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Toward Visualization in Policy Modeling

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Information visualization and visual analytics (VA) have become widely recognized research fields applied to a variety of domains and data-related challenges. This development's main driver has been the rapidly increasing amount of data that must be dealt with daily. Virtually every industry or business, or any political or personal activity, generates vast amounts of data. At the same time, citizens, shareholders, and customers expect highly efficient, informed decision-making based on increasingly complex, dynamic, and interdependent data and information.

All this applies in many ways to public-policy modeling. As the recent financial crisis has shown, policy making and regulation are highly challenging tasks. The outcomes of policy choices and individual behavior aren't easily predictable in our complex society. Ubiquitous computing, crowdsourcing, and open data, to name just a few examples, are creating masses of data that governments struggle to make sense of for policy modeling.

Increasingly, policy makers are perceiving visualization and data analysis as critical to this sense-making process. Current practice uses visualization mainly during postprocessing. Although this is an important step in the right direction, a more promising trend is the integration of visualization tools with simulation and automated analysis. This is clearly in line with the general approach employed by various domains that apply VA techniques for interactive analysis.

Here, we examine the current and future roles of information visualization, semantics visualization, and VA in policy modeling. Many experts believe that you can't overestimate visualization's role in this respect. For example, the recent EU roadmap for this area goes as far as saying that "ensuring appropriate visualisations can … be considered a key component of a mature democracy."[1]

The Policy-Making Process

Policies are usually defined as principles, rules, and statements that assist in decision-making and that guide the definition and adoption of procedures and processes. Typically, government entities or their representatives create public policies, which help guide governmental decision-making, legislative acts, and judicial decisions.

Some policy-modeling research emphasizes theoretical formal modeling techniques for decision-making, whereas some applied research focuses on process-driven approaches. These approaches determine effective workflows through clearly defined processes whose performance is then monitored (for example, as in business process modeling). This applied-research approach is widely seen as one way to effectively create, monitor, and optimize policies. One aspect of process-driven policy making is the clear definition of the sequence of steps in the process. This ensures the consideration of the most relevant issues that might affect a policy's quality, which is directly linked to its effectiveness.

Ann Macintosh published one of the most widely used policy-making life cycles; it comprises these steps:[2]

1. *Agenda setting* defines the need for a policy or a change to an existing policy and clarifies the problem that triggered the policy need or change.
2. *Analysis* clarifies the challenges and opportunities in relation to the agenda. This step's goals are examining the evidence, gathering knowledge, and a draft policy document.
3. *Policy creation* aims to create a good workable policy document, taking into consideration a variety of mechanisms such as risk analysis or pilot studies.
4. *Policy implementation* can involve the development of legislation, regulation, and so on.
5. *Policy monitoring* might involve evaluation and review of the policy in action.

The entire life cycle is a loop.

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Other, more specific process definitions are available, but these often vary significantly. Depending on the domain—for example, in the social sciences versus in computer science—the definition has different scopes and thus very different process steps.

For adopting visualization in policy making, we simplified the general model and introduced three iterative stages (see Figure 1):

1. *Information foraging* supports policy definition. So, this stage requires visualization techniques that obtain relations between aspects and circumstances, statistical information, and policy-related issues. Such visualized information enables optimal analysis of the need for a policy.
2. *Policy design* must visualize the correlating topics and policy requirements to ensure a new or revised policy's functional interoperability.
3. *Impact analysis* evaluates the designed policy's potential or actual impact and performance, which must be adequately visualized to support the policy's further improvement.

All phases involve heterogeneous data sources to allow the analysis of various viewpoints, opinions, and possibilities. Without visualization and interactive interfaces, handling of and access to such data is usually complex and overwhelming because too much data is available. The key is to provide information in a topic-related, problem-specific way that lets policy makers better understand the problem and alternative solutions.

Today, many data sources support policy modeling. For example, *linked open government data* explicitly connects various policy-related data sources (for instance, see http://data.gov.uk/linked-data). Linked data provides type-specific linking of information, which facilitates information exploration and guided search to get an overview and—later on—a deeper understanding of a specific topic. Massive, multidimensional databases for statistical data also exist—for example, the EuroStat database (http://epp.eurostat.ec.europa.eu).

Currently, policy-modeling approaches don't use visualization intensively either for the general process or in any of the three stages. The first research prototypes are close to traditional information visualization techniques, and no visualization approach addresses all the required policy-modeling aspects. As we mentioned before, the goal of introducing more visualization and VA techniques goes one level further. The objective is to ensure more efficient and effective policy modeling by integrating visual methods and automatic analysis methods.

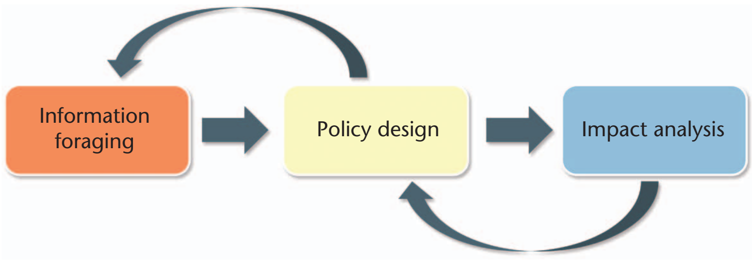

Figure 1. A simplified policy-modeling process. All three stages involve heterogeneous data sources to allow the analysis of various viewpoints, opinions, and possibilities.

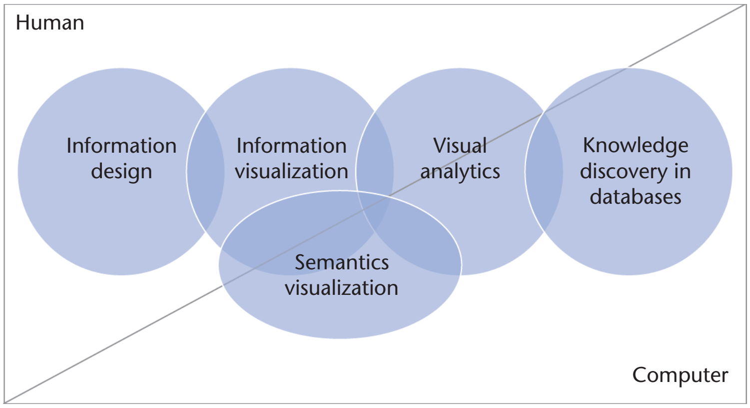

Figure 2. The computer's and human's roles in visualization disciplines in policy modeling.[3] From left to right, the computer's role increases and the human's role decreases.

Visual Support for Policy Modeling

The simplified policy-modeling process in Figure 1 enables an abstract view of policy evolution. This model can provide only an overview of the stakeholders, political processes, and activators for new or changed policies. Nevertheless, it gives a good foundation for identifying the application of information and communications technology (ICT) to policy creation. In particular, graphical systems that give insight into the heterogeneous, complex, and huge amount of data and information can be adapted to the model's stages.

Here, we look at various visualization disciplines in this context and classify visualization methodologies on the basis of the human's and computer's roles in the transformation from data to insight. In this process, visualization supports users in various ways. One example is integrated intelligence that recognizes patterns or clusters in data or that considers human abilities or interaction patterns when providing adaptive visualization techniques. In this context, we categorize visualization for policy modeling into information design, information visualization, semantics visualization, VA, and knowledge discovery in databases (KDD).

Figure 2 illustrates this separation of roles, in which the computer's role increases and the human's role decreases from left to right. For example, in information design, the computer plays no role per se, whereas in KDD, automatic methods process the underlying data typically without user interaction. We consider semantics visualization very relevant for policy modeling, as we explain later.

Information Design

Political decisions often progress through stages involving stakeholders with heterogeneous skills, knowledge and preferences, and positions in the political chain. The actual decision-making often occurs higher on that chain, with lower-level discussions or workshops taking analysts' input into account to help determine policy changes. At this lower level, the data and information should be presented adequately. The main target is to convey a matter of interest and present the essential issues.

Information design investigates the rules for adequate information presentation and the communication of knowledge. Here, humans with their communication skills are the major actors and use outcomes from perception science. Information design focuses on visualization to support human communication during policy making.

Information Visualization

To achieve a summary of the most important data and information relevant for decision-making, political analysts must aggregate vast amounts of data, analyze it, and form an overview of it. For these tasks, they can apply information visualization techniques. Often, automatic analysis preprocesses the data, and the analysts usually visualize only these techniques' outcomes. The analysts can visually and interactively browse through the results and detect the most relevant information to condense for decision-makers.

Every stage of policy modeling can involve information visualization. For example, information foraging could use Gapminder (www.gapminder.org) to explore the evolution of a nation's wealth to analyze the need for new policies.

Semantics Visualization

The increasing amount of semantically annotated open data, especially in the area of linked government data, justifies investigating semantic technologies for visualization related to policy making. Semantic-technology research focuses on data's machine readability, whereas semantics visualization focuses on human-centered approaches for conveying information. Semantics visualization goes beyond ontology visualization, which focuses on visualizing a formal knowledge description in a certain domain. It provides a comprehensible, interactive view of semantics.[4]

In visualization, semantics is the meaningful relation between two or more data entities. These relations can be described explicitly by formal semantic languages (for example, OWL—Web Ontology Language) or gathered implicitly with semantic-mining methods. With the ability to correlate linked government data to data from domains unrelated to politics, analysts can find new relations and visualize them for decision-makers.

Semantics visualization is applicable to all three stages of our simplified policy-making model. Information foraging can employ the search, exploration, and decision-support methods we've described. Policy design can employ semantically structured policy formalisms and visual authoring environments. Impact analysis can employ logical inferences, predicate logic, and fuzzy cognitive maps to provide a comprehensible comparison of scenarios.

Visual Analytics

For complex analysis tasks—for example, during impact analysis—political analysts might have to incorporate complex algorithms and deal with vast amounts of data. Political analysts can't be experts in every computational discipline that might contribute to the analysis. So, interactive visual displays could help them access the complex computational models.

VA exactly addresses this problem by combining computers' data-processing capabilities with the strength of humans' visual perception. On the one hand, computers process vast amounts of data for aggregation, structuring, or summarization. This provides users with intuitive visual access to the data. On the other hand, users can visually detect interesting patterns in visualizations and can control computers to get a more precise analysis. So, VA can help political analysts incorporate complex ICT into policy making.

KDD

VA strongly involves KDD techniques because it employs interactive visual displays to control and use automatic data analysis tools. KDD uses visualization techniques only in restricted ways—for example, in GUIs to set automatic analysis techniques' parameters.

Researchers are already applying KDD techniques to policy making, especially during information foraging and impact analysis. For example, a large KDD community focuses on automatically extracting public opinions from the Web. A VA approach would couple visualization techniques with

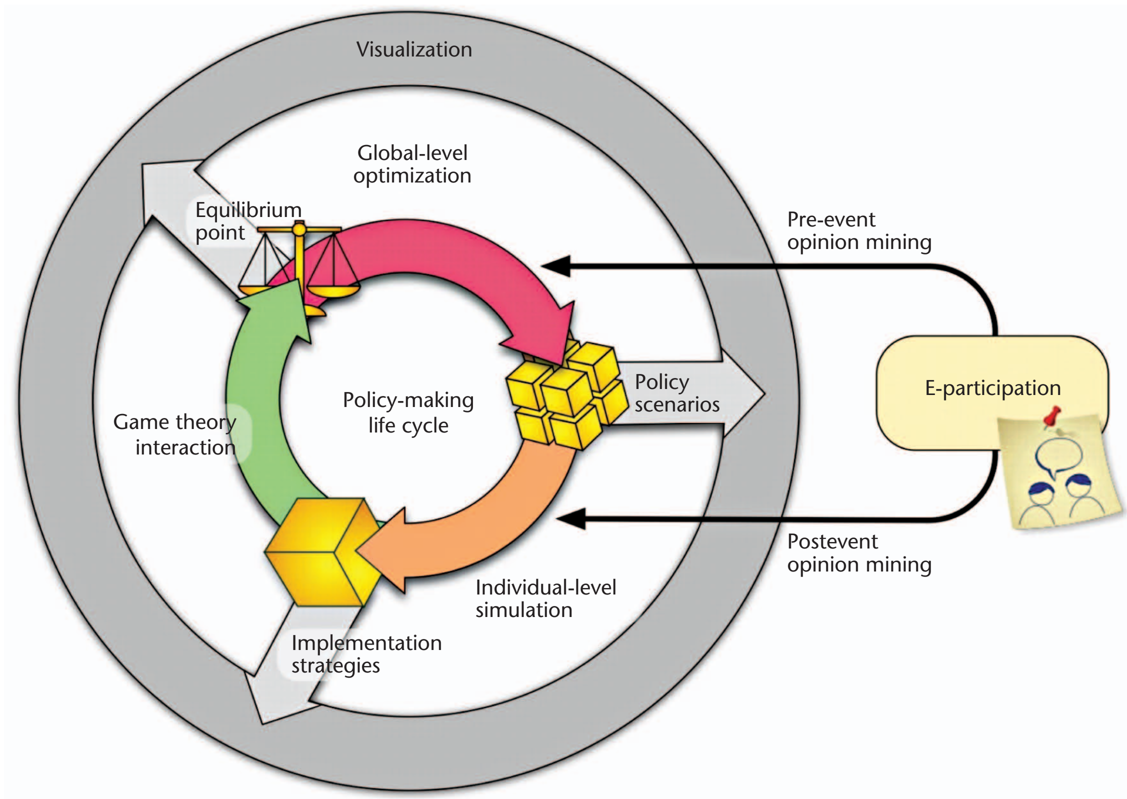

Figure 3. The policy-making life cycle in the ePolicy project, which aims to provide a decision support system for policy makers.

such KDD techniques to directly involve policy makers in opinion analysis.

Two Use Cases for Policy Modeling

Two European Commission-funded projects that focus on integrating visualization into policy modeling are ePolicy and Fupol.

ePolicy

The ePolicy (*E*ngineering the *Po*licy-Making *Li*fe *C*ycle; www.epolicy-project.eu) project aims to provide a decision-support system for policy makers. To do this, the project is engineering a policy-making life cycle for regional energy planning. The life cycle will bring to policy makers' attention both global concerns (for example, regional energy incentives' impacts, budget constraints, and objectives) and individual concerns (for example, opinions and reactions), guiding them toward better policy implementation.

Technically, ePolicy integrates these perspectives through global-level optimization, individual-level social simulation, game theory for managing conflicts and regulating the interaction between these two levels, and opinion mining (see Figure 3). The project's goals are to uniquely combine these research areas and provide intuitive visual-interactive access to the underlying techniques.

The project integrates information visualization and VA into policy making, especially during policy design and impact analysis. It uses information visualization mainly to visualize the vast amounts of data generated by automatic analysis tools such as opinion mining or social simulation. It closely connects VA tools to these analysis tools to set parameters and interactively control them for advanced impact analysis.

This project uses visualization techniques particularly to make complex analysis processes accessible for political analysts supporting decision-makers who are setting political agendas.

Fupol

Fupol (*Fu*ture *Pol*icy Modeling; www.fupol.eu), a four-year project that started in late 2011, will integrate multichannel social computing, crowdsourcing, and semantics visualization into political decision-making. It will consolidate heterogeneous technologies into a core system, which will automatically collect, analyze, interpret, and visualize opinions expressed on the Internet. This will enable governments to gain a better understanding of citizens' needs. A new governance model will support policy design and implementation. The approach is based on complexity science; it aims to reduce complexity through a spiral life cycle for policy design that's appropriate for complex societal problems.

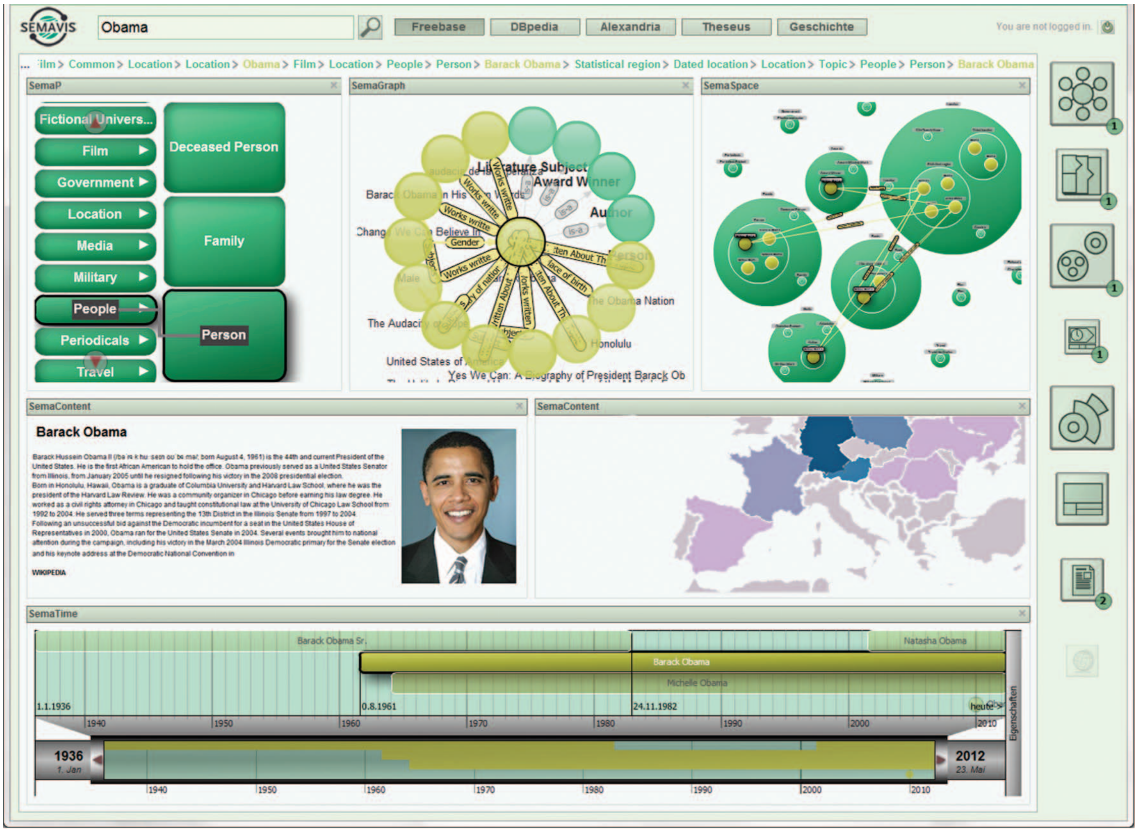

Figure 4. Semantics visualization for political information analysis. The figure illustrates the SemaVis visualization framework[4] in the information-foraging phase of policy modeling. Using semantics enables the visual abstraction of information in categories, the visualization of relations and dependencies of information entities, and geographic and time-related correlations. (Source: Fraunhofer IGD; used with permission.)

The policy design cycle will follow the three stages in Figure 2. Information foraging will apply semantics and information visualization to support new policy requirements and changes. Furthermore, Fupol will use opinion mining and analysis to gather information on information transparency and visualize it for politicians and citizens. This stage will consider using data from the linked-open-data initiative and other social and semantics data sources for visualization. Usage behavior analysis will be important in this stage. The visualization methods (see Figure 4) will be able to automatically adapt the visual structure, visual complexity, and data to be visualized to stakeholders' abilities and interests.[5]

Policy design will employ process-driven visualizations. Users' observed usage patterns will be analyzed to dynamically adapt functionalities and user guidance in a policy creation workflow that's strongly supported by visualizations and simulations.

In impact analysis, semantics visualizations will employ predicate and fuzzy logic to visualize a policy's impact.

The project is at an early stage that focuses on requirements analysis with the participating cities. Its outcomes will include the governance model, a policy knowledge database, an ICT framework based on cloud computing, and pilot applications for several European cities and one Chinese city.

The European Commission is investing heavily in policy-modeling research through the ICT for Governance and Policy Modeling initiative. The Crossroad (http://crossroad.epu.ntua.gr) project has set the tone for various projects in this area, such as ePolicy and Fupol. For the visualization and VA aspects, Crossroad has relied on the European VA research roadmap that the VisMaster coordination project presented in 2010.[6] To create this roadmap, VisMaster pulled together European VA experts; the project also had links to a roadmap written in the US and Canada.

The EU projects on governance and policy modeling have just started; it will be interesting to see how far they can introduce visual elements to policy modeling. For example, the European FET (Future & Emerging Technologies) Flagship Initiatives (http://cordis.europa.eu/fp7/ict/programme/fet/flagship/home_en.html) include the FuturICT pilot project, which brings together ICT research, complex-systems research, and the social sciences.

One goal is to give governments and citizens much more capable tools for policy modeling and policy analysis, including a strong visual component.

Similar projects are under way elsewhere, especially in Canada and the US. One example is Vaccine (Visual Analytics for Command, Control, and Interoperability Environments; www.purdue.edu/discoverypark/vaccine), a US Department of Homeland Security Center of Excellence that's using VA to enhance policy modeling for public safety and public health.

All these initiatives point in one common direction: visualization and VA are vital for informed decision-making and policy modeling in a highly complex information environment overloaded with data and information. We expect that policy modeling will be a common application domain in upcoming US and European visualization conferences. In the end, it might determine not only our policy makers' efficiency and proficiency but also citizens' involvement and confidence in future policy modeling.

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