Spatio-temporal Visualization of Simulation Results using a task-oriented Tile-based Design-Metaphor

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Abstract

Space and Time show a strong relationship as spatial processes are always connected to the temporal dimension. Hence, if spatial processes should be mapped accordingly, time is an inevitable dimension in order to understand the genesis of an event or a certain state of the universe of discourse. In the FP7 research project MOSIPS ("Modelling and Simulation of the Impact of Public Policies on SMEs") space and time play a critical role in simulating the results of 'public policy making' on socio-economic processes. To present simulation results appropriately, a geoportal is employed that facilitates a task oriented result presentation strategy. This geoportal usage approach comprises of the identification of the key tasks reflecting the end-users' needs for information discovery and provides singular "apps" that answer the projects' key questions comparable to 'Apps' on Smartphones. Following this strategy, we propose that, the layman user is less distracted by a reduced level of information complexity. Hence, the user can focus on the task he has to accomplish. The geoportal follows a task-oriented 'Windows 8' former 'Windows Metro style' design philosophy highlighting the advantages of modern user guidance. This tightly focused presentation approach enhances the clarity of the offered results and fosters the insight of occasional users and decision makers explaining complex spatial-temporal processes.

Keywords: spatial-temporal visualization, task-oriented design, metro design metaphor

Introduction

Space and Time show a strong relationship as spatial processes are always connected to the temporal dimension. Hence, if spatial processes should be mapped accordingly, time is an inevitable dimension in order to understand the genesis of an event or a certain state of the universe of discourse. In contemporary Geographical Information Systems (GIS) the integration of time as 4^{th} dimension shows potential for further development and improvement, as the concept of Time Geography (Hägerstrand, 1970) and its descending papers show. In contemporary GI-applications, time is represented as static "variable" that hides the dynamic nature of spatial phenomena.

The FP7 research project MOSIPS ("Modelling and Simulation of the Impact of Public Policies on SMEs") aims to simulate the results of 'public policy-making' on socio-economic processes. Due to the inherent dynamic behaviour of social processes, the temporal dimension is crucial in order to understand and to present such procedures accurately and in a self-explanatory manner. This is necessary in order to foster the understanding of simulation results and their implication on the decision making process.

In order to generate a basic geo-enhanced system architecture as part of the research project, the goal will be to leverage Service Oriented Architectures (SOA) on a technical level for spatial-temporal socio-economic simulation and exploit harmonized data (e.g. from INSPIRE) and information models on the semantic level. This allows for a seamless integration of different components – e.g. visualization engine or simulation and forecast engine – by communicating using standardized interfaces. Thus, the simulation and forecast engine relies on (spatial) data present in the data layer. The latter holds spatial-temporal data regarding census, economics and other relevant statistics in general. In order to present simulation results appropriately, a geoportal is employed that supports semantic search capabilities for spatial and non-spatial information resources. In general, a geoportal, like any other web based information portal, shall support a task oriented result presentation strategy. This approach comprises of the identification of the key tasks/questions reflecting the end-users' needs providing singular "apps" that answer the users' key questions split up into singular encompassed tasks, comparable to 'Apps' on Smartphone devices. Following this strategy, we propose that, the layman user is less distracted by a reduced level of information complexity and thus is better able to focus on the task users have to accomplish. In this paper, a geoportal solution presenting spatial-temporal data – results of the FP7 project "EnerGEO" and preliminary results of the FP7 project "MOSPS" are presented. The portal website concept is geared to the task-oriented 'Windows 8' design philosophy highlighting the advantages of this approach, namely recognizing and reusing common web navigation and operation strategies. Thus, the user is able to "navigate" through space and time in an interactive way, by using well established tools like a (time) slider, integrated in the user interface of the mapping solution. This tightly focused presentation approach enhances the clarity of the offered simulation results and fosters to focus on the insight of the presented results, especially for occasional users and decision makers explaining complex spatial-temporal processes.

The research question of this paper focuses on the presentation of Service-Oriented mapping contents, emphasizing on the hypothesis, that task-oriented presentation of spatial-temporal maps fosters the perceivability of the results and usability of the user interface by novice or occasional users.

The structure of the paper is as follows: Relevant literature is mentioned in chapter 2, followed by a brief description of spatial-temporal processes that are part of the MOSIPS project. Additionally, the intended modelling and simulation efforts are briefly covered in this chapter. Chapter 3 describes the tile based geoportal communication approach that presents the applications of the geoportal in a task oriented style. Chapter 4 focuses on the applications of the geoportal itself and their simplistic design approach including an interface for the spatial domain.

Relevant Literature

This chapter highlight the literature and previous work done in the field of geo-visualization, human computer interaction and SOAs relevant in the context of this paper. The chapter elaborates on the approaches to visualize spatial-temporal scenarios in a web-based environment, followed by a brief description of scientific work published in the field of Human Computer Interaction and SOAs. A central idea of designing an interface for the occasional user is ‘task-orientation’, which is mentioned in the majority of the papers listed here.

Cartography holds a rich set of visualization methods and techniques to visualize geospatial data accordingly – and to turn data into information (Collins, 1993). Nevertheless, the environment where cartography “lives” drastically changed during the last decades. The emerging Internet, utilizing a variety of connected data sources, has dramatically changed the characterization of geographic representations, which are now described by two keywords: interaction and dynamics (MacEachren and Kraak, 2000). Hence, contemporary maps are not only static content but should let the user get access to connected, distributed spatial data resources in an interactive manner. This opens the floor to leverage geoinformation to discover trends, structures or relationships from without having any prior hypothesis, which is a research field on its own called “Geovisual Analytics”. Andrienko, et al., (2007) published the research agenda for Geovisual Analytics for spatial decision support and formed the term Geovisual Analytics based on research in the newly formed field Visual Analytics coined by Thomas and Cook (2005). Basically, Geovisual Analytics aims to support the human in the analysis of spatial-temporal problems. Due to the fact that a human is very strong in identifying patterns and relationships in spatial-temporal data sets, Geovisual Analytics combines the strength of humans and computers (Andrienko, et al., 2010). Nevertheless, Andrienko, et al. (2010) identified the combination of space and time as the main future research areas, in order to deal with time in combination with space much more efficiently.

In general, user interface design is a technique that aims to develop interfaces that enable a seamless communication between the user – i.e. a human – and an application running on a computerized device. The goal of user interface design is to create an interface that is “usable” – thus supporting the user in his tasks. Early, efforts have been done in the 1980s and 1990s where two books on this topic were published (Medyckyj-Scott and Hearnshaw, 1993; Nyerges, Mark, Egenhofer and Laurini, 1995). Due to the fact that the term Usability is gradually replaced by the term User Experience, this article refers to this term. Hassenzahl (2008) describes User Experience (UX) as *“a momentary, primarily evaluative feeling (good-bad) while interacting with a product or a service”*. Additionally, Hassenzahl (2008) extends the UX definition and mentions that *“good UX is the consequence of fulfilling the human needs for autonomy, competency, stimulation, relatedness and popularity through interacting with the product and service […]”*. Hence, this definition emphasizes the subjectivity and the well-being as an outcome of interaction with a system (Law, et al., 2009). In order to measure UX, a complete set of research techniques have been established which are mentioned e.g. in Kuniavsky (2003) or Tullis and Abert (2008). In Geographical Information Science Möltgen and Kuhn (2000) have published a methodology to apply well-known techniques for task analysis in transportation planning to design a user interface metaphor. Gould (1994) mentions, that a common reason for GIS projects to fail is due to the ignorance of user requirements.

Contemporary visualization and presentation – i.e. web cartography – of spatial data relies on SOAs as they try to include several distributed data sources (Maguire and Longley, 2005). Hence, there is a need for seamless information sharing, which is realized through (standardized) geographic information services (Tsou and Buttenfield, 2002). Maguire and Longley (2005) critically discuss the impact of emerging geoportals on information access with respect to enterprise GIS and Spatial Data Infrastructures. In addition, the authors describe metadata as essential components of GI services. The standards of the Open Geospatial Consortium (OGC) attempt to standardize GI services and have yet published a number of standards. Zhang, Li and Zhao (2007) describe contemporary SOAs and relevant OGC standards for sharing spatial information, and extend their approach by including semantic web technologies. Hence, the authors of this paper do not describe OGC standards in detail here, but refer to the paper of Zhang, Li and Zhao (2007) and the OGC respectively.

Modelling of Socio-Economic Spatial-Temporal Processes

Spatial-temporal processes are found everywhere in the real world especially in environmental, social and economic problems. Due to the fact that spatial-temporal processes are continuous processes the modelling and simulation thereof should reflect most of their continuous behaviour. This chapter is devoted to a brief description of the simulation of spatial processes. Preliminary results are presented in the last chapter of the paper. The test area of the simulation is the municipality “Plainfeld” located in the east of the City of Salzburg.

In the course of the FP7 research project MOSIPS – which aims to provide decision support for public policy makers with respect to small and medium Enterprises (SMEs) – a forecasting system is developed that simulates the socio-economic impact of public policies on SMEs. Hence, decision makers gain the ability to systematically evaluate the possible results of public policies in a spatial-temporal manner, due to the spatial relations of socio-economical phenomena.

The modelling and simulation of the impact of public policies on SMEs is done with an Agent-based Simulation – a topic that is has been covered by literature in the last years (Axelrod, 2006; Axelrod and Tesfatsion, 2006; Bonabeau, 2002; Brown, 2006; Casti, 1997; Couclelis, 2002; Crooks, Castle and Batty, 2008; Epstein, 1999; Epstein and Axtell, 1996; North and Macal, 2007; O'Sullivan, 2004; Parker, et al., 2003; Parker 2005; Torrens 2004). Agent-based Models (ABMs) consist of multiple agents that interact with each other. Agents are placed in a simulation environment that allows movement in a defined way with respect to certain relationships between Agents. The simulation environment is the space in which agents "live" – i.e. move, interact with other agents and the environment. In the project MOSIPS several classes of agents exist that are placed in the simulation environment: (a) Establishments and Firms: productive firms, establishments; (b) Individuals and families: individuals, immigrants, households; (c) Other Entities: financial firms, public sector, external sector;

There are three markets – i.e. environments – where agents and other entities relate to each other: labor, financial and goods and services market. Agents, other entities and markets are affected by the macroeconomic environment and public policies. The relations of the agents and their actions are modelled in the course of the research project MOSIPS, and implemented in a multi-agent modelling and simulation environment that takes the spatial and temporal dimension into account. By exploiting spatial relationships – e.g. nearness – Tobler's first law of Geography (Tobler, 1970) can be applied. Hence, nearby things present in the simulation environment influence agents more than distant things.

To evaluate the approach of the MOSIPS project – using a spatial multi-agent model and simulation – a prototype is created that aims to simulate the demographic development and intended land use of a small municipality in the province of Salzburg, Austria. The simulation environment in which the agents "live" is a digital map of the current land use/land cover as well as a representation of the suitability for residential areas based on the land use/land cover. The basic agents are individuals that can form households, get descendants and vanishes (dies). Individuals are capable of forming households, where each household consists of at least two individuals and their eventual descendants. Generally, the model assumes that each household owns a property of a certain size. If a new household is created, the simulation searches for unused properties and moves the new household to the unused property. A property may become unused if and only if the members of the household die. If a new household cannot "find" an unused property a new property will be created. In order to locate the new property in the simulation environment the following heuristic is applied: Locate the new property on land that is best suited for residential areas, closest to existing residential areas. The heuristic described above is applied to an initial situation in the municipality of Plainfeld. The multi-agent simulation is implemented with the Repast modelling suite (North et al. 2007). The spatial data used by the simulation represents the situation of Plainfeld (see Figure 1).

Service Oriented Mapping coupled with a task-oriented presentation

To publish results obtained of the simulation, a geoportal utilizing a service-oriented mapping solution is developed. The geoportal utilizes mapping services of a standard mapping server and presents the results in a task-oriented manner similar to Apps on mobile devices. This design approach should decrease the barrier of using advanced mapping solutions especially for occasional map users. This goal is reached through the geoportal's simplicity and reductionist approach that intentionally omits elements (e.g., additional layers or spatial analysis functionalities) that are not directly necessary for answering the question raised by the user – i.e. the task the user needs to accomplish. The geoportal, that provides access to spatial data and information, is divided into several predefined parts. Basic tasks are e.g. display solar potential or wind energy potential. These pre-defined tasks are included in the start page of the geoportal, similar to an application-hub of mobile devices. Each offered application is intended to answer a certain question the user of the system has – equal to a task the user has to accomplish. This fosters the clarity of the information offer especially for occasional users.

The design of the geoportal is geared to some ideas and design principles of the tile-based “Windows 8” – design metaphor that is used by Windows Phone 7 Phone and Windows 8 operating systems (see Figure 2). This “simplistic” approach implicitly focuses the attention of users to the available functionalities – i.e. the apps – of the geoportal itself. Thus, the tile-based design approach fosters the user experience (Arnold, 2011). This design is intended to match with the experience of the occasional user, when using a computerized device or a website. Due to the fact that mobile phones –i.e. any smartphone – and Windows 8 show a tile-based user interface the user implicitly recognizes certain kind of interface and its usage strategies. Hence, this allows to user to focus on the presented content and the task and not the usage of the geoportal system itself.

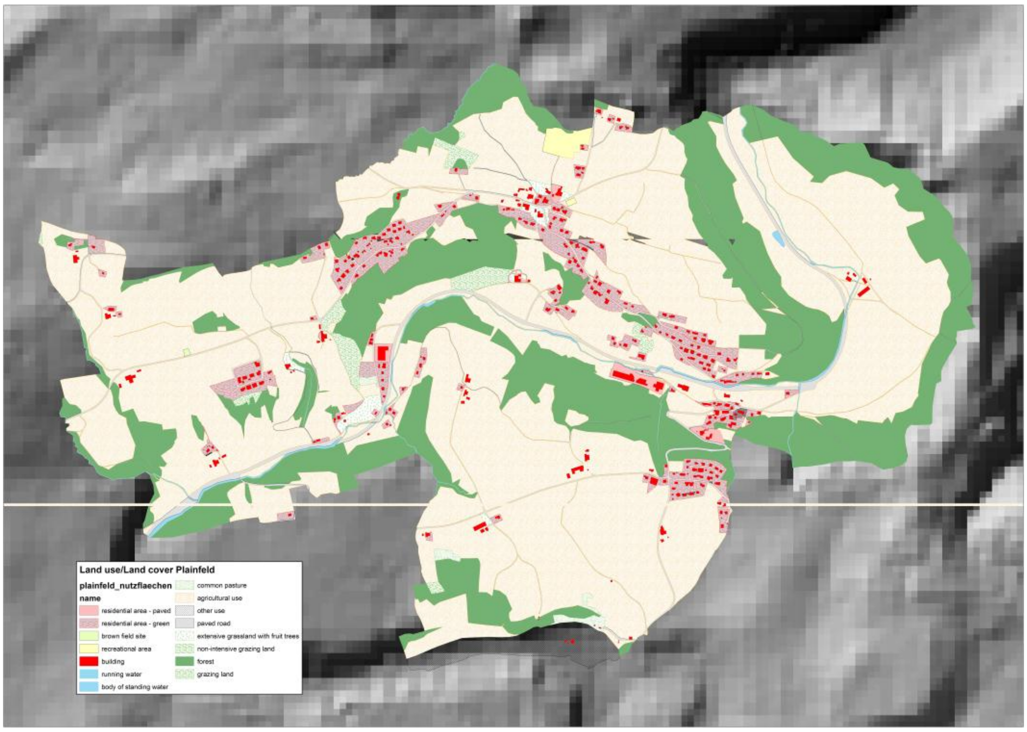


Figure 1: Land use and Land Cover in the municipality of Plainfeld.

In order to align with Service Oriented Architectures (SOAs) on a technical level, each tile is equivalent to a standardized web service that offers a predefined functionality. This detachment of functions enables the applications to be shared due to a standardized service interface. Hence, the geoportal can be extended or limited depending on the needs of the potential users and the technological environment – i.e. smartphone, tablet, desktop.

The geoportal is designed to foster the clarity of the offered applications and to reduce the distraction of users while working on a specific task. In order to achieve distortion reduction when designing user interfaces and data visualization several techniques are mentioned in literature (e.g. Ellis and Dix, 2007; Leung and Apperley, 1994). Generally, the user experience of overcrowded interfaces and/or too much data on too small displays results in visual clutter. Clutter reduces the usefulness of a user interface or the information visualization, due to overcrowded visualizations that hide essential things the user should discover. Hence, the geoportal works with tiles containing links to distinct applications of the portal. Figure 3 shows a detailed view of the geoportal. This portal shows different applications that present results of the FP7 Project EnerGEO. Among them are “Wind Pilot”, ”Solar Radiation” or “EnergGEO Discovery” – the latter provides an intelligent search engine for spatial data that are part of the EnerGEO project. In addition, the geoportal offers a multi-page entry site – comparable to a mobile app that allows switching between different screens with a finger gesture. Buttons that are designed as white arrows in grey colored circles mark the UI elements that provide this functionality. Switching between different screens is chosen in order to provide a user friendly and clearly arranged interface reducing clutter. Furthermore, this approach of presenting geo-spatial knowledge for occasional users orients itself on ideas of smartphone app development. Hence, the occasional user – usually having less experience in using Web-

Mapping applications, but having more familiarity with using mobile apps available on everybody's smartphone – does not get confused when working on a geoportal, due to the recognition of the concepts of application operation for mobile devices and the geoportal approach presented in this paper.

(a) (b)

Figure 2: Comparison of Windows 8 user interface (a) (source: http://cdn4.digitaltrends.com/wp-content/uploads/2011/09/windows-8-metro.jpg) and geoportal approach (b) – here an application for the FP7 project "EnerGEO".

In addition, this approach can easily be migrated to applications for mobile devices (e.g. Tablets, smartphones), as the geoportal's design can be changed to fit common smartphone screen sizes. To support different screen sizes the number of application screens can vary, according to the number of applications available on the geoportal. This fosters the development of clear user interfaces avoiding any visual clutter. In order to enhance the UX when used on tablets or other touchscreen devices, the size of the tiles is designed to support tapping – an interaction of the user's finger and a touchscreen in order to invoke the primary action of the user interface element.

Mapping Applications: a simplistic and task-oriented approach

The design of the applications offered by the geoportal shows a simple and reductionist approach. This is achieved by concentrating on only the functionalities that are needed to answer a certain question. Thus, a complex interface providing rich functionality is omitted, due to the fact that this approach would distract the user from his primary task and goal Figure 4 shows a typical geo-spatial application offered by the geoportal. Here, the Wind Pilot app is presented as prototypical implementation that intentionally hides the central layer manager and shows only a base map selection panel. The main map is formed by a wind speed information layer– i.e. is able to compare wind speeds for certain geographical locations and specific months. Additionally, the Web Map allows for zooming and panning the web-map, search locations and getting legend and layer information.

In order to cope with space and time in web based spatial applications an interface element to have control over the temporal dimension needs to be included in the application. Due to the fact that time can be represented in at least two ways – time stamp and/or duration (International Standards Organization, 2012) – the interface should support these requirements. Figure 5 shows a prototype of a real-time monitoring application designed for the Nationalpark Berchtesgaden. Interfaces like a time-slider allow the evaluation of current and historic movement patterns of game. This user interface provides two interaction modes (see Figure 5): (a) as point in time and (b) as time interval. Hence, the user is able to visualize the trajectory of the game in two ways: (a) only the point in time indicated by the time-slider – with the result geometry: point – or (b) the part of the trajectory that is in the time interval indicated by the time slider – with the result geometry: linestring.

Following the presentation strategy introduced in this section, the authors intend to set up a comparable portal for visualizing the results of the FP7 project MOSIPS. In the chapter "Modelling of Socio-Economic Spatial-Temporal Processes" the underlying spatial-temporal simulation is explained in detail. In order to provide decision support for decision makers the presentation of the results in an intuitive web-based tool is necessary. Hence, the interface has to reflect the need for an interface with high user experience for occasional users. To achieve this goal, a set of well-chosen simulation parameters can be altered with guidance by the system, similar to the application depicted in Figure 4. Here, the user will be able to influence the transition matrix between different land-use and land-cover types. For instance, the user is able to define, if forested areas can change to residential area and at which cost this transition is possible. In addition, the application has to support a spatial-temporal visualization which allows the user to monitor the land use and cover changes over time. Hence, a time-slider is intended in order to switch between the simulation results of different points in time and to monitor the change of land use and land cover. In Figure 6 preliminary simulation results of the municipality Plainfeld are depicted, focusing on land use and land cover change over the next 10 years assuming that the population will grow.

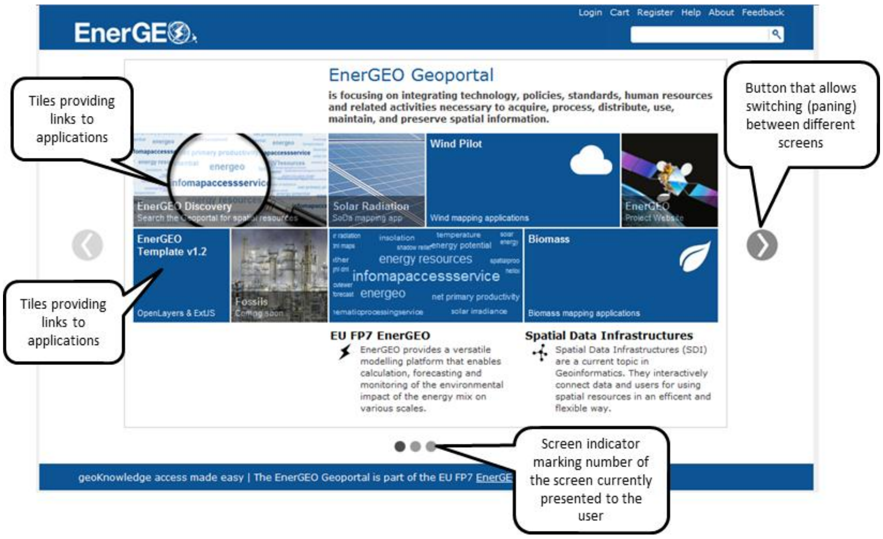


Figure 3: Detailed entry page of the geoportal showing the task-oriented presentation of available applications.

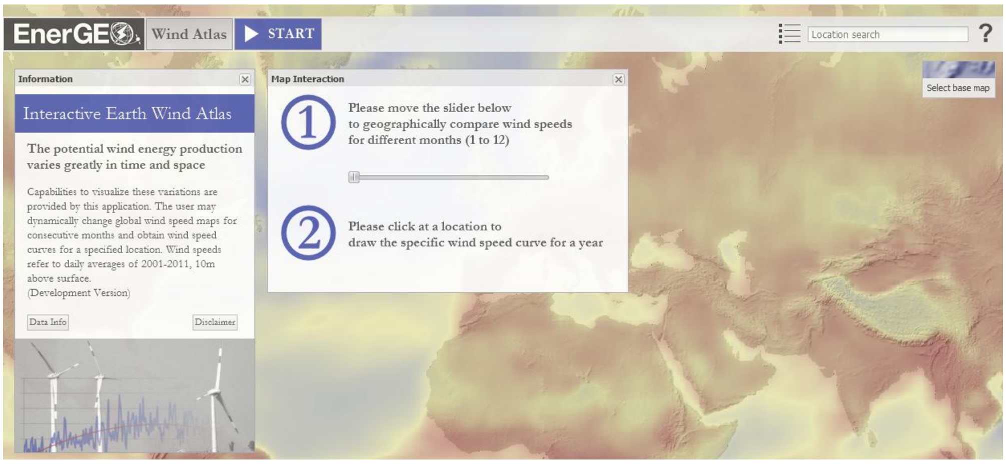
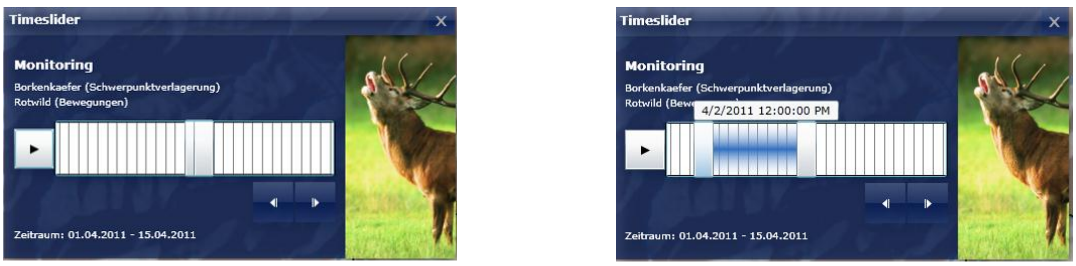
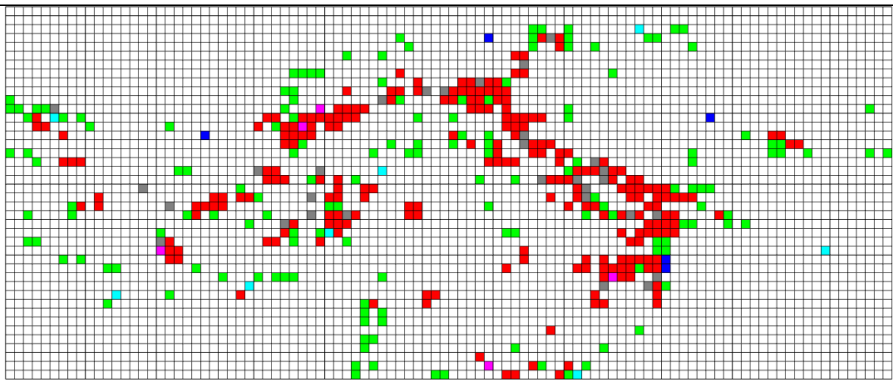


Figure 4: Task oriented - Mapping application - Wind Atlas. The application shows a reductionist approach by intentionally omitting user interface elements that are not directly needed to answer a certain question.

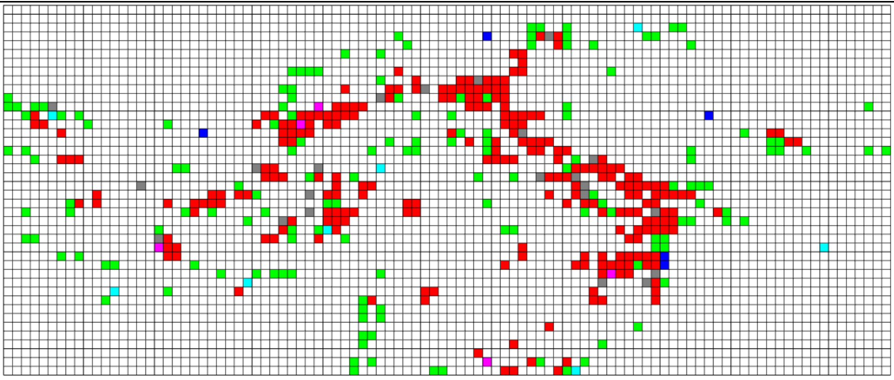


(a) (b)

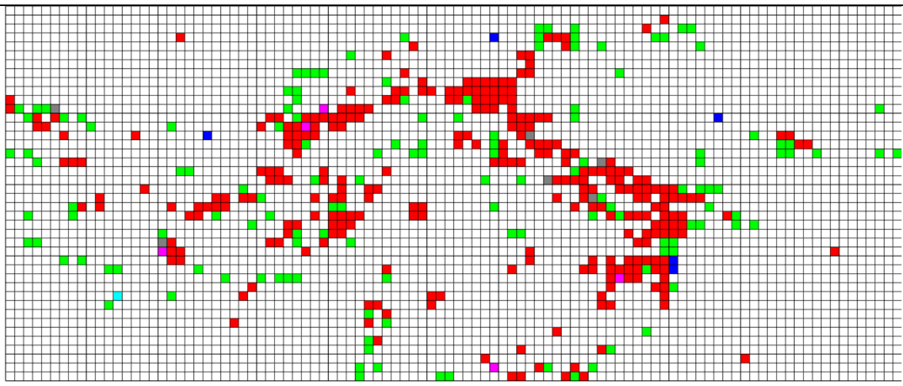
Figure 5: Time slider representing a point in time (a), and a time interval in (b).



(a) Plainfeld: land use and land cover initial situation



(b) Plainfeld: land use and land cover situation after 5 years



(c) Plainfeld: land use and land cover situation after 10 years

Figure 6: Preliminary land use and cover simulation results of the test area Plainfeld in the province of Salzburg, Austria. The red pixels represent residential areas-paved, the grey ones residential areas-green, the green pixels forested areas, the blue pixels water and the magenta colored pixels reflect other land use types.

Conclusion and Future Work

The paper presents an approach for presenting spatial-temporal simulation results in a task-oriented manner. This approach focuses on the needs of the occasional web-map user by serving an easy-to-understand interface in a tile-based design philosophy. Hence, the content and functionality of the geoportal is split up into several sections and applications – comparable to 'Apps' on smartphones – this design concept is equivalent to tasks the user needs to accomplish on handheld devices. By choosing a design metaphor the layman web-map user is familiar with, he the focuses on the content and the task rather than the usability of the system itself. Furthermore, the geoportal approach presented in this paper is customizable to be consumed on different environments like smartphones and tablets. The applications itself are designed in a simplistic manner – "one task - one application" – by intentionally omitting complex user interface elements like complex layer managers – which are present in many contemporary mapping applications. In addition, the temporal dimension is included by time sliders that allow “navigating” through space and time. The applications are built using open web standards (e.g. HTML5) and SOA based standardized (OGC) map and download service infrastructures (OGC compliant services) and thus can be shared and integrated in other portal solutions accordingly. Open research items are user experience tests including cognitive load measurements that will be carried out in the next months at the Human Computer Interaction Lab of the University of Salzburg in order to verify the advantages of the approach presented in this paper.

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