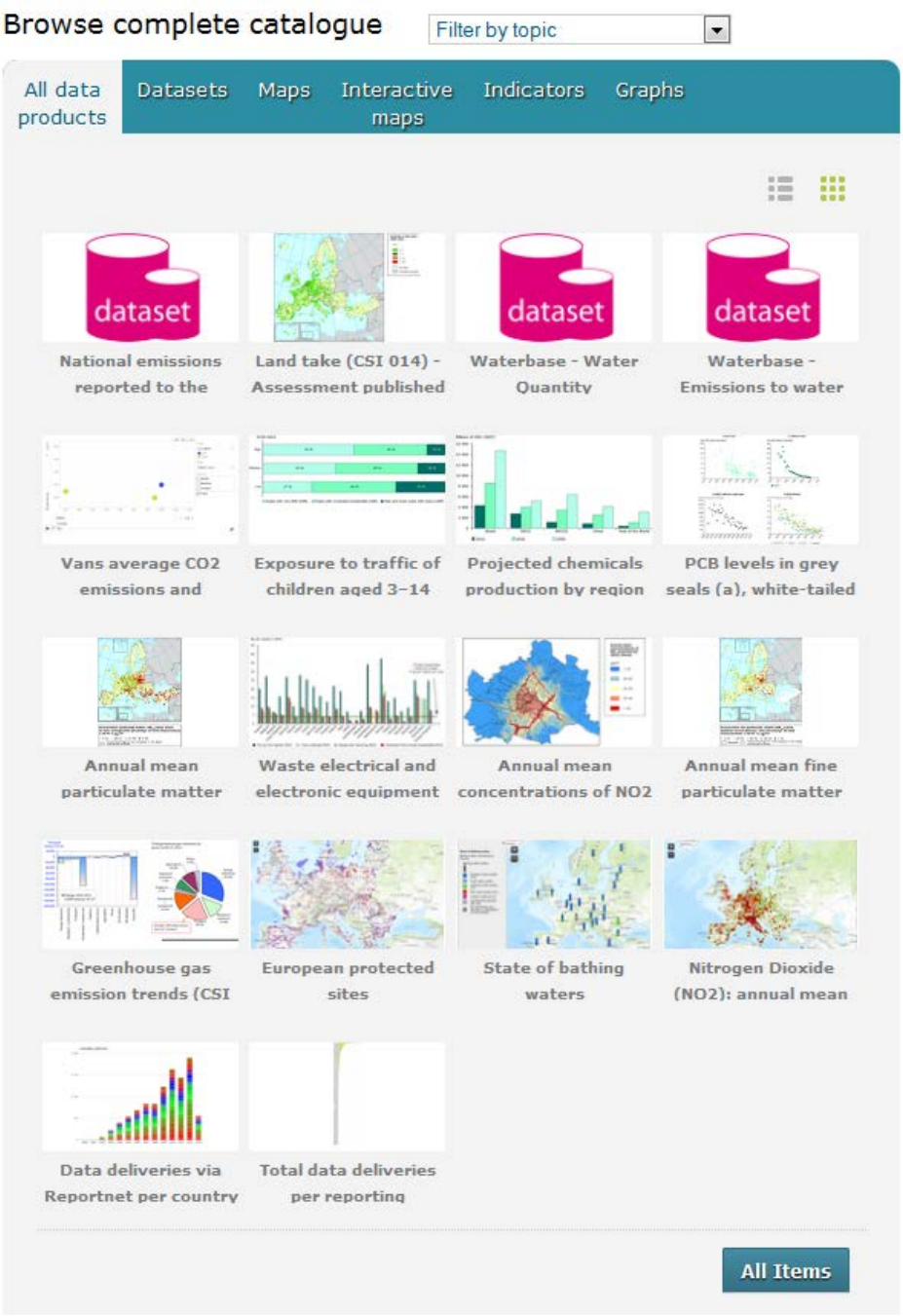
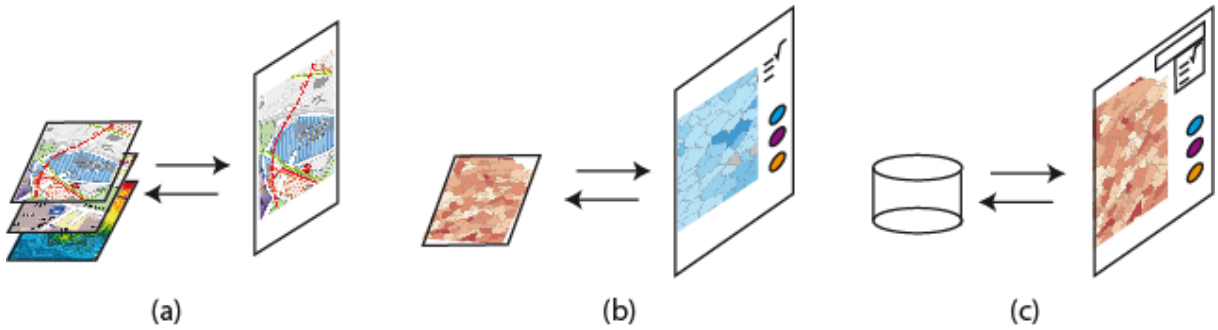


Figure 1: Example of a catalogue: European environment Agency

Recommendations

The different types of publishing environment used for maps need to be distinguished according to their structure and their level of interactivity: collections of maps also known as catalogues (a), where the maps are predefined and produced in a particular setting and then published on a website; online atlases (b), where the maps are developed upstream and displayed via a browser, possessing certain interactive functionalities, ranging from classic navigation to functions controlling the display of different elements on the map and its visual appearance; cartographic data exploration environments (c), where the user can develop his or her own map and interact with the data. This last category has links with geographical databases.



Thus "cartographic atlases" should not be confused with "geo-catalogues", also known as "spatial data infrastructures". These tools have different objectives. A geo-catalogue assembles various productions and spatial services relating to a variety of themes. It aims to facilitate accessibility and sharing of raw or processed data via display of descriptive information. It does not offer functions for map development. A cartographic atlas, on the other hand, systematically offers a cartographic visualisation of the data, which can vary in complexity and can be suited to the user. It aims to assist analysis and exploration of the data.

1.3. Overview of the basic functions of interactive atlases

Presentation of the data in the atlas

Interactive atlases have particular ways of presenting the themes covered by the atlas (Figure 2):

- Certain atlases take the form of a cartographic interface which comprises a zone for the selection of data, classified according to theme (e.g. the Eurostat Statistical Atlas).
- Others offer first a list of themes on a web page, and the chosen theme then opens an interactive interface dedicated to the theme (a map on the theme "Demographics" will enable the user to choose a set of data, "population" or "life expectancy" - see for instance the Hungarian Statistical Office).
- Finally, a third type of presentation consists in an interactive map that is different for each dataset (e.g. Online Atlas, Statistik Austria)

Figure 2: Atlas presentations (to the left, choice of information from the map, source: Eurostat; to the right, choice of data before accessing the map, source: Statistik Austria)

Recommendations

The most user-friendly maps are those that dissociate themes into several interactive maps. This method enables the visibility of the available date to be enhanced and facilitates navigation from one map to another, in particular when there are numerous themes. The most elaborate atlases can produce maps dynamically to meet user needs. In this case, the data for a given theme can be consulted interactively within a single map.

Elementary interactivity functions

Navigation and positioning functions are found in all the interactive cartographic environments. They are considered elementary but essential in interactive atlases. These functions are now standard inclusions, and are expected by users with and without experience.

- Zooming into the map. This is often on offer via a command button in the form of a magnifying glass, via a vertical slider or by scrolling with the mouse

- Panning. This is often a drag-and-drop function, a standard navigation tool, but in certain atlases there may be displacement arrows on the edges of the map.

- Display of tooltips. For this function the user places the cursor on a geographical entity on the map or selects by a mouse click. Tooltips display thematic data that characterise the spatial entity under the cursor or selected: name, value of statistical indicators.

- Selecting and de-selecting spatial entities. Thus function enables the highlighting of one or several geographical entities. It is operated via a mouse click or selection in a menu of items.

Intermediate interactivity functions

- **Selection of spatial entities.** The display of geographical coordinates as the mouse moves across the map and the situation inset is an essential function to enable the user to locate elements on the map.

- **Full-extent.** This function enables a view of the whole map

- **Positioning or situation.** The display of geographical coordinates as the mouse moves across the maps and situation inset is an essential function to enable the user to locate elements on the map.

Recommendations Panning, zooming, tooltips, selection of spatial entities are the elementary functions of an interactive atlas. Full-extent and geographical positioning may be added to these first ones to enhance elementary navigation.

1.4. Overview of advanced functions in interactive atlases

Advanced interactivity functions

Other functions are commonly encountered in interactive cartography environments. They provide the user with more freedom, whether for exploration of the data or for its representation.

- **Altering the legend**. The user can interact with the legend in several manners: he/she can alter the method of data classification (for quantitative data), change the class boundaries manually, or change the colour palette of the legend, from predefined palettes or according to personal choice.

- **Altering the base-map**. This function consists in adding or removing layers of geographical information representing reference or localisation elements. The data can be topographical (relief, water courses, lakes, communication infrastructures) or administrative or regional boundaries. Certain atlases also offer a few predefined base-maps (orthoimage, Google maps, OpenStreetMap, etc.) among which the user can choose.

- **Changing the scale**. If data are available for different geographical grid sizes, the atlas can enable the user to alter the units considered (e.g. shift to the scale of countries via aggregation of the data at a lower geographical level)

- **Filtering data**. Filtering means displaying only part of the data available on a map, so as to analyse subsets of the original data, or more readily identify the geographical entities belonging to a given class. A filter is commonly applied via criteria (e.g. "display the municipalities whose population is between 1000 and 10000"), or else by using the legend to click on one of the classes (Figure 3).

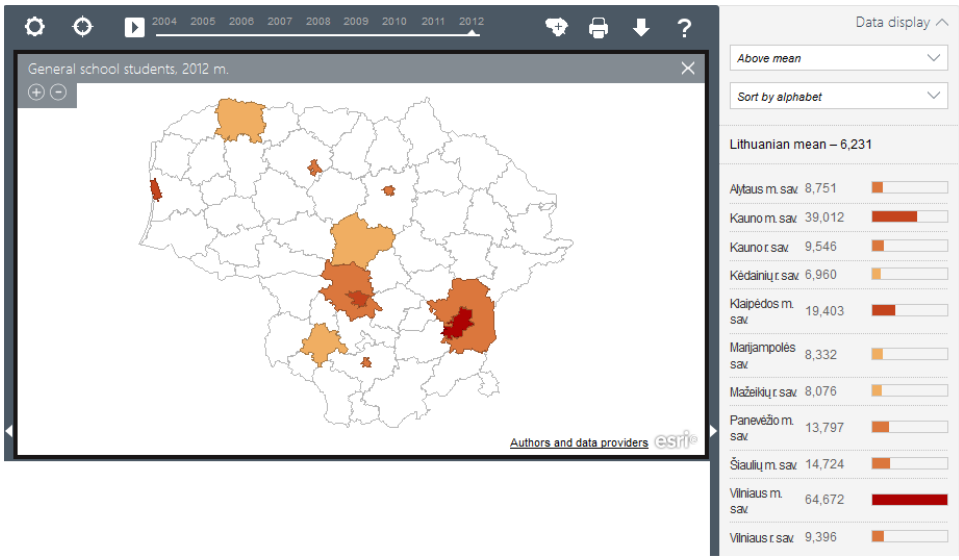


Figure 3: Interface enabling data to be filtered according to their position in relation to the mean. Source: Lithuanian Statistics

- **Comparing data.** To facilitate comparisons of variables or datasets, two methods are mainly used: a visual method and a statistical method.

  - Visual method: this consists in offering two cartographic views simultaneously, enabling the values for two different variables to be compared for a given zone, or to compare a given zone at two different dates (Figure 4).

  - Statistical method: converted values for geographical entities are displayed via a statistical method: centring, reduction, neighbourhoods (e.g. displaying populations of European countries in percentages of the population of Germany).

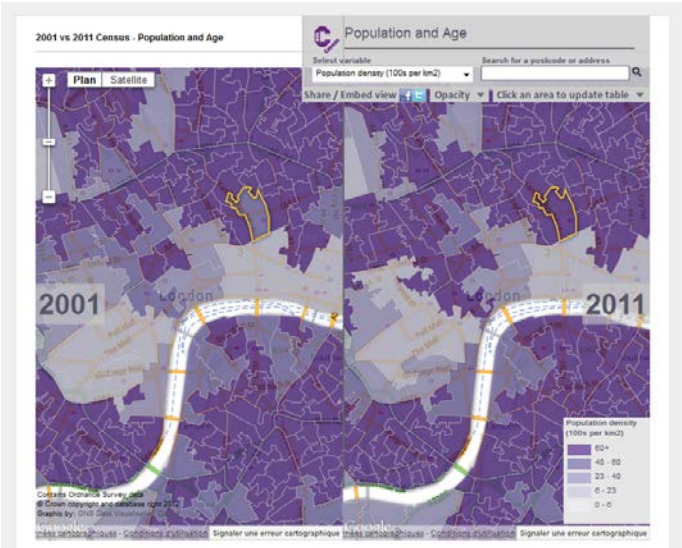


Figure 4: Population of London in 2001 (left) and 2011 (right) using parallel maps - Source: UK National Statistics

- **Integrating animation.** The animation enables navigation through time if the thematic data is available for several dates. Animation techniques are detailed in Part 3.

- **Print-out or export of maps.** The user can print the map he/she has "created" or can export it in pdf format.

- **Exporting data.** The user can export raw data, for instance in spread sheet format (csv, tab, xls etc.) or in geographical format (shp, mif/mid etc.).

- **Sharing data.** The user can share the map via the social network (links to Facebook, Twitter, LinkedIn etc.) or with another website by embedding the map.

Recommendations

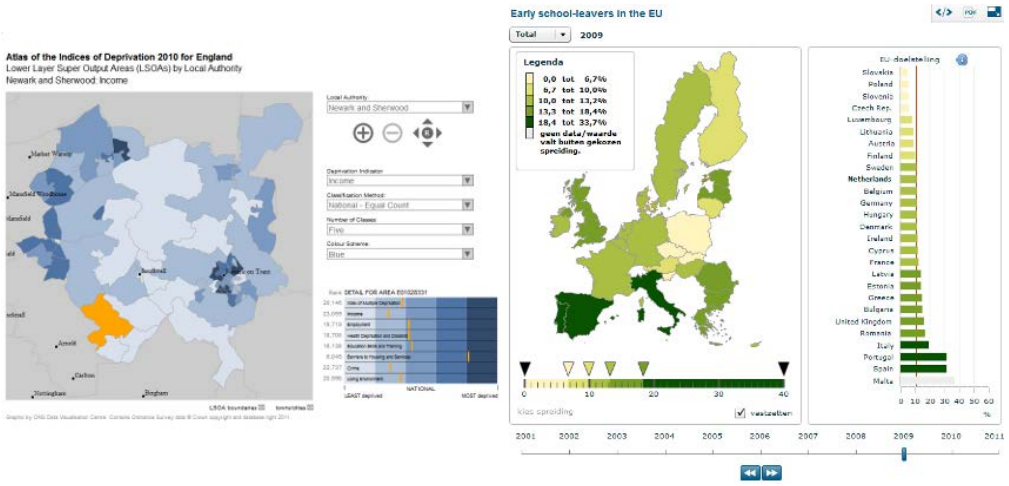
The so-called "advanced" functions enhance the process of discovering data. The freedom afforded to users for personalising maps, or the range of functions on offer is an important aspect, especially for Web-surfers who wish to personalise their own cartographic developments.

Synchronisation with graphic views

Interactive cartography environments often include graphic elements that provide a different view of the data on the map. They are derived from various statistical processes, and enable information to be presented from a different viewpoint (temporal, statistical summary, e-spatial viewpoint, etc). They also enable comparison of values of the different geographical entities, or enable these values to be compared to reference values (mean, standard deviation) (Figure 5).

For instance, graphic elements can also show general trends using histograms for the numbers in each class (e.g. number of regions belonging to each class in the legend), or again to show evolutionary trends over time (Figure 6).

This synchronisation between the graphic element and the map by way of a mouse click facilitates apprehension.



Source: United Kingdom National Statistics *Source: Statistics Netherland*

Figure 5: Graphic elements accompanying maps

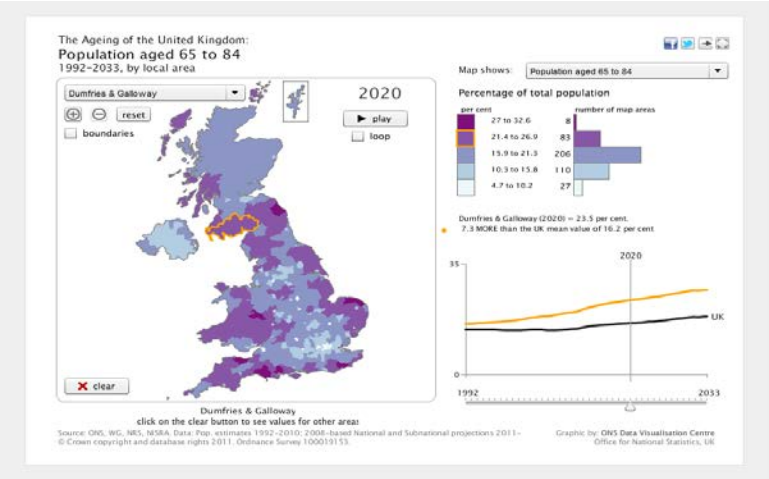


Figure 6: Histogram showing numbers per class and graph for evolution over time - Source: UK National Statistics

Recommendations

It can be helpful to accompany maps with interactive graphic elements. These can provide a new viewpoint, and they enable trends and information that would not be easy to represent on the map to be perceived. These elements are useful to provide synthetic information both on the territory under study and on the situation of a geographical entity in relation to its territorial environment. For easier perusal it is also important for these graphic elements to be synchronised with the map. In some cases they can be used as the map legend (for example, distribution histograms).

1.5. Functions that are specific to innovating cartography

Innovating interactive representations encountered in European atlases

As already mentioned, the European atlases offer little innovation (in the sense defined in Tasks 3 and 4). Only two of the atlases analysed include representations using non-contiguous cartograms. In this type of cartogram, the outline of the territorial units is preserved, but the surface area is rendered proportional to the value of a particular indicator (Figure 7). While this method is at the expense of territorial continuity, it makes it easier to recognise the units in the territory under study.

Left: Mean ages in regions of Slovenia; the surface areas are proportional to employment rates (Source: Slovenia Statistical Office). Right: Holidays destination of Dutch tourists; the surface areas of the countries are proportional to the numbers of holiday-makers having stayed there (Source: Statistics, Netherlands).

Figure 7: Two examples of non-contiguous cartograms.

It is however important to underline that innovating technique are not necessarily useful for all types of data. The atlases proposing innovating presentations are often those that choose to present a map via a set of data, rather than using a single interface for all (cf. part 1.2.). In this instance, each map is liable to use different techniques, and both classic and innovating techniques.

Specific functions for innovation

- Transition to a different cartographic view.

Innovating representations can provide an original, interesting and attractive viewpoint for the data, but perusal is always a little difficult for non-experienced users. Interactivity provides two advantages: it can assist in interpretation, especially by way of tooltips and interactive legends; and in cases where several types of maps are offered, it enables the user to switch from the innovating mode of representation to a classic cartographic visualisation. This enables the user to find elements enabling localisation so as to understand the contribution of the innovation, or else to avoid using the innovating mode if it does not suit his or her purposes.

- Transition to a non-spatial viewpoint.

A non-spatial representation presents data in graphic form (histogram, bar diagram, pie chart, curve etc). This graphic representation can be used in several ways: in certain cases it corresponds to an alternative presentation of the data. But in this case the spatial dimension is not predominant. In other cases the graphic representation is associated with a spatial view, and the two are viewed simultaneously. Here the two views complement one another.

- Exploring the "inside" of geographical entities.

The elementary zoom function enables the enlargement or reduction of the map, but does not provide any extra information. A zoom function innovates if it consists in displaying more detailed information (de-aggregated), or in providing access to new information or new representations.

- Changing the cartographic projection (2D) or the angle of viewing (3D).

- Applying a distortion to the geographical space (cartogram, 3D)

- Animation (temporal or otherwise)

- Fly-over.

This function, which is applied to the visualisation of ortho-images, aerial views, or virtual cartographic environments, enables a 3D view of the image to be obtained and displacement above the image (hence "fly-over").

In conclusion, the study presented here focuses on interactive atlases and catalogues presenting territorial statistical data. These atlases all possess elementary functions enabling navigation on the map, and access to spatial data. They differ to the extent that they present the themes and the datasets, and in the number of functions they offer for exploring and personalizing data.

Some of them offer innovating, original cartographic representations. The most interesting from this point of view are atlases using technologies and modes of representation that differ according to the data-set represented.

Other innovating interactive representations do exist, but they were not encountered in the corpus analysed here. Indeed, any original static representation can be enhanced by interactivity. The dynamics can go even further by offering the option of personalising elements on the map, or of scrolling through different animations, whether temporal or statistical.

Part 2

Examples of interaction and animation on maps

In this section we propose to start from the different types of cartography presented in Task 4 and to analyse the scope for appropriate and reasoned introduction of interaction and/or animation functions. Our proposals take the form of recommendations. Several possible options are proposed. Obviously the intention is not to produce and exhaustive list of solutions, since combinations are numerous, and they of course depend on objectives.

We first return briefly to the list of functions that are at present on standard offer for the design of dynamic maps. Then, for each type of map, there will be a summary sheet containing one or several suggestions for making a dynamic map useful and with improvements as compared to a static version.

2.1. Types of interactivity according to modes of representation

Making a map "dynamic" consists in endowing it with some form of interaction and/or animation: the map will change or even show motion.

Types of interactivity

Four types of interactivity can be defined:

• Generic interactivity: this refers to functions that have become standard, and that all users expect when they access a web page comprising an image, whether or not it is a map: these functions are panning, zooming, overview, highlight and selection of territorial units.

• Design interactivity: This enables the user to customise the base map or the elements of the map (colours, symbols, and even discretisation).

• "Vertical" interactivity: this consists in considering the map as the superimposition of layers that can be displayed independently one from the other, where each layer amounts to a coherent vector entity (for instance the layer containing the rivers, the borders, or the capital cities).

• "Horizontal" interactivity: this consists in changing the geographical reference (territorial divisions), or in shifting from one cartographic mode to another (for instance shifting from a choropleth map to a cartogram, or from a proportional circle map to a 3D perspective view, etc).

It can be noted that the introduction of interactivity provides the user with a degree of freedom: the greater the scope of the interactivity is, the more difficult it is to completely control the original representation, and to ensure compliance with the graphic semiology rules determining content of the message delivered. The following proposals do not take this aspect into account.

Another dimension is however taken into account in our proposals: that of the purpose of the map. According to previous discussion, two main purposes are differentiated: thus our proposals can differ according to whether we are dealing with a map designed for presentation or one designed for exploration.

From standard to advanced functions

The generic interactivity functions are not discussed in what follows. We begin with those specific to cartography; and naturally, the advanced functions used for a dynamic map need to be defined in relation to the purpose of the map, its target audience and the message to be delivered, which are decided on, when the mode of visualisation is chosen. These different criteria have been discussed in task 4. Here our aim is to show the contributions of interactivity in terms of communication power.

Starting from nine "families" of maps described in the task4, we propose to illustrate possible "upgrading" using 12 generic functions belonging to the 3 types of interactivity, other than the basic one, presented above:

• Interactivity related to the cartographic styling.

- Colour-symbol: in this category we group all the functions relating to cartographic choices affecting the appearance of the map – choice of the colour palette, shape and size of symbols.

• Vertical interactivity: this type contains functions entailing interactivity either with a large number of pre-designed maps or with data

- composition: scope for overlaying elements of information (borders, river basins, land use, in transparent mode).
- tooltips: display of contextual information in tooltip-type "bubbles" when an entity is selected or when the mouse is positioned.
- discretisation: scope for changing the mode of discretisation.
- reference (statistical): scope for changing the statistical reference (shifting from raw values to standardised values, from standard deviation to deviation from a different reference value, etc).
- choice of indicators: access to metadata in the database and scope for choosing the theme to be represented.
- selection, contextualisation: simultaneous access to other elements in the database, and contextualisation of the entities selected on the basis of other statistical elements.
- graphic elements: display of synchronised statistical graphic elements complementing the cartographic view.
- filtering: selection of data to be displayed (via window or legend).
- navigation: the ability to navigate across the image in virtual reality mode.

• Horizontal interactivity

- territorial divisions: changes in subdivisions or grid used to obtain a view with a different resolution.
- switching: between two mode of representation. This generally corresponds to a change in geographical reference.

Interactivity scenarios

Using the list in task 4, we have collated different map types according to the categories of functions targeted. For example the first category assembles the types of map that constitute reference cartography methods. The proposals concerning this category of maps therefore **relate to standard functions, which are not returned to for the other map types**, except where they cast a particular light.

Type of interactivity	Purpose of interactivity	Choropleth, Symbol, count, ratio	Grid	Flow	Isopleth	3D, prism, extruded, Smart projection	Cartogram, Dorling	Discontinuity	Dot density	Animation, story telling
Map styling	Colour, size, symbol	X	X	X	X	X		X	X	
Vertical	Composition	X	X		X		X			X
	Tooltips	X	X	X		X	X		X	
	Discretisation	X	X		X	X		X		
	Reference (stat)	X	X			X				
	Choice of indicators	X	X							
	Contextualisation	X	X	X				X	X	
	Graphic elements	X	X	X			X			
	Filtering	X	X	X						
	3D Navigation					X				
Horizontal	Subdivisions, grid		X			X	X	X	X	
	Transition/Switch	X	O>	O>	O>	O>	O>	O>	O>	O>

Table 2: Type and purpose of interactivity

Animation

It seems to us a major asset in map-making, but it may be seen from different point of views:

- First of all, it is really connected with question, for the ability to shift from the "classic" map to an innovating representation. For instance, it has been seen how the use of anamorphosis to illustrate accessibility is not easy to read, because it upsets the classic representation of the geographical space. An animated visualisation enabling a switch from the standard map to the anamorphosis map enables the distortion to be apprehended, and better identification of the places that are "further away" and those that are "nearer" (i.e. places that are functionally less well served than others, whatever their localisation. The same consideration applies to a shift from a 2D isopleth map to a 3D map: shifting to 3D does not in itself contribute anything, since it is generally used to emphasise a variable that is already represented. But seeing a representation of the relief enables return to a continuous scale (an isopleth map is discontinuous); the same information is presented, but in 3D, and differences are easier to perceive. The last line in the table relates to this aspect. As we proceed, information will be provided on animations enabling a switch from an innovating presentation to a standard representation, useful from a cognitive point of view.

- The second aspect is the ability to show story and scenario. This dimension is treated separately in the last summary sheet.

- And finally animation, as already remarked, can concern semiological elements (blinking cursor, sets of symbols associated with selected entities, etc). All these elements are also very useful, because they enable an enhancement of the message, organisation into a hierarchy of information and asynchronous perusal of the information. This will not be specifically discussed because it opens on discussion on semiology, which is not the purpose here. Only some examples will be discussed in the last summary sheet.

Choropleth maps, typology maps, (segmented) proportional symbol maps, count & ratio maps

Insights

In task 3 we looked at the different trends increasingly integrating cartography into environments enabling the user to be active, by providing elements to stimulate questionings. The table below provides a few examples of the functions that are now part of the dynamic cartography standard offer. We will not consider them in systematic manner: overall these tools enhance maps by enabling the user to adopt new viewpoints, either by altering the appearance, or by searching data and producing new representations via changes in the variables used or changes in the territorial grid or subdivisions. By using and comparing different views, the user explores different spatial distributions and thus may find elements of understanding. For instance the ability to mask or display boundaries can for instance show that there is a "regional" effect, or an effect of distance from waterways. The table below gives the most significant examples of these options.

Proposals

In bold: the most innovating functions

Type of inter-activity	Purpose of interactivity	Choropleth, Symbol, count & ratio maps
Design	Semiology: colour, symbol	Any form of interactivity enabling the user to adapt the map to his/her perception and to improve readability
Vertical	Composition	Enables elements to be added to the map (place-names, borders, rivers etc) for purposes of localisation or for exploration of certain forms of organisation
	Tooltips	Displays extra information (names of entities, exact values if the map is discretised) on demand (click, flyover)
	Discretisation	Enables changes in the number of classes, in class boundaries or in the method of discretisation
	Change of reference (stat)	**Enables a viewpoint relating to a different statistical reference (move from raw values to standard values, from standard deviation to deviation from a reference value)**
	Choice of indicator	Enables other themes to be explored

	Contextualisation	Provides interpretation elements relating to correlations or concomitance with other variables
	Graphic elements	Enables the construction of a-spatial statistical views, and further exploration of hypotheses.
	Filtering	Enables sub-groups of homogeneous entities to be identified in relation to a given factor
	Navigation	
Horizontal	Change in subdivision/grid	
	Transition/switch	Switch between all these types of cartography, according to the type of the variable to map

Examples

Purpose of the map/ type of the map	Functions	Examples on the web
Presentation / Choropleth map	Changing the colours in the legend Changing the territorial divisions	http://www.wnyc.org/articles/wnyc-news/2013/mar/05/mega-commuters-take-manhattan/
Exploration / Choropleth map :	Changing the discretisation Graphic zone locating one zone in relation to other zones and to the average value. Changing the reference value (e.g. an arbitrary value rather than the mean of the entities)	http://stats.oecd.org/OECDregional statistics/
Presentation / Symbol map	Variation of minimum and maximum size of entities Displaying or masking territorial unit boundaries to combine spatial and territorial views Adjusting the transparency of circles	http://www.guardian.co.uk/environment/interactive/2013/apr/19/countries-exposed-carbon-bubble-map
Exploration / Symbol map	Filtering: displaying only the circles between a minimum and a maximum value Viewing symbols as a graph	http://www.gapminder.org/world/ http://tulpinteractive.com/close-votes/
Presentation / Count-ratio map	Same functions as for proportional circles Choosing from a list of indicators determining size and colour of the circles	http://www.cbeventoux.com/images/cartes/potentiel_conso/equipement_informatique.htm

Exploration / Count-ratio map	Same functions as for proportional circles	
Presentation / Typology map	Histogram for the values of each unit compared to mean values at different level Changing the colours in the legend Displaying or masking upper level boundaries Contextual information: cities, rivers, etc.	http://www.espon.eu/main/Menu_ToolsandMaps/ESPONHyperAtlas/
Exploration / Typology map	Select different number of types	Philcarto http://franceo3.geoclip.fr/#v=map12;i=pop.cataeu10;l=fr http://www.histoire.ac-versailles.fr/IMG/swf/europegv.swf

How interaction and animation may improve some identified weaknesses of static maps

Symbol maps

- Super-imposing of circles
- Displacement of circles leads to inaccurate localisation
- Administrative regions difficult to identify

Segmented symbol maps

- Not suited to large numbers of territorial units
- Difficult to determine the right size for circles
- Comparison of respective weights not possible for small circles

Choropleth maps

- Representation not suited to heterogeneous territorial divisions
- The scale of the phenomenon is not taken into account
- Manipulation of data via choice of discretisation

Count & ratio maps

- Overlap of circles
- Colour variations may not be legible

➢ Functions relating to appearance enable the property of "transparency" to be introduced. Combined with selection or filtering functions, this enables higher values to be selected and displayed in transparent form.

➢ Transparency

➢ Scope for enlarging or reducing the circles
➢ A graph crossing the two phenomena can help to integrate the heterogeneity of two distributions

➢ Switch to continuous representations of space or to new subdivisions

➢ Cumulative graphic element
➢ Discretisation is interactive

➢ Transparency
➢ Selection of groups of items in the legend to highlight a class of entities

Grid maps

Insights

Grid maps are particularly well-suited to changes in resolution: changes in subdivisions or in grid enable the spatial organisation to evolve, and they have a "smoothing" effect on the distribution. In addition, where it is possible, switching from a choropleth map to a grid map enables the problems posed by heterogeneous territorial divisions to be solved, without losing the links with territorial boundaries. All the other functions noted for choropleth maps are also valid for this type of representation.

Proposals

Type of inter-activity	Purpose of interactivity	Grid maps
Design	Semiology: colour, symbol	(cf. choropleth map)
Vertical	Composition	(cf. choropleth map)
	Tooltips	(cf. choropleth map)
	Discretisation	(cf. choropleth map)
	Change of reference (stat)	(cf. choropleth map)
	Choice of indicator	(cf. choropleth map)
	Contextualisation	(cf. choropleth map)
	Graphic elements	(cf. choropleth map)
	Filtering	(cf. choropleth map)
	Navigation	
Horizontal	Change in subdivision/grid	**The change of subdivision corresponds here to a change of resolution**
	Transition/switch	**<•> choropleth map <•> Isopleth map**

Examples

Purpose of the map	Functions	Examples on the web
Presentation	Change in grid resolution Display/remove regional boundaries Change colors in the legend <•> Transition to a smoothed map <•> Transition to an extruded map	http://www.poissons-afrique.ird.fr/faunafri/
Exploration	Filtering by selection in the legend	http://phyto-afri.ird.fr/carte_accueil/flash/

How interaction and animation may improve some identified weaknesses of static maps

From static to dynamic

The method depends on the underlying administrative divisions

As a result of the ability to change the grid, the number of views is increased, and this enables bias resulting from the reference administrative subdivisions to be highlighted

Flow maps

Insights

Mapping flows is fairly difficult to perform effectively. Depending on the phenomenon, there can be very numerous flows, or they can be organised in such a way that they overlap and become illegible. Interactivity functions can here again facilitate interpretation, depending on the purpose:

- If the purpose is the presentation, it is possible to reduce the number of elements on the map by displaying contextual information only when the mouse overfly a specific flow, such as the names of origin and destination, the value of the exchange in absolute and relative…
- If the purpose is the exploration, selection and filtering will be used to alternate views, and go from local to global distributions.
- In addition, since flows are associated with movement, the construction of scenarios and visualisation in animated form are particularly suitable (see Mapping Spatial scenario)

Proposals

Type of inter-activity	Purpose of interactivity	Grid maps
Design	Semiology: colour, symbol	(cf. choropleth map) Same functions for the flows
Vertical	Composition	
	Tooltips	Value of the flow – names of the origin and destination
	Discretisation	
	Change of reference (stat)	
	Choice of indicator	
	Contextualisation	Relative value (part of the flow in the count of origin...)
	Graphic elements	Histograms of the distribution of counts if more than one category of exchange
	Filtering	Filtering by origin, value, distance…
	Navigation	
Horizontal	Change in subdivision/grid	
	Transition/switch	**<•> 3D map**

Examples

Purpose of the map	Functions	Examples on the web
Presentation	Selection of a region to display only its partners Selection of a flow to obtain a detailed graphic view in a tooltip bubble (evolution if time series, position in a distribution by category if more than one category of exchange ...) Animation: displaying flows one by one, from largest to smallest (or the reverse)	http://www.neighbourhood.statistics.gov.uk/HTMLDocs/ITIS/index.html#UK,nat,from http://www.forbes.com/special-report/2011/migration.html
Exploration	Filtering: displaying only imports or only exports Filtering: displaying only flows exceeding a certain value of exchange (relative or absolute) Filtering: displaying only flows exceeding a certain distance Switch with representation without links when selection of one origin or one destination: representation dependency rate of the places that are strongly (>k %). Clicking on two countries to obtain a graphic comparison of their imports and exports. <•> 3D map : allow to use a supplementary dimension for very dense network of flows; very efficient for presentation of large volume of flows, or flows at a large scale	http://code.google.com/p/jflowmap/wiki/Flowstrates http://www.comeetie.fr/galerie/velib/index.html http://workshop.chromeexperiments.com/projects/armsglobe/

How interaction and animation may improve some identified weaknesses of static maps

From static to dynamic

- Positioning of the flows is complicated

- Display of contextual information in tooltip bubbles
- Animation

Isopleth maps

Insights

Isopleth maps have the advantage of representing territory in continuous manner, which most of the time is quite close to reality, since divisional boundaries are rarely seen "on the ground". However the problem in this instance is that localisation is difficult, and interactivity can remedy this without losing sight of the representation.

Proposals

Type of inter-activity	Purpose of interactivity	Isopleth maps
Design	Semiology: colour, symbol	(cf. choropleth map)
Vertical	Composition	Enables place-names and delineations to be added to the map
	Tooltips	
	Discretisation	Enables changes in the number of classes or in the method of discretisation
	Change of reference (stat)	
	Choice of indicator	
	Contextualisation	
	Graphic elements	
	Filtering	
	Navigation	
Horizontal	Change in subdivision/grid	
	Transition/switch	<•> choropleth map <•> 3D map

Examples

Purpose of the map	Functions	Examples on the web
Presentation	• Personalising the legend (choice of colours, discretisation method, number of classes etc) • Displaying/removing boundaries between coloured areas • Overlay with transparency others layers	http://www.londonheatmap.org.uk/Content/HeatMap.aspx
	<•>Switching from continuous to discretised surface <•>Transition to 3D view where high values are displayed as peaks and low values as hollows.	http://www.cartovista.com/CartoVista/CrimeAnalysis.aspx?Language=fr
Exploration	Filtering using the legend	http://www.cartovista.com/CartoVista/Montreal.aspx?Language=fr

How interaction and animation may improve some identified weaknesses of static maps

From static to dynamic

Administrative units cannot be identified Difficult to interpret	Facilitated by tooltip bubbles and scope for map composition Possibility to show administrative boundaries on demand

3D maps, Prism (or extruded) maps, Histo maps, Smart projected maps

Insights Whatever the map, 3D representations raise problems of legibility when projected in 2D. This produces a view in perspective in which, according to distributions, the "higher" elements in front can conceal the other elements. In fact only a spatial organisation in gradients is suited to this type of representation. In this instance, navigation options are particularly important, since they enable a view of the whole map. Indeed, depending on the type of spatial distribution they can be essential. In addition, navigation is a very stimulating element in apprehending a distribution: it places the user in a position of exploration via the artefact of "virtual reality". However the "semantic" relief requires situational elements, so that the tooltip bubbles are also essential. They mainly inform on peaks and hollows, but they can include other locations that are required for effective localisation.

Proposals

* main functions

Type of inter-activity	Purpose of the interactivity	3D, prism, extruded, smart projected maps
Design	Semiology : colour / symbol	Size and height of the symbols can be parameterised, colour palette can be changed
Vertical	Composition	
	Tooltips	Information on "peaks" and "hollows" by positioning the mouse
	Discretisation	Discretisation mode can be changed
	Change of reference (stat)	Scope for changing the 3D scale
	Choice of indicators	
	Contextualisation	
	Graphic elements	
	Filtering	
	Navigation	Flyover of whole territory with change in orientation*
Horizontal	Change of grid	Switch to a 3D grid map = extruded map
	Transition/switch	Switch to a 2D view

Examples

Purpose of the map/ type of the map	Functions	Examples on the web
Presentation / 3D map	Navigation : Change in orientation of the view (N-S) and inclination with respect to the vertical	http://www.time.com/time/interactive/0,31813,1549966,00.html
Exploration / 3D map	• Display of multiple layers and overlay with transparency • Flyover	http://www.londonair.org.uk/london/asp/virtualmaps.asp?view=maps
Presentation / 3D Histogram map	Rotation of the map around a central vertical axis Temporal animation, where heights in the graphic representation alter with time **<•>** Switch from a cartographic view to a graphic representation in the form of a histogram, ordered alphabetically or in increasing values	http://mappemonde.mgm.fr/num27/fig10/fig10302.html Example in 'Symbol map' (http://www.gapminder.org/world/)
Exploration / 3D Histogram map	Switching from one visualised indicator to another (number of working hours required to buy a short-stay visa, average wage/net salary per month, cost of the visa)	
Presentation / smart projected map	Change from sloping to vertical Switch to projection from the north Variation in the degree of transparency of the circles Switch from display of circles to display of numerical values Temporal animation with display of major geopolitical events in the zone on a timeline	See 3D map (http://www.time.com/time/interactive/0,31813,1549966,00.html)

How interaction and animation may improve some identified weaknesses of static maps

From static to dynamic

Administrative units cannot be identified	Scope for localisation from one point to the next via tooltip bubbles
Difficult to interpret	Navigation enables local and global views to be obtained

Cartogram maps, Dorling maps

Insights

Although the cartogram and anamorphosis families of mapping techniques are highly innovating and useful, by the way they are constructed they distort geographical space and thus are unsettling for the reader. Most of the time the shift is from a "chorotaxic" space (Cauvin, 1984) to functional spaces: the geographical representation is distorted (shrinking) in favour of a variable illustrating its functioning – wealth, accessibility etc. These maps can be difficult to decipher (in particular accessibility anamorphosis). Interactivity functions enable the re-composition of the map obtained, and re-establish links between the "distorted" entities and the classic representation.

Proposals

Type of inter-activity	Purpose of interactivity	Cartogram maps, Dorling maps
Design	Semiology: colour, symbol	
Vertical	Composition	All the elements of composition that facilitate places identification
	Tooltips	Names of places, evaluation of the deformation, display of the non-deformed area
	Discretisation	
	Change of reference (stat)	
	Choice of indicator	
	Contextualisation	
	Graphic elements	Link with a synchronized ordered distribution graph of the values
	Filtering	
	Navigation	
Horizontal	Change in subdivision/grid	Possibility of visualize another subdivision space.
	Transition/switch	<•> switch with the referential map

Examples

Purpose of the map/ type of the map	Functions	Examples on the web
Presentation / Cartogram map - anamorphosis	• Cartographic projection in a Euclidian space. The map distorts as the cursor is displaced across it. • Displaying/removing contextual information (capital cities, rivers etc). <•> Switching possible between the Euclidian view and the distorted view. Animation between the two states, automatic or progressive via a cursor.	http://www.carbonmap.org/# http://www.sasi.group.shef.ac.uk/worldmapper/animations/wm01to02.html
Exploration / Cartogram map - anamorphosis	Visualisation of territorial changes over time seen as pulsation Addition of a second indicator to produce a choropleth cartogram	
Presentation /Dorling cartogram map	• Tooltip bubbles attached to each circle displaying actual outline of the country • Displaying oceanic and sea zones so as to distinguish coastlines <•>Transition from a graphical view to a geographical view, with countries as background, to obtain a proportional circle map	http://www.datadrivenconsulting.com/js/protovis/cartogramemp.html http://www.jeromecukier.net/blog/2011/03/26/la-carte-des-cantonales/
Exploration / Dorling cartogram map	• Selection of several countries to compare their data in graphic form • Shifting from a view of the circles ordered geographically to a graphic view where they are ordered according to values (line, circle etc)	Example in 'Symbol map' (http://tulpinteractive.com/close-votes/)

How interaction and animation may improve some identified weaknesses of static maps

From static to dynamic

Cartogram maps

Administrative divisions are distorted and cannot be identified

Difficult to localise entities on the map

Dorling cartogram maps

Not suited to large numbers of territorial units.

Topology is lost

Tooltip bubbles can enable localisation

Filtering and selection can be useful, as can transparency effects

Scope for displaying topology

Discontinuity maps

Insights

The innovating aspect of discontinuity maps is that it is symbols that form boundaries. In this case, interactivity tools linked to the cartographic design (semiology and discretisation) are particularly useful. They enable identification of the best suited semiology to show regional effects.

Proposals

Type of inter-activity	Purpose of interactivity	Dicontinuity maps
Design	Semiology: colour, symbol	(cf. choropleth maps) and all the functionalities that are useful for changing the display of lines Animation of discontinuities as symbols : flashing, transparency
Vertical	Composition	
	Tooltips	
	Discretisation	Change the method of discretization in order to highlight some pattern of discontinuity
	Change of reference (stat)	
	Choice of indicator	
	Contextualisation	Possibility of visualizing exact values of contiguous units; visualizing contextual data
	Graphic elements	
	Filtering	
	Navigation	
Horizontal	Change in subdivision/grid	Display of the same discontinuities at different geographical levels
	Transition/switch	<•> switch with the 3D map <•> switch with the anamorphosis map

Examples

Purpose of the map	Functions	Examples on the web
Presentation	• Tooltip displayed on the zones of discontinuity showing values and rank in the overall distribution, with histograms for instance. • Change in appearance of the lines symbolizing discontinuities (thickness, colour , discretisation) • Displaying/removing boundaries between entities **<•>** Transition to an anamorphosis where discontinuity is symbolised by a proportional space between contiguous entities.	http://aire.ums-riate.fr/
Exploration	Displaying/removing contextual information - cities, rivers, relief Temporal animation showing countries per year of entry to the EU, to explore the possible historical causes of discontinuities **<•>** switch with the 3D map	Didelon-Loiseau C., Lambert N., De Ruffray S., "Hard" and "soft" continents in world mental representation. Methods of analyse and visualization. ETCQG 2013 p81

How interaction and animation may improve some identified weaknesses of static maps

From static to dynamic

Discontinuities differ markedly according to the territorial divisions used

Exploration of the pattern obtained by changing geographical level.

Dot density maps

Insights

This kind of map is designed to give information of quantity, in the form of dot densities per territorial subdivision. The scale of subdivision is therefore an important parameter, as well as the quantities of dot per surface units, representing the maximal and minimal values. Interactivity enables the user to customise these parameters, regarding his representation aim. The main issue encountered in this map is that dots are randomly spread on the zone, sometimes all in the same place. Interactivity can enable to reload the spreading of dots until the visual result is satisfying.

Proposals

Type of inter-activity	Purpose of interactivity	Dot density maps
Design	Semiology: colour, symbol	Change of maximal and minimal number of dots per territorial unit, or colour of dots
Vertical	Composition	
	Tooltips	Give information to confirm the visual impression of dot density
	Discretisation	
	Change of reference (stat)	
	Choice of indicator	
	Contextualisation	Grid or subdivision used to spread the dots
	Graphic elements	
	Filtering	
	Navigation	
Horizontal	Change in subdivision/grid	Change the scale of subdivision to distribute the dots differently
	Transition/switch	**<•> proportional symbols maps <•> isopleth maps**

Examples

Purpose of the map	Functions	Examples on the web
Presentation	Show borders of territorial units Change the colour of background and dots Change the subdivision of the territory to spread the dots Transition to a proportional symbol map	http://www.daylightmap.com/?hl=en Philcarto

How interaction and animation may improve some identified weakness of static maps

From static to dynamic

Need for local data and local territorial subdivisions	**Show borders of the subdivisions on-demand to assess the quality of spreading**
Random dots spread	**Reload random dots spreading**

Mapping spatial scenarios

"Good data visualization is all about telling a story." J. Steele & N. Iliinsky (2011)

Proposals

For mapping spatial scenarios, the contribution of animation is obvious. It enables the elements in the scenario to be displayed according to a hierarchy, with or without temporal links. This guides and assists the user in a mental process that is in all events required to understand the representation. Elements can appear and disappear, and symbols can be animated to back up the chosen semiology. Examples are numerous. We just list some diversified examples from history to some scientific demonstration. The last example illustrates how semiology may be used in different way and leads the highlights of the story.

Examples

Purpose of the map	Type	Examples on the web
Presentation	The story	http://www.nola.com/katrina/graphics/flashflood.swf
	Prospective map	http://www.cauedordogne.com/images_contenus/1_CONNAITRE/urba_isle_anim.swf
	Synthesis map	http://www.cartomouv.parisgeo.cnrs.fr/index.php?page=anim&page2=map5

How interaction and animation may improve some identified weaknesses of static maps

From static to dynamic

The information represented is complex and interpretation is lengthy

Complex knowledge need to be organised and synthesised

Animation provides a breakdown into simple elements
Animation of symbols enables organisation into a hierarchy of elements on the map
Repeat animations allow to understand and learn

Part 3

Review of the main computing technologies used in interactive web maps

To produce online interactive maps, several technical choices need to be made:

- the choice of the programming language in which to publish the map – this will have an effect on the level of interactivity, the aesthetics and the general appearance.

- the choice of whether or not to use function libraries and/or generalist software. There are already numerous computing developments, and they can be used to create, publish or merely visualise maps.

- the choice of the software to use to develop the map: depending on the programming language and the software used, the map can be produced by computer programming a soon as it is published, or beforehand using software that produces classic statistical maps. This software can be GIS software, vector graphics software, or specific software in the case of particular cartographic representations (cartograms, 3D maps, etc).

- if the interactive maps is to be based on dynamic interaction with a database, the choice of a cartographic server to transfer the data from the database to the online map.

This section presents different technologies available to publish interactive maps on the Web, and software and libraries enabling innovating cartographic productions.

3.1. Programming languages

The technologies used to produce interactive visualisations on websites vary widely, although two of them dominate the field because they are long-standing: Flash and JavaScript (see Figure 8). Often, interactive visualisations combine several of the technologies listed below, and sometimes the trio HTML5-SVG-Javascript.

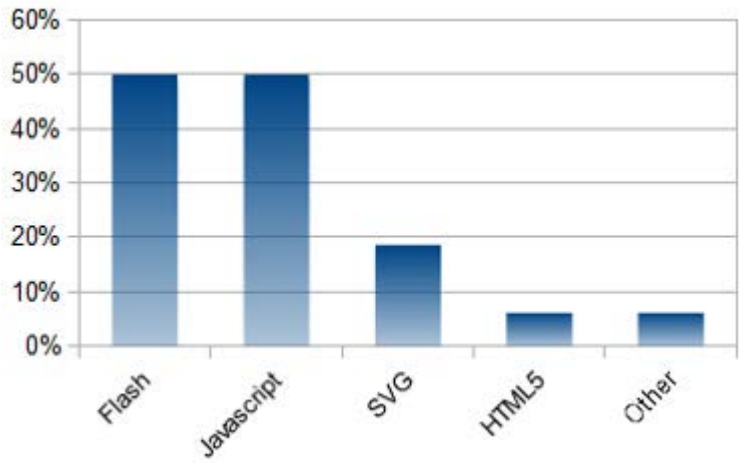


Figure 8. Frequency of use of interactivity technologies in European interactive atlases (several can be used simultaneously)

- **Flash** is proprietary programming software issued by Adobe. It has been in existence since 1986. It is used to integrate animations and interactive objects in Web pages.

  Since 2004, a new language called **Flex** was developed on the same base as Flash. Their aims are different: Flex is more dedicated to applications programming while Flash is more adapted to animations and web design. So, many developers keep using Flash, mainly because it enables to create custom functions when they do not exist in Flex.

Advantages	Drawbacks
Smooth and aesthetic appearance of animations	The loading time is long for the launch of the application
Easy to use	Not suitable under all operating systems (especially Linux)
Many interactivity and animation functions	Each user has to install a plugin in his web browser to read this language
	Not suitable for pads and smartphones
	Purchased software, requiring licence

Table 3: Advantages and drawbacks of Flash

- **JavaScript** is a programming language used on websites to interact with objects on HTLM pages (HTLM is the language that describes the structure of web pages). It has been in existence since 1995. It is widely used to make web pages dynamic (it is one of the motors in Web 2.0). However the aesthetics of animations produced with JavaScript are rather restricted. To go further, it needs to be coupled with other technologies, such as HTML5 or SVG for the graphic aspect of the page, while JavaScript assumes the role of animation engine.
-

Advantages	Drawbacks
Many interactivity functions (especially via APIs)	Aesthetic appearance of animations is limited
Suitable for the main recent platforms and operating systems	Compatibility issues with 'Internet Explorer'
	Execution speed depends on the user's computer and web browser

Table 4: Advantages and drawbacks of JavaScript

- **HTML5** (+ JavaScript): HTML5 appeared in 2012. It is a development from HTML language (which structures web pages) facilitating the inclusion of videos and dynamic content. It is used coupled with other technologies that manage part of the interactivity, such as JavaScript.

Advantages	Drawbacks
Simple and aesthetic animations (coupled with CSS 3)	Only suitable for recent web browsers
Many interactivity functions (when coupled with JavaScript)	Execution speed depends on the user's computer

Table 5: Advantages and drawbacks of HTML5

- **SVG** (+ JavaScript): SVG is a data format used to produce vector graphics. It has been available for use in web browsers since 2011, although the actual format was developed in 2001. On websites it enables the integration of geometrical objects, which may or may not be animated, into the page content. It is possible to use it in interactive setting with a language dedicated to interactivity such as JavaScript.

Advantages	Drawbacks
Image with high graphic resolution Simple and aesthetic animations Easy to use	Some features of animation are not suitable for every web browser Execution speed depends on the user's computer
Many interactivity functions (coupled with JavaScript)	

Table 6: Advantages and drawbacks of SVG

3.2. Libraries of functions

Today numerous Web sources offer ready-to-use libraries of functions, for the development of dynamic online maps. The purpose of these function libraries is to simplify the development of web applications by offering large numbers of ready-made functions. In this document, we distinguish between libraries that offer **interface services** (these libraries are sometimes called **API** - Application Programming Interface - but this term is debatable), and **other libraries**:

- Interface services libraries offer ready-to-use functions to create interface of visualisation. Thus, the main internet providers of interactive maps (Google, Michelin, Bing, etc) offer versions of their own cartographic API, and even "lend" their topographic data to map-developers.
- There are also numerous other libraries of functions (in JavaScript, Flash, etc.) dedicated to interactive visualisations or more specifically to maps, but that do not offer specific services or data.

Function libraries offer a basis for the development of interactive online maps, but unlike "turnkey" tools they do not do away with the need for programming.

Libraries of graphic functions

These libraries enable the development of interactive maps, the appearance of which is personalised and independent for each new map. Some of these APIs are not specific to cartography, and apply info-visualisation techniques to mapping (in the table below, they are called 'libraries for visualisation'). Others are dedicated to mapping, but can be modulated (called 'libraries for cartography'). The majority are written in JavaScript.

A few examples of libraries are quoted in the table below, but they are not an exhaustive inventory of what is available.

Libraries for visualisation, enabling the development of maps	*Libraries for cartography*
D3	*AmMap*
Processing	*Kartograph*
Weave	*Polymaps*

Table73: Libraries of graphic functions

Interface services libraries

These are function libraries that are more specialised than those quoted above. They generally provide a visualisation interface and sometime data (base maps for instance), in addition to the interactivity and animation functions they offer to mapmakers. Some of them are proprietary and entail data usage or confidentiality clauses that are variously restrictive (cost for commercial use, limited number of visualisation of the map per month, etc). A map designed using one of these tools cannot be re-used with a different tool, except in the case where it was designed with one of the few generic libraries.

These libraries can be classified in two groups: those that only offer functions and visualisation interfaces and those that also offer data. The generic libraries, which can be re-used in several other APIs, are classified apart. Here again, the list of APIs given in the table below is not exhaustive.

Cartographic API	Cartographic API that offer proprietary data	Generic inter-API libraries
Leaflet	Bing Maps	Mapstraction
Modest Maps	Google Maps	
OpenLayers	HERE Maps	
Mapbox	ViaMichelin	
	CartoDB	

Table 8: Interface services libraries

3.3. Generalist "turnkey" software

The so-called "turnkey" software does not require any particular computing skills or knowledge. These programmes enable the development of interactive maps which can then be integrated into web-pages to be accessed by a wide public. Most of them come with a cost, as they offer considerable services.

A distinction can be made between tools intended to present data and those intended for online exploration and analysis.

Presentation tools	Exploration and analysis tools
DataAppeal	ArcGIS Online
Geoclip	CartoVista
Statsilk	CommonGIS
Tableau Public	DynMap
	GeoViz Toolkit
	HyperAtlas
	InstantAtlas
	Spotfire
	Statistics eXplorer
	QGIS – webclient /LizMap

Table 9: Turnkey tools

3.4. Map servers

For an interactive map to use data from a database, a more complex software system needs to be installed, comprising a map server.

A map server is an application that takes geospatial data as input and renders graphical output in various formats. Although the Web server receives and processes the requests from the user of the map, it transmits requests for spatial information to the map server. The role of the map server is to find the requested data in databases and to send back formatted spatial data (Figure 9).

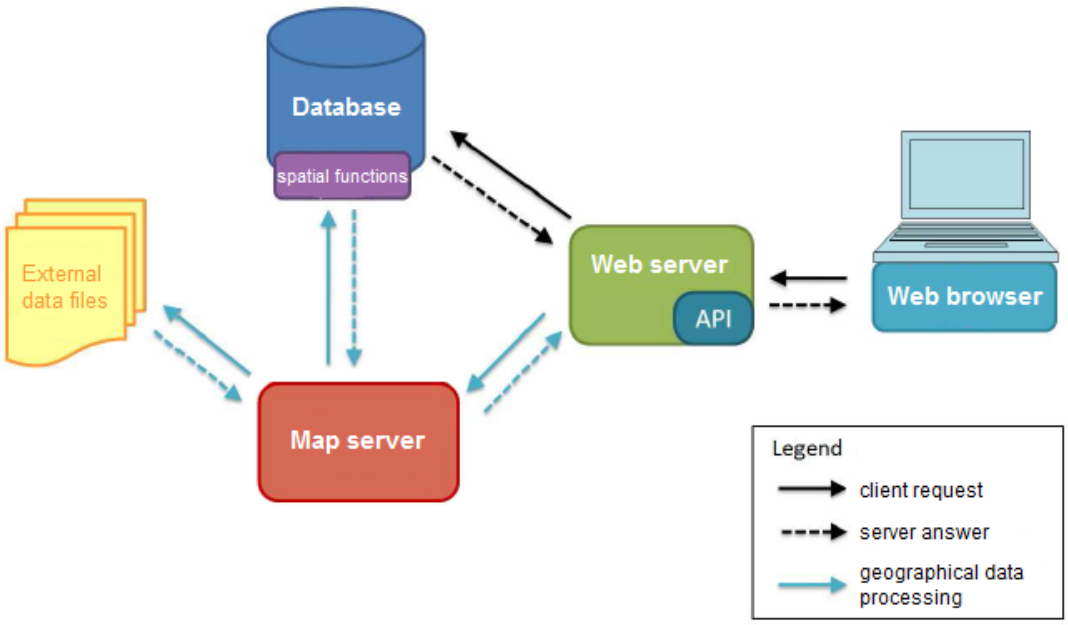


Figure 9: Software setup for online interactive maps to be dynamically linked to a database

When the user displays the interactive map on the browser, the map server will read and recognise the geographical data in the database, and then send it back to the interactive map via the web server coordinating the operation.

Map server	Advantages	Drawbacks
GeoServer	Open-source compliant with OGC webservice standards Presence of an administration interface Reads many data formats High execution speed	Limited choice in cartographic semiology
MapServer	Open-source compliant with OGC webservice standards Reads many data formats High execution speed	Configuration only with computer code (MapFile) Not compliant with WFS-T standard of OGC
QGIS-Server	Open-source Vehicle for WMS, WFS and WFS-T standards of OGC Configuration via QGIS interface (open-source software)	Patches required to manage vector files Not compliant with several OGC standards Few functions because the project is still recent
ArcGIS Server	compliant with many of OGC webservice standards Presence of an administration interface Configuration of map via ArcGIS software interface Many features High execution speed Technical back-up	Proprietary, under licence Only caters for shapefile and geodatabase data formats
MapGuide OS	Open-source Compliant with WMS et WFS standards of OGC Presence of an administration interface Reads many data formats	Not compliant with WFS-T et WCS standards of OGC Medium quality of display
Mapnik	Open-source High quality of image display Reads many data formats High execution speed	Not compliant with standard OGC webservices Configuration only with computer code (XML or Python) Few functions on Windows platform, because developed on Linux/Mac

Table 10: Advantages and drawbacks of MapServer

3.5. Software specific to cartographic innovation

Cartographic software rarely provides for innovating cartographic representations. To develop innovating maps and subsequently make them interactive, we need to resort to the technologies dedicated to the particular type of map.

Producing anamorphosis cartograms

Name	Type	Description
ScapeToad	Desktop software	Free and cross-platform software, needing an input geographical file and producing an output SVG file. This output file can then be included in a web page and made interactive with JavaScript.
MAPresso	Desktop or web software	Open-source application to generate interactive cartograms online.
Anaplaste	Desktop software	Cross-platform software to create piezopleth cartograms, i.e. cartograms where geographical space is distorted continuously, and not according to territorial unit.
QGIS cartogram creator	Desktop software	QGIS is open-source GIS software. It enables the creation of cartograms with the plugin 'Cartogram creator'. The output file is a geographical file, which can then be included in a webmap.
Cartogram.js	JavaScript API (based on D3 library)	Library of functions to generate interactive online cartograms from input files in TopoJSON format.

Table 11: Anamorphosis Cartograms software

Producing Dorling cartograms

Name	Type	Description
MAPresso	Desktop or web software	Open-source application to generate online interactive cartograms.
Protovis Dorling Cartograms	JavaScript API	Library of functions to generate Dorling cartograms online. The output cartogram can then be made interactive with JavaScript.
GeoDa	Desktop software	Software for advanced spatial analysis, including generation of Dorling cartograms. The result can be exported to a geographical file, to be included in a webmap.

Table 12: Dorling Cartograms software

Producing 3D maps

Producing online interactive 3D views requires the use of two successive techniques:
• a tool to create a 3D view
• a tool to visualise it on the web page and to render it interactive
Existing tools are often specialised for one of these tasks. Function libraries catering for both these tasks exist, and enable the creation and display of simple 3D images, rather less sophisticated than those produced by specialised software.

Different formats for 3D objects can be read on the Internet. The standard WebGL format is the most recent and the most versatile today, but there are others. It is also important to ensure that the output format of the 3D development software is compatible with the visualisation software.

Languages for describing 3D images:

Name of the format	Year of publication	Description
VRML	1994	VRML, or 'Virtual Reality Modeling Language', follows an ISO standard and enable to describe 3D scenes.
X3D	1997	X3D or 'Extensible 3D' is an open standard file format and run-time architecture, created by the Web 3D consortium, to represent and communicate 3D scenes and objects using XML. It should be compatible with HTML5 in the near future.
Shockwave	2001	Created by Adobe (private company), this is a programming language to create animations, like Flash, but suitable for 3D and interactive animations. It is viewable only with Adobe software.
WebGL	2009	WebGL is a language to create 3D views, based on OpenGL standard. It enables 3D views to be directly included in web pages, without having to install a plugin, using HTML5.
CSS 3D Transform	2012	CSS language is used to stylize HTML page objects. It implements features to give the impression of 3D by modifying the appearance of the elements in the page using geometric transformations: rotations, translations, dilations or perspective.

Table 13: Language for describing 3D images

Tools for creating 3D images:

Name	Type	Description
ArcScene	Desktop software	Part of the ArcGIS software range, ArcScene enables geographical files and elevation data to be combined to make 3D views. These views can then be exported in VRML format.
Adobe Director	Desktop software	Software from the Adobe range, enabling complex 3D interactive animations to be created, is using Adobe Schockwave language.
Blender	Desktop software	Free software to create 3D scenes, with numerous features.
Maya, 3ds Max, Softimage	Desktop software	3 professional programmes, created by Autodesk company, to make 3D scenes and animations. They differ by their features (animation, design, interactivity, etc) and the quality of display.
Cinema4D	Desktop software	Professional software by Maxon company, with fewer features than the Autodesk range, but equally versatile and cheaper.

Table 14: Tools for creating 3D images

Tools for online visualization of 3D images:

Name	Type	Description
Cortona 3D Viewer, Cosmo Player, BS Contact	Plugin VRML	These 3 plugins enable files in VRML format to be visualised interactively in a web browser. The most popular is 'Cortona 3D Viewer'.
Adobe Shockwave Player	Plugin Shockwave	Plugin by Adobe company, to include interactive 3D animations in web pages. It has to be downloaded by the user of the website.
Silverlight 5	Plugin Silverlight	Plugin by Microsoft company, cross-platform, an alternative to Adobe Flash Player. Came in 2011, its fifth version enables 3D visualisation. Silverlight applications are written in 'Microsoft .NET' language. The plugin has to be downloaded by the user of the website.
Three.js **(create + view)**	JavaScript API for WebGL, HTML5 or SVG	Open-source JavaScript library, which enables a scene to be drawn using the canvas of HTML 5, WebGL or SVG. The user does not need to install any plugin in the web browser.
O3D **(create + view)**	JavaScript API for WebGL	Open-source function library by Google company, using JavaScript and WebGL to introduce 3D in web pages. The user does not need to install any plugin in his web browser.

Table 15: Tools for online visualization of 3D images

CONCLUSION

Nowadays, the Web is an essential tool to make geographic information and cartographical data more widely known and give them more impact. The map is now an integral part of the Web. Technologies associated with maps have increased their capabilities of representation and expression of maps, enabling to animate, to consult and to explore them with interactivity tools. The association of graphical expressions with other Medias thus increases the power of maps. The development tools are more and more performing, enabling to create more and more complex applications, to deal with multi-scale and multi-dimensional data, and with multi-disciplinary and multi-format datasets.

In this Task, we made several recommendations and proposals to develop mapping applications. Our proposals address different objectives and needs that ESPON can face up: the diffusion or the use of this data by different operators. In a first part, we chose to establish recommendations on the building of interactive atlases, because we think that this type of environment suited particularly well to ESPON data and works. We tried to make recommendations according to the level of complexity of the atlas to be made, that have to be designed with a consideration for a specific target and an audience.

Interactive and innovative maps have been proposed also. They could be used in this atlas. The recommendations on interactivity functions are generic and can be applied in another context of development of mapping application, if the aims and the audience of the applications are identified. Nevertheless, the proposals of animation and interactivity of Part 2, in the file cards, are linked with the mapping representations coming from Task 4. Their uses in another context require further studies.

Finally we presented a sample group of development software and identified their strength and weaknesses. Nowadays, if informatics software aims at facilitating the development of innovative mapping applications, they have to be used in consideration of the audience that will use the application and its needs. Priority is always to be given to the public accessibility and understanding.

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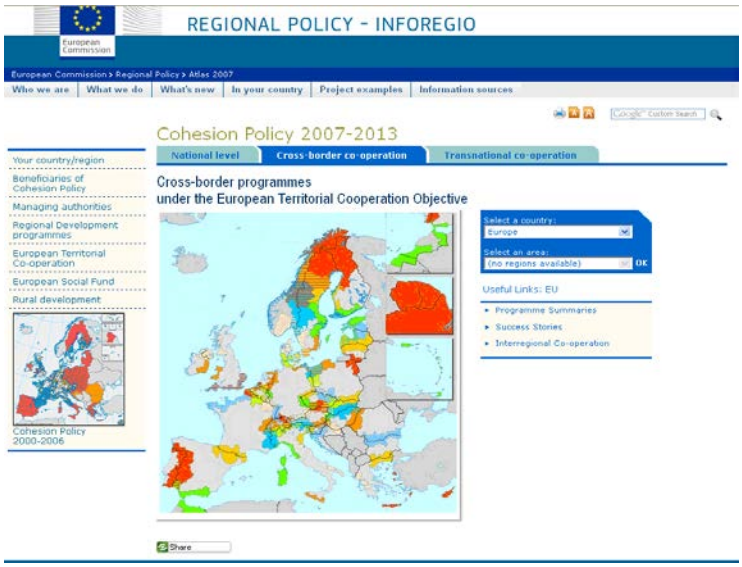
ANNEXE 1: REVIEW OF TERRITORIAL ATLASES ON OFFER FROM NATIONAL OR INTERNATIONAL INSTITUTIONS

<table>
<tr><th>Name – Link - Overview</th><th>Description</th></tr>
<tr><td>Regional Policy - InfoRegio

Cohesion Policy 2007-2013

 
</td>
<td>Atlas structure : Interactive maps structured via three tabs per theme:
1) Convergence, competitiveness and employment,
2) Cross-border cooperation,
3)Transnational cooperation.

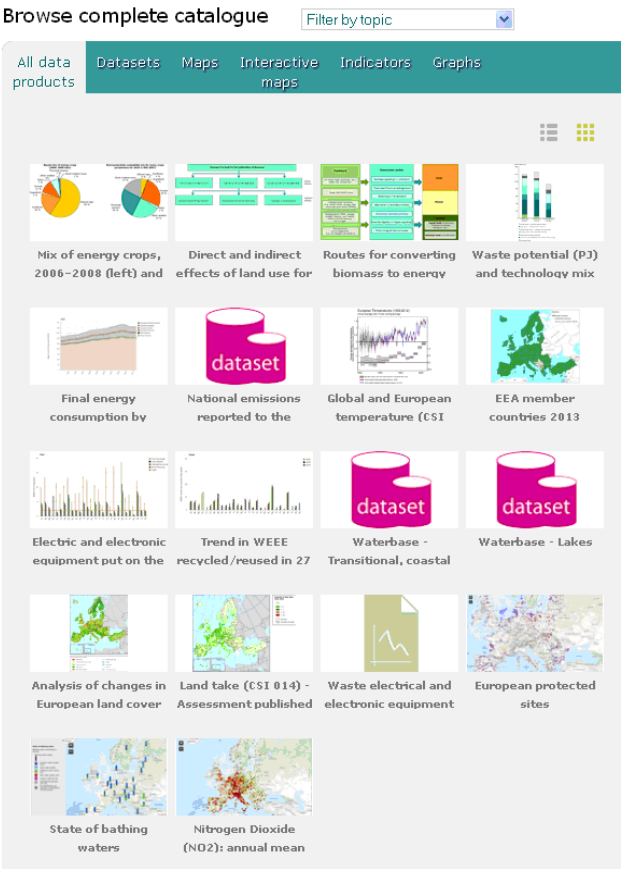
Technologies : HTML

<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Easy to use</td><td>- No functions for navigate in the maps (static maps)
- Little information provided in the map
- Not easily adaptable to show other thematic data</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Name – Link - Overview</th><th>Description</th></tr>
<tr><td>

European Environment Agency

Interactive Maps



</td><td>

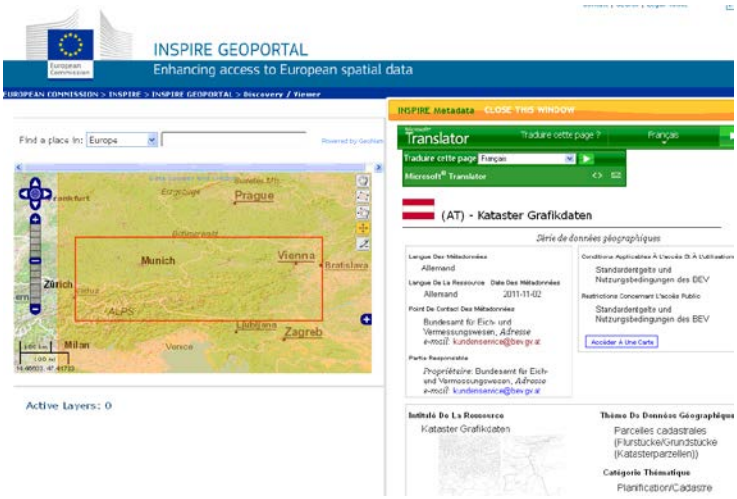
Atlas structure : Data catalogue of static and interactive maps, graphics, presented in miniature format. Each access to a map opens a new window.

Technologies : JavaScript (ArcGIS Online)

<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Standard navigation features
- Via the zoom, access to detailed levels of information
- Personnalisation du fond de carte et impression</td><td>- Only one type of interaction with the data : selection of a territorial unit</td></tr>
</table>

</td></tr>
<tr><td>

INSPIRE Geoportal



</td><td>

Atlas structure : Single page with 3 views:
1) central map on which a zone is drawn,
2) list of datasets for the zone,
3) layers selected and displayed on the map

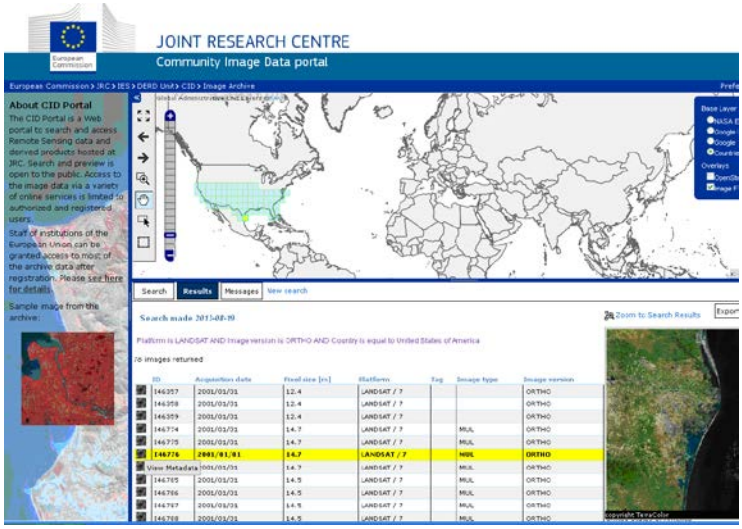
Technologies : JavaScript (OpenLayers)

<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Standard navigation features
- Adaptable and evolving</td><td>- Page structure not clear
- No interaction with the content of the datasets</td></tr>
</table>

</td></tr>
</table>

<table>
<tr><th>Name – Link - Overview</th><th>Description</th></tr>
<tr>
<td>Joint Research Center

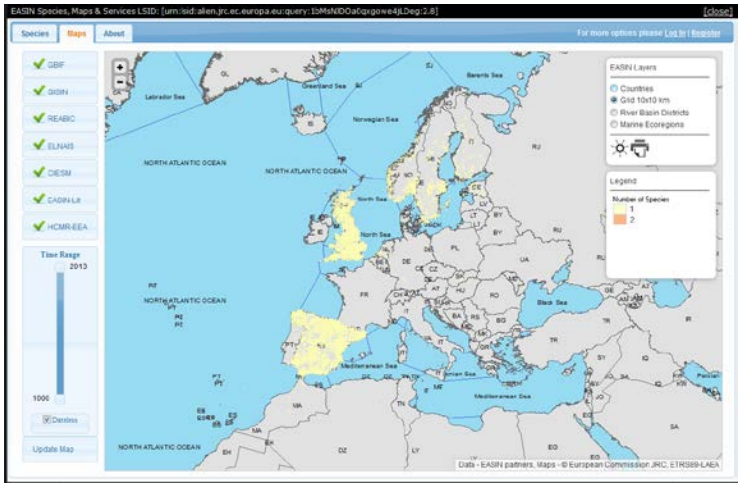
Community Image Data Portal

 
</td>
<td>Atlas structure : Interactive map alongside a text window with 3 tabs :
1) multi criteria search facility,
2) list of results of the search,
3) messages

Technologies : JavaScript (OpenLayers)

<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Standard navigation features
- Synchronization between the result list and the map
- Export of spatial data</td><td>- No interaction with the content of the datasets</td></tr>
</table></td>
</tr>
<tr>
<td>Joint Research Center

EASIN

  </td>
<td>Atlas structure : Interface for multi-criteria search to choose the data to display on the map. New window open with two tabs:
1) data and metadata,
2) map

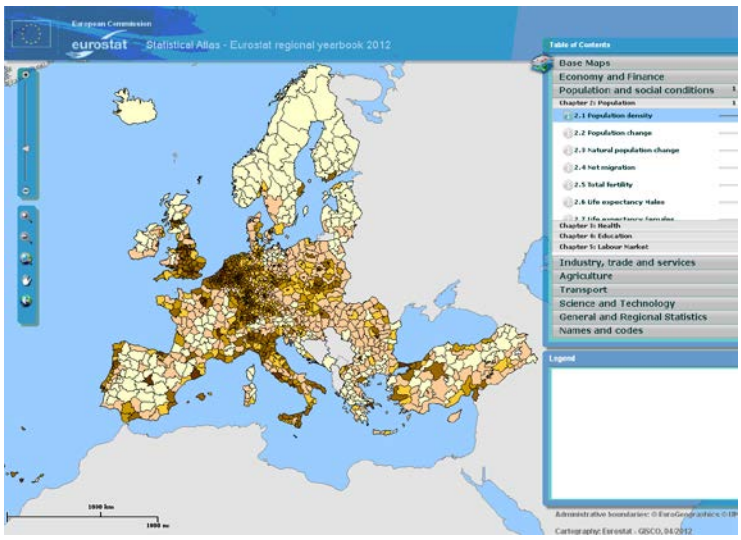
Technologies : JavaScript (MapLab Gmap Factory)

<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Standard navigation features
- Three grids available to see data
- Temporal filtering</td><td>- Only usable with inventory data</td></tr>
</table></td>
</tr>
</table>

<table>
<tr><th>Name – Link - Overview</th><th>Description</th></tr>
<tr><td>

Eurostat

Statistical atlas



</td><td>

Atlas structure : Choice of data within a cartographic interface.

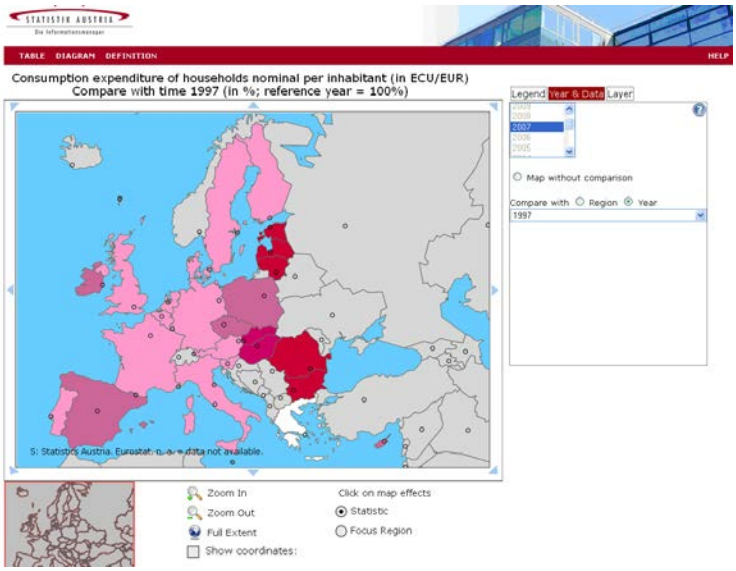
Technologies : Flex (API ArcGIS)

<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Standard navigation features
- Sorting of the content by theme
- Possible overlaying of spatial layers
- Export of maps</td><td>- No choice of territorial subdivision</td></tr>
</table>

</td></tr>
<tr><td>

Statistik Austria

Online atlas



</td><td>

Atlas structure : Choice of theme and then choice of data before the map is displayed.

Technologies : SVG, JavaScript

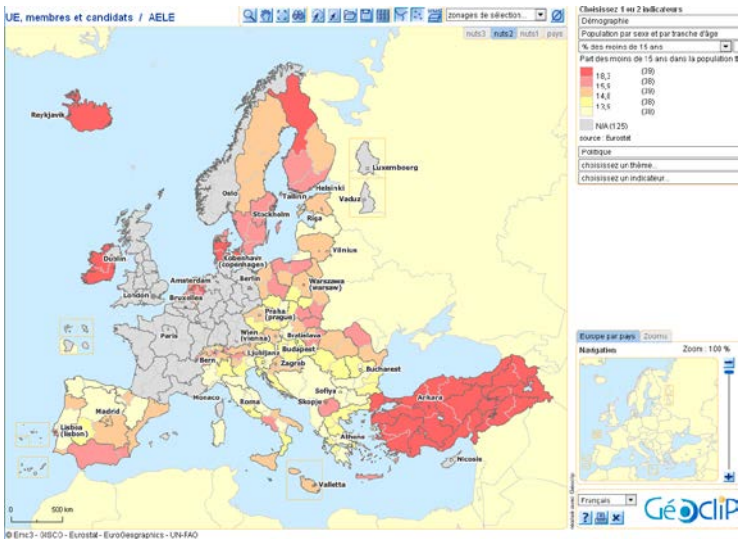
<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Different dates of visualisation
- Tables and histograms showing the data
- Comparative analysis between two dates, or with a reference region</td><td>- No choice of territorial subdivision
- Non-standard navigation features</td></tr>
</table>

</td></tr>
</table>

<table>
<tr><th>Name – Link - Overview</th><th>Description</th></tr>
<tr><td>

Géoclip

Europe



</td><td>

Atlas structure : Single window. Interactive map on the left, choice of indicators and legend on the right.

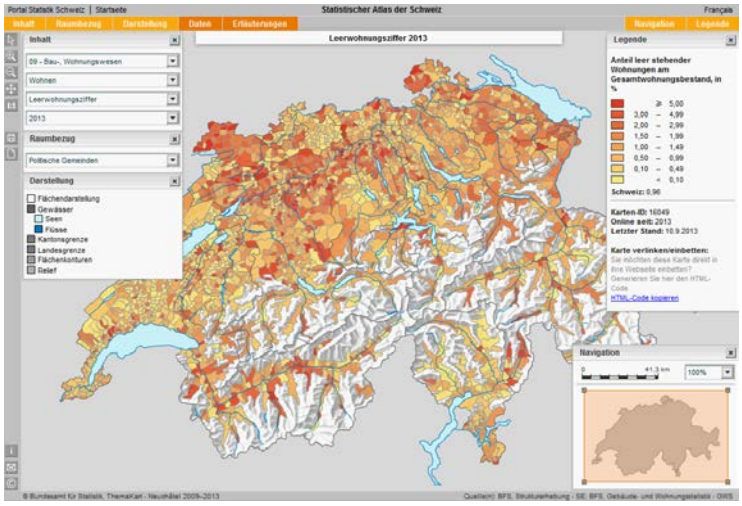
Technologies : Flash

<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Standard navigation features
- Possibility of overlaying two indicators
- Different dates of visualisation
- Choice of territorial subdivision
- Customisation of the legend
- Filtering of data through the legend</td><td></td></tr>
</table>

</td></tr>
<tr><td>

Atlas statistique de la Suisse

Stat@tlas



</td><td>

Atlas structure : Choice of data within a cartographic interface.

Technologies : Flash

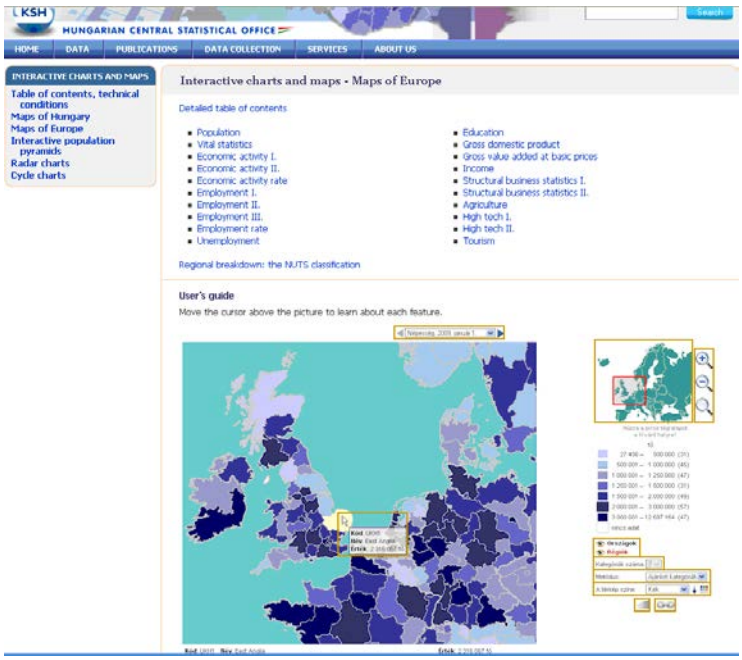
<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Choice of territorial subdivision
- Visualization of data scenarii instead of individual indicators
- Customization of the background and printing</td><td>- Non-standard navigation features
- Impossible to customize data scenarii</td></tr>
</table>

</td></tr>
</table>

<table>
<tr><th>Name – Link - Overview</th><th>Description</th></tr>
<tr><td>

Hungarian Central Statistical Office

Regions of Europe



</td><td>

Atlas structure : Choice of theme from a list, then access to the interactive map interface for that theme.

Technologies : SVG, JavaScript.

<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Choice of territorial subdivision
- Customization of the legend
- Situation of the countries via an histogram</td><td>- Non-standard navigation features
- Not easy to explore the maps by theme</td></tr>
</table>

</td></tr>
<tr><td>

Ireland AIRO/CSO

Census 2011 National Mapping Viewer

</td><td>

Atlas structure : Choice of data within a cartographic interface.

Technologies : Flex (API ArcGIS)

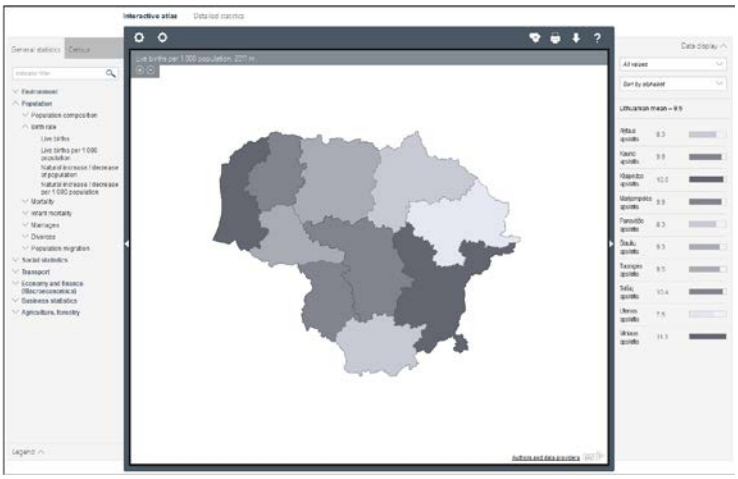
<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Standard navigation features
- Thematic graphic images by territorial unit
- Printing of the map
- Street View (Google)</td><td>- No choice of territorial subdivision
- The many themes make the exploration of the data not legible</td></tr>
</table>

</td></tr>
</table>

<table>
<tr><th>Name – Link - Overview</th><th>Description</th></tr>
<tr><td>

Statistics Lithuania

Interactive Atlas



</td><td>

Atlas structure : Choice of data in a column, generating the display of a map in the centre of the window.

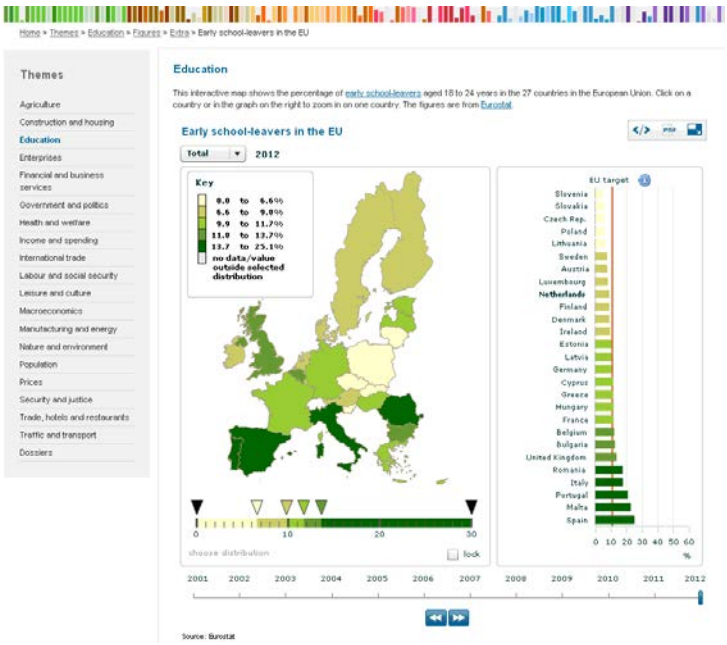
Technologies : JavaScript (API ArcGIS)

<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Standard navigation features
- Synchronous visualisation of several maps
- Simple temporal animations
- Filtering of data in relation to the mean
- Thematic graphic images by territorial unit
- Customization of the legend</td><td>- No choice of territorial subdivision</td></tr>
</table>

</td></tr>
<tr><td>

Statistics Netherland

Atlas



</td><td>

Atlas structure : Choice of theme and then choice of data before the map is displayed.

Technologies : Flash

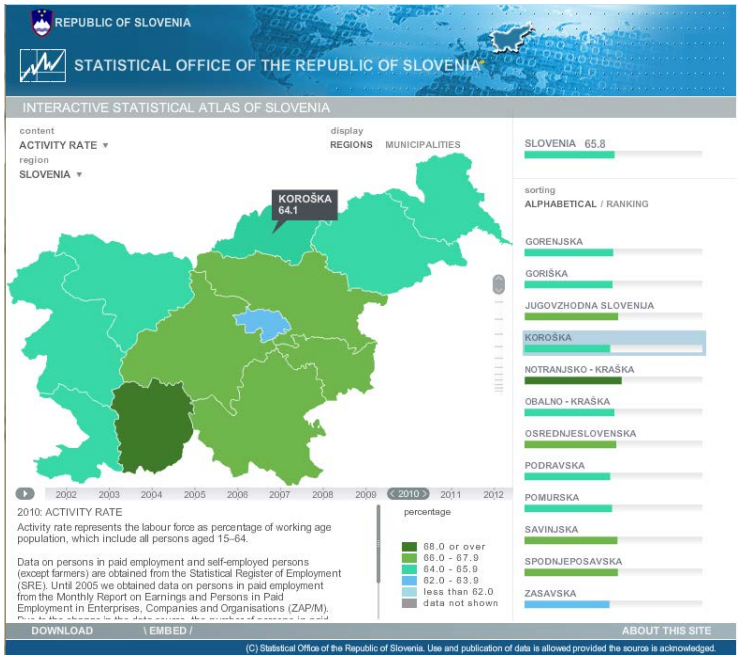
<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Possible change of classes in the legend
- Simple temporal animation
- Thematic graphic images by country</td><td>- Non-standard navigation features
- No choice of territorial subdivision</td></tr>
</table>

</td></tr>
</table>

<table>
<tr><th>Name – Link - Overview</th><th>Description</th></tr>
<tr><td>

Slovenia statistical office

Interactive atlas



</td><td>

Atlas structure : Choice of data within a cartographic interface.

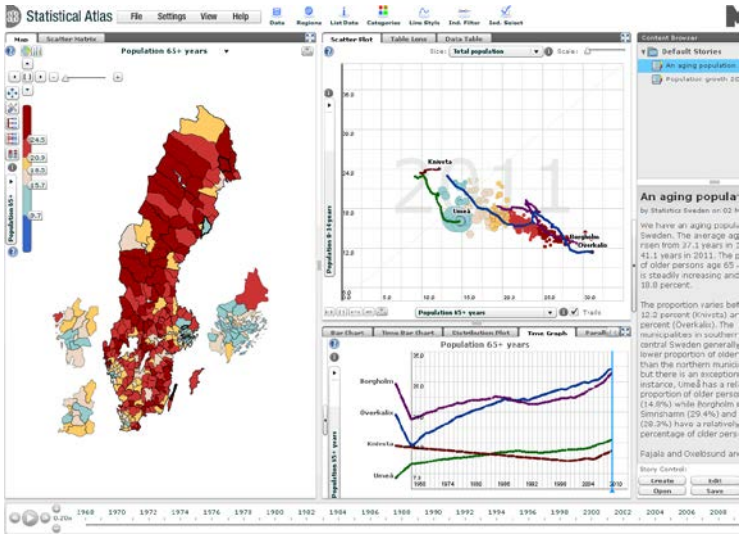
Technologies : Flash

<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Choice of territorial subdivision
- Simple temporal animation
- Thematic graphic images by territorial unit
- Export of the map or data
- Resize the map, by giving each unit a surface proportional to its value</td><td>- Non-standard navigation features</td></tr>
</table>

</td></tr>
<tr><td>

Statistics Sweden

Statistical Atlas



</td><td>

Atlas structure : Choice of data within a cartographic interface.

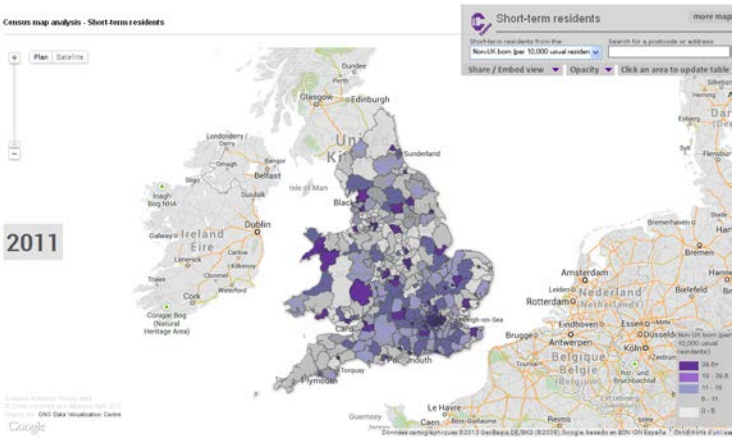
Technologies : Flash

<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Standard navigation features
- Customization of the legend
- Many graphic views
- Filtering of data
- Multi-selection of zones and graphical comparison</td><td>- No choice of territorial subdivision</td></tr>
</table>

</td></tr>
</table>

<table>
<tr><th>Name – Link - Overview</th><th>Description</th></tr>
<tr><td>United Kingdom National Statistics

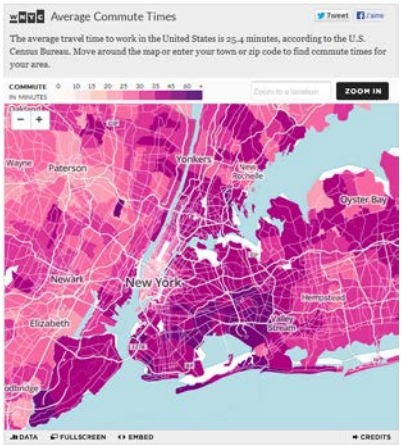
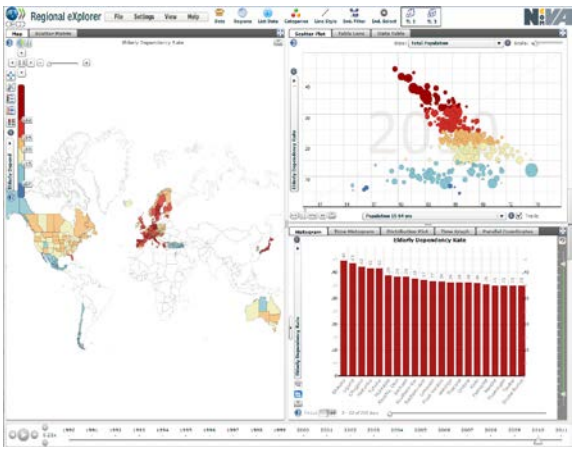
Interactive maps

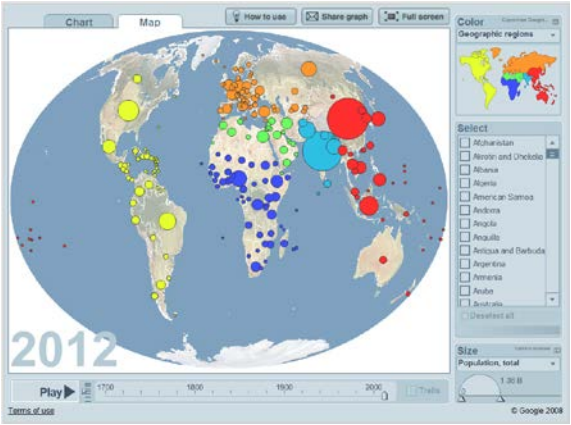
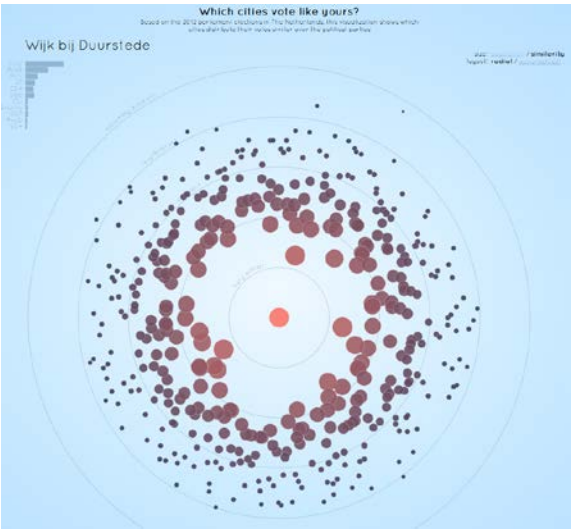
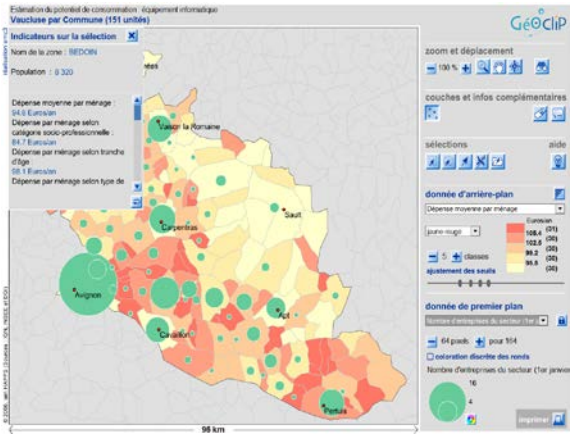
 
</td><td>Atlas structure : Maps classified by theme, mixed with interactive graphic images.

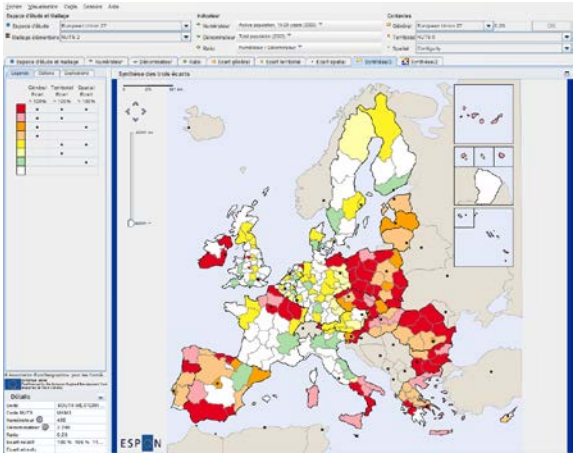
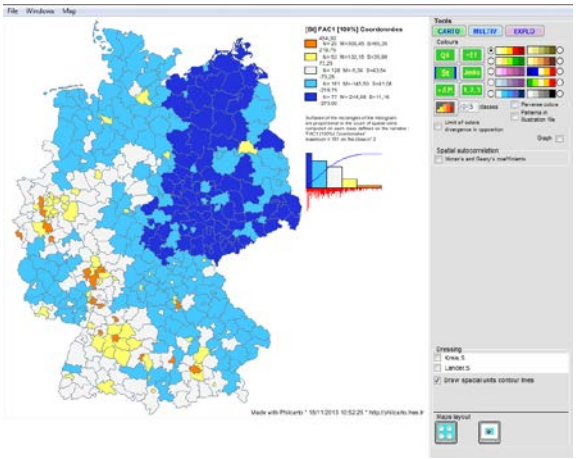
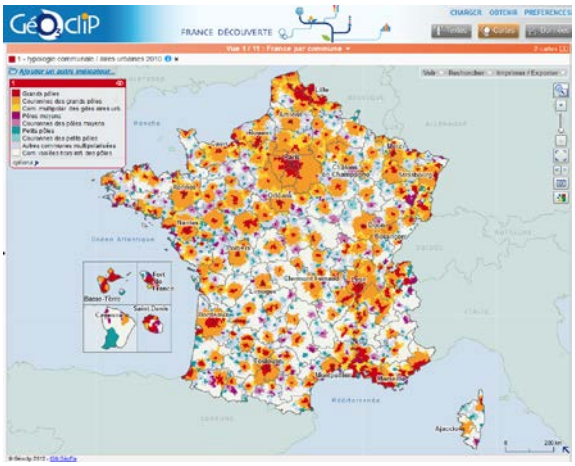
Technologies : JavaScript (Google Maps), Flash, HTML5-SVG-Javascript

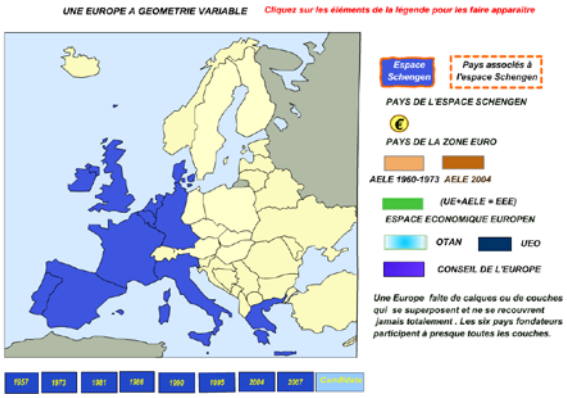
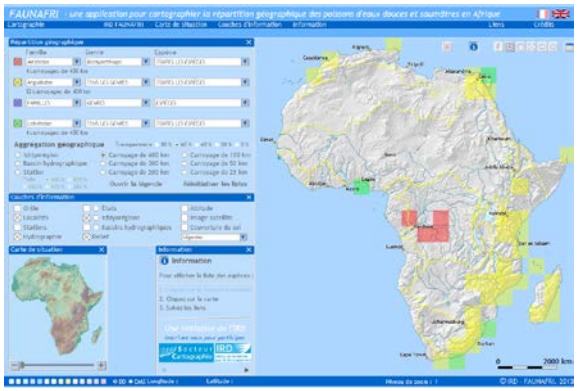
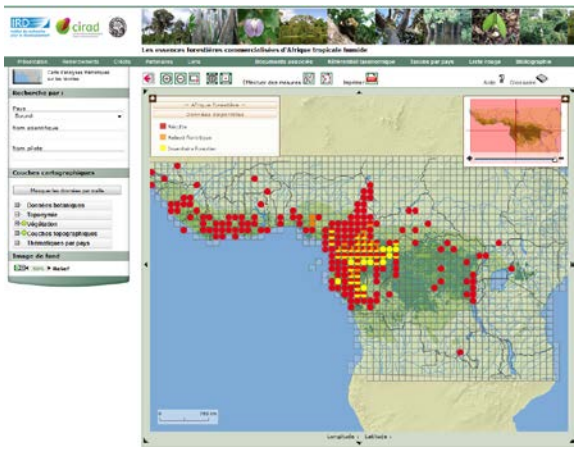
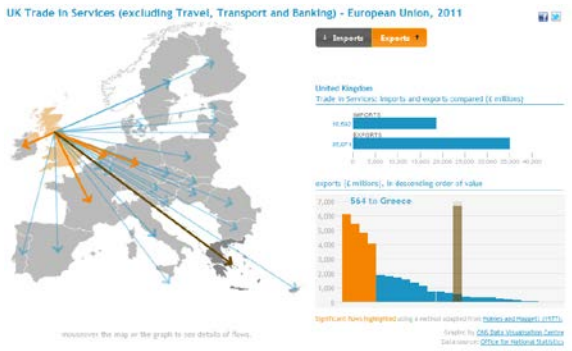
<table>
<tr><th>Strength</th><th>Weakness</th></tr>
<tr><td>- Different display mode (two synchronous maps, animation and prediction of future data, flow maps)
- Standard navigation features
- Temporal graphic images</td><td>- No choice of territorial subdivision</td></tr>
</table></td></tr>
</table>

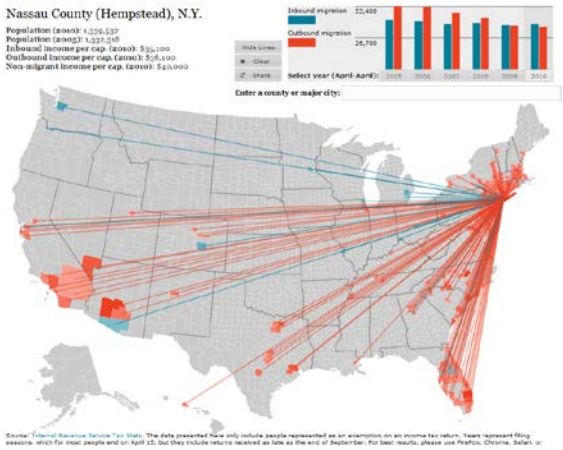
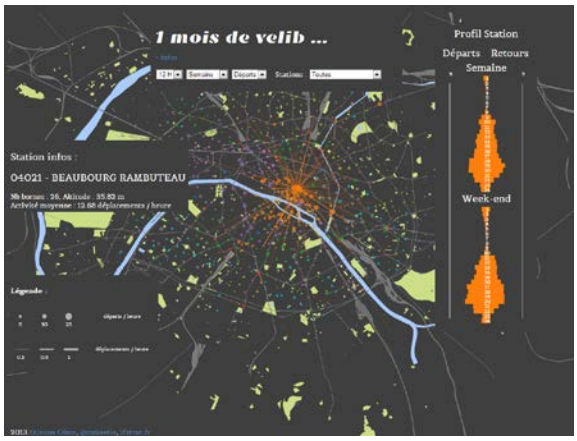
ANNEXE 2: LIST OF EXAMPLES OF INTERACTIVE WEBMAPS

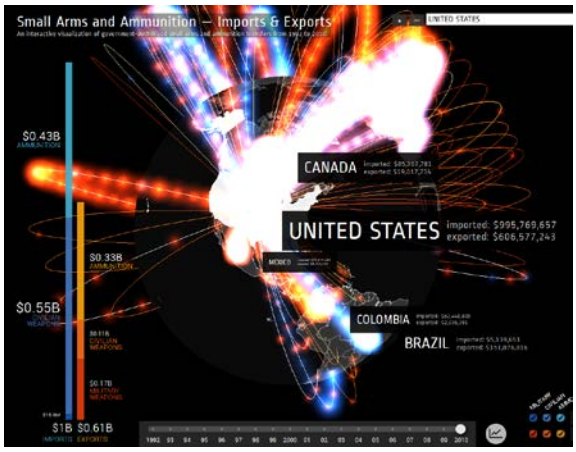
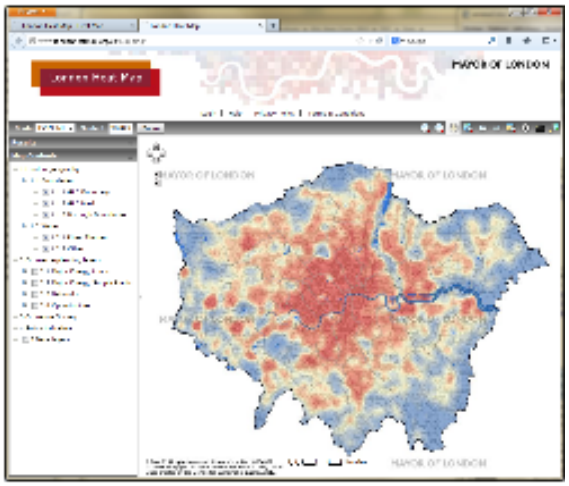
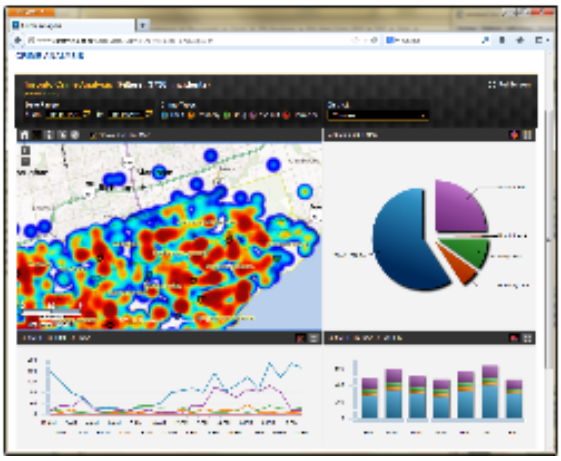
Link	Type	Objective	Screenshot
Mega-commuters take Manhattan http://www.wnyc.org/articles/wnyc-news/2013/mar/05/mega-commuters-take-manhattan/	Choropleth map	Presentation	
OECD eXplorer http://stats.oecd.org/OECDregionalstatistics/	Choropleth map	Exploration	
Carbon bubble map http://www.guardian.co.uk/environment/interactive/2013/apr/19/countries-exposed-carbon-bubble-map	Proportional symbols map	Presentation	

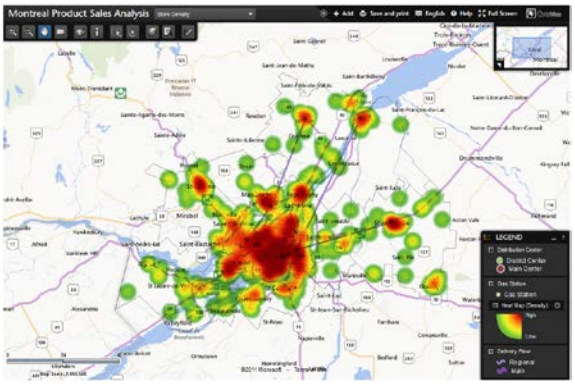
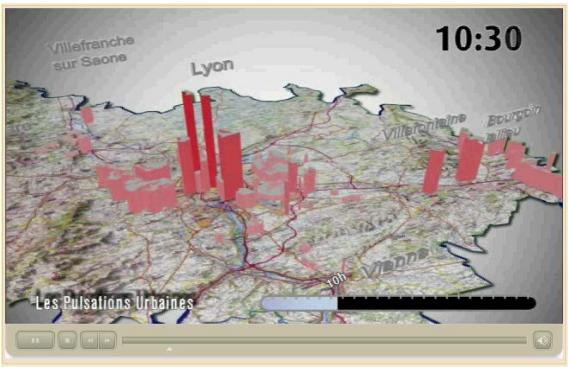
Link	Type	Objective	Screenshot
Gapminder World http://www.gapminder.org/world/	Proportional symbols map	Exploration	
Close votes http://tulpinteractive.com/close-votes/	Proportional symbols map	Exploration	
CBE Ventoux http://www.cbeventoux.com/images/cartes/potentiel_conso/equipement_informatique.htm	Count-ratio map	Presentation	
-	Count-ratio map	Exploration	

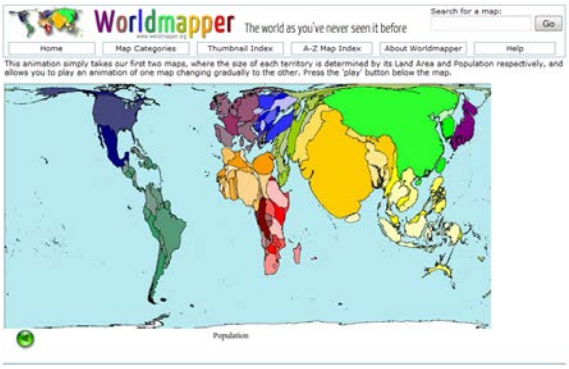
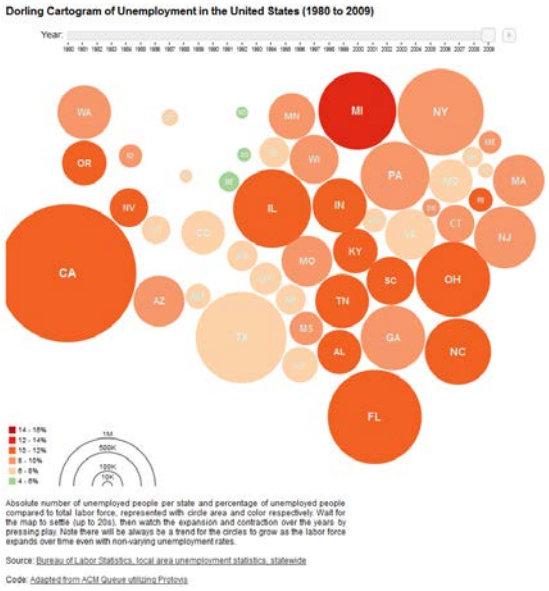
Link	Type	Objective	Screenshot
HyperAtlas http://hypercarte.espon.eu/	Typology map	Presentation	
Philcarto http://philcarto.free.fr/	Typology map	Exploration	
Geoclip - France communes http://franceo3.geoclip.fr/#v=map12;i=pop.cataeu10;l=fr	Typology map	Exploration	

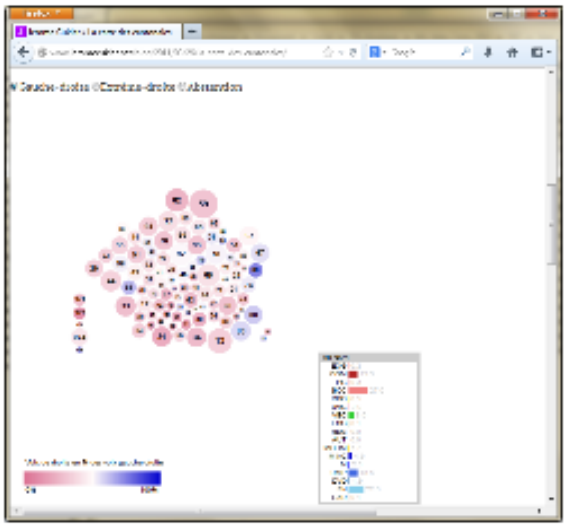
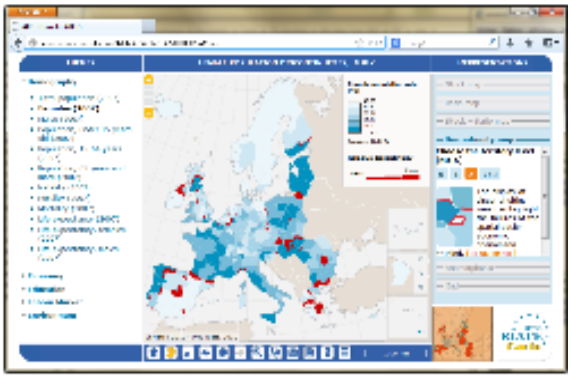
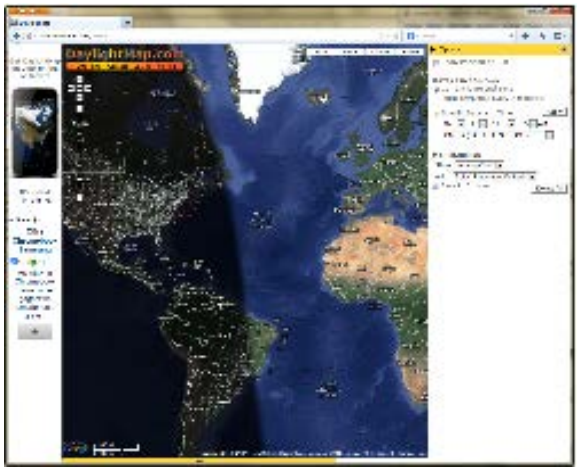
Link	Type	Objective	Screenshot
Geometry of Europe http://www.histoire.ac-versailles.fr/IMG/swf/europegv.swf	Typology map	Exploration	
Faunafri http://www.poissons-afrique.ird.fr/faunafri/	Grid map	Presentation	
Tree species in tropical Africa http://phyto-afri.ird.fr/carte_accueil/flash/	Grid map	Exploration	
UK Trade in Services http://www.neighbourhood.statistics.gov.uk/HTMLDocs/ITIS/index.html#UK,nat,from	Flow map	Presentation	

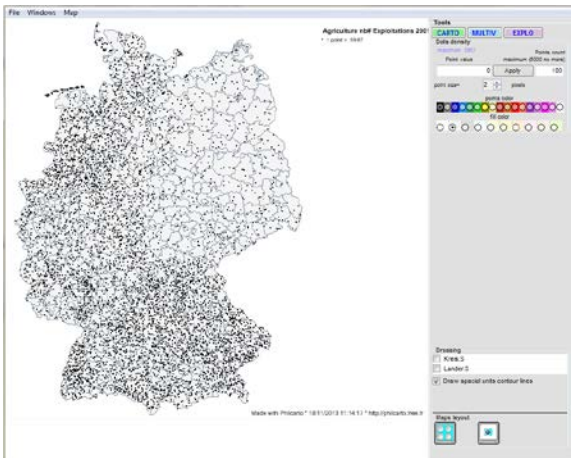
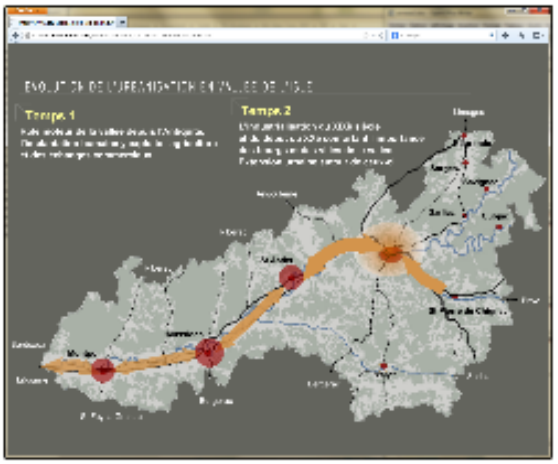
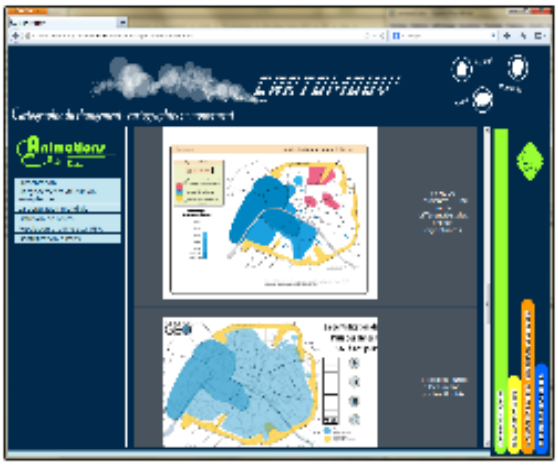
Link	Type	Objective	Screenshot
American Migration http://www.forbes.com/special-report/2011/migration.html	Flow map	Presentation	
Flowstrates http://code.google.com/p/jflowmap/wiki/Flowstrates	Flow map	Exploration	
1 month of Velib' http://www.comeetie.fr/galerie/velib/index.html	Flow map	Exploration	

Link	Type	Objective	Screenshot
3D representation for arms and amunition transferts http://workshop.chromeexperiments.com/projects/armsglobe/	Flow map	Exploration	
London Heat Map http://www.londonheatmap.org.uk/Content/HeatMap.aspx	Isopleth map	Presentation	
Crime Analysis http://www.cartovista.com/CartoVista/CrimeAnalysis.aspx?language=en	Isopleth map	Exploration	

Link	Type	Objective	Screenshot
Montreal Product Sales Analysis http://www.cartovista.com/CartoVista/Montreal.aspx?language=en	Isopleth map	Exploration	
Where America Lives http://www.time.com/time/interactive/0,31813,1549966,00.html	3D map	Presentation	
Air Pollution in London http://www.londonair.org.uk/london/asp/virtualmaps.asp?view=maps	3D map	Exploration	
Urban pulse http://mappemonde.mgm.fr/num27/fig10/fig10302.html	3D Histogram map	Presentation	
-	3D Histogram map	Exploration	
-	Smart projected map	Presentation	

Link	Type	Objective	Screenshot
The Carbon Map http://www.carbonmap.org/#	Cartogram map - anamorphosis	Presentation	
Worldmapper http://www.sasi.group.shef.ac.uk/worldmapper/animations/wm01to02.html	Cartogram map - anamorphosis	Presentation	
-	Cartogram map - anamorphosis	Exploration	
Unemployment in the United States http://www.datadrivenconsulting.com/js/protovis/cartogramemp.html	Dorling cartogram	Presentation	

Link	Type	Objective	Screenshot
Map of counties elections http://www.jeromecukier.net/blog/2011/03/26/la-carte-des-cantonales/	Dorling cartogram	Presentation	
-	Dorling cartogram	Exploration	
Aire http://aire.ums-riate.fr/en#content/index.en.php	Discontinuity map	Presentation	
-	Discontinuity map	Exploration	
Daylight Map http://www.daylightmap.com/?hl=en	Dot density map	Presentation	

Link	Type	Objective	Screenshot
Philcarto http://philcarto.free.fr/	Dot density map	Presentation	
-	Dot density map	Exploration	
Flash Flood http://www.nola.com/katrina/graphics/flashflood.swf	Scenario map	Presentation	
Urbanisation in Vallée de l'Isle http://www.cauedordogne.com/images_contenus/1_CONNAITRE/urba_isle_anim.swf	Scenario map	Presentation	

Link	Type	Objective	Screenshot
Cartography of changes http://www.cartomouv.parisgeo.cnrs.fr/index.php?page=anim&page2=map5	Scenario map	Presentation