# MAP GENERALISATION TECHNOLOGY: ADDRESSING THE NEED FOR A COMMON RESEARCH PLATFORM


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## ABSTRACT

The paper considers the issue of creating a common platform with which to collaborate and coordinate generalisation research. It suggests the timeliness of launching such an initiative based on the desire amongst research institutions to work together, the increasing level of complexity in generalisation research and the broadening demands on research for generalisation functionality. It goes on to consider current development and standardisation efforts with related aims and how these might be utilised. Finally, it discusses issues related to the design and implementation of such a platform using the experiences of the authors.


## 1. INTRODUCTION

There is a general consensus within the map generalisation research community of the need for a common research platform. This is evidenced by discussions around this issue at the last three meetings of the ICA Commission on Map Generalisation (Beijing 2001, Ottawa 2002 and Paris 2003 (1)). This paper examines the issues raised in these meetings in more detail and suggests how further progress might be made in achieving the goal of developing a common platform on which to carry out research. A major new challenge, also evident in these meetings, is provided by the need for visualization on small mobile displays. These new applications, in particular in the context of Location-Based-Services (LBS), form new demands beyond those approached to traditional generalisation, e.g. different types of generalisation operations are needed and there are real-time aspects relevant to their application.

## 2. BACKGROUND

In the past, much of the research in map generalisation has focussed around questions that could be explored largely independently of other researchers. Research generally followed two themes; the development of algorithms to implement generalisation operators (cf. (2)), often using standalone programs and purpose-built test harnesses, and, the acquisition and representation of cartographic knowledge for generalisation (cf. (3)), including applying this to automate the selection and/or parameterisation of algorithms, for example within expert systems. Commercial needs for automated generalisation were met through the provision of interactive workbenches using "Toolboxes" of algorithms, for example in geographic information systems such as Intergraph's dynaGEN, ESRI's ArcInfo and Laser-Scan's Lamps2.

In more recent times, the direction of research in generalisation has changed, integrating the outputs of these two research themes. Algorithm development has become more focussed on satisfying constraints which model knowledge ((4), (5), (6), (7)). This has meant that algorithms have had to become more complex, needing both intelligence to optimise amongst numerous design constraints ((8), (9), (10), (11)) and better representations of geographic phenomena, space and spatial relations ((12), (13), (14)). Lessons learned from attempts to automate the generalisation process using rule based approaches have also led to more complex self-evaluating techniques for the orchestration of algorithms (15), for example using multi-agent systems ((16), (17)).

## 3. MOTIVATION

### 3.1 Increasing Complexity

These developments in generalisation have resulted in a number of new needs:

- The need to utilise more complex tools for spatial analysis (e.g. Delaunay Triangulations and Voronoi Diagrams) in algorithm design, provided either within high-end GIS systems or by third party software toolkits such as CGAL (18) and Triangle (19).
- The need to model phenomena using object based representations with more complete and accessible geometric and topological structures.
- The need to link between sets of multi-scale representations of the same data.
- The need to integrate sufficiently rich libraries of algorithms within the same framework in order to study their sequencing and orchestration.

Considerable effort is often required to meet these needs, gathering together tools, designing a platform, integrating tools etc. This means researchers must spend significant amounts of valuable time just to reach the research frontier. Moreover, the platforms developed through this process are institute specific and differ greatly, leaving little opportunity for sharing research. As the field develops further increased complexity will likely only draw such platforms further apart. Increasingly different decompositions of components as well as mixtures of proprietary and non-commercial software are making it harder for two sets of researchers to agree on the same tools, at a time when complexity demands that it is more and more important to do so.

The alternative approach has been to work with a commercial GIS company to develop their platform to meet common research and development needs. This was the approach of the AGENT project which used Laser-Scan's LAMPS2 as the basis for its prototype (17). The success of this project clearly demonstrates the value in working within a common framework. It allowed a more holistic view of the generalisation process to be adopted through the development and sharing of code within in a single language and object-oriented framework. Research could also draw on a rich library of existing spatial analysis tools and support for, including tailoring of, the core GIS platform that was freely available.

However, such a relationship is not without its cost. A company must be able to justify its expenditure on supporting research, meaning that research must be sufficiently close to their commercial goals and target markets. The company must also be free to change, or even drop, the platform as it or its customers require. It must also be able to exclusively protect and exploit the intellectual property contained within it. For research groups such restrictions are often unacceptable. Research institutes must be free to follow their own research agendas without commercial justification. They must be free to publish results of research to the benefit of the wider community. More pragmatically, research institutes may anyway have existing contractual obligations to other vendors, for example as project partners, which mean they cannot adopt such a platform of a competitor.

### 3.2 Evaluation and replicability

The growth of the field of generalisation has meant that increasing numbers of algorithms are available to perform similar tasks and that therefore, more than ever, it is necessary to evaluate a new algorithm against what already exists. Comparison based on published results or on results achieved with sample data may be problematic because of the difficulty in showing that these are representative. The alternative is to benchmark the algorithms themselves. As the complexity of algorithms also grows this becomes harder to do simply by implementing alternatives and running them side by side in benchmark tests. The alternative approaches may have specific requirements on third party software that inhibit their reimplementation. Moreover, the actual code of the algorithm may have become "lost" with the passage of time and academic papers describing it may not fully capture its intricacies. Thus, in order to replicate and evaluate results, it makes sense to have a common research platform that leads to the possibility of archiving and reusing the research results.

### 3.3 New demands on generalisation

The opening up of a broad range of new research areas in dynamic cartography has generated new demands for generalisation. In particular are the recent developments of on-demand mapping and those of highly service-oriented thematic mapping, for example LBS applications such as navigation and route services. New devices, with smaller screens, for displaying mapped information have also suggested the need for more flexible methods for portrayal and generalisation of geographic information based on users' contexts and tasks, e.g. using fish-eye projections ((20), (21)), explicit emphasis (22) or adaptive visualisation (23). This enthusiasm for generalisation in new research areas is also evidenced by its inclusion in a number of current European research projects (e.g. WebPark (24), GiMoDig (25), SPIRIT (26)). What is interesting to note about these projects is that generalisation is not the main goal of the project, but rather a work package within it, indicating the continuing integration of generalisation into other areas of GIS research. These demands are not just confined to the research arena. The successes of recent commercial products such as Netsolut's Map24 (27) and Idevio's RaveGeo (28) indicate there is a commercial demand for these types of techniques. One might even speculate that the shot in the arm needed to drive the commercial uptake of LBS is the improvement in portrayal quality that could be achieved by the use of generalisation techniques.

From discussions within the research community it is apparent that these new forms of portrayal provide the most important justification for a common platform, since their needs are not currently met by existing commercial products otherwise. Meeting these goals provides the principal motivation for this work. Most of the platforms used for this type of research focus around lightweight web mapping platforms with generalisation functionality built in as a middleware component. One advantage of this approach has been from the standardisation of components, interfaces and data exchange formats by the Open GIS Consortium (29) and other bodies such as the World-Wide Web Consortium (30). GML (31) and the Web Map (WMS) (32) and Web Feature Server (WFS) (33) standards of the OGC have meant that researchers can proceed with development in the knowledge that they can interchange fundamental components without affecting their development environments. Another advantage is that they can reuse standardised components developed for other projects, for example those for rendering graphics and those for accessing different data resources. Clearly, the presentation of generalisation functionality as a middleware component doesn't solve any of the issues for research collaboration *per se*, since it doesn't deal with the internals of a generalisation component which is where interoperation amongst the research community will need to take place. However, it does present the strongest candidate for the way forward.

## 4. RELATED DEVELOPMENTS

### 4.1 Standardisation

As has been mentioned above, the provision of standards for components has assisted the development of individual research platforms by maximising reuse of technology, minimising duplication of effort and avoiding software lock-in. However, the kind of standardisation referred to so far has been of a relatively coarse granularity. What also needs to be considered are the more low-level standards that relate specifically to the needs of generalisation and which might supply the necessary glue to allow generalisation components to interoperate. Table 1 illustrates several such candidates.

Table 1. Current relevant standardisation efforts.

| Standard | Description. |
|---|---|
| Styled Layer Descriptors (SLD) (34) | The SLD specification is an OGC specification that provides a standard method for describing symbology styling and tying this to an abstraction for cartographic presentation (the map "layers"). Layers are themselves described using OGC abstractions related to data; the simple features abstraction and the filter encoding specification. For generalisation this specification provides a neutral format for describing map specifications that, in particular, can be directly used for the parameterisation of constraints. |
| Filter encoding (35) | The Filter Encoding specification is an OGC specification for accessing simple features data. It provides a neutral method for composing spatial and semantic queries. Generalistion processes need to be able to make considerable use of such data access transactions, for example to consider the spatial context of an object or to restrict processing to partitions of data or to perform model generalisation operations. It is therefore importance that this can be done through an abstraction that is independent of the data resource. |
| Scalable Vector Graphics (SVG) (36) | SVG is a W3C XML specification that allows the description of graphics composed of vectors. There are several plug-ins for web browsers and handheld computers that will then display these graphics directly. It provides an abstraction for relatively low-level map display elements that can combine styling and geometric information in a non-device specific way. The standard has attracted much attention from both the cartography research community, as evidenced by the SVGOpen conference series, and the generalisation community (57). The main advantage is that it allows developers to be independent of rendering issues making map results more portable. Also because it is defined in XML Schema, developers can take advantage of XML and XSLT tools to handle it ((51), (52), (53)). |
| Geographic Objects (GO-1) (37) | GO-1 is an OGC initiative aimed at standardizing low level components used in geographic applications. The standardization is through capturing classes and their interfaces in UML to ensure platform independence. Currently 12 classes are being considered, organized into 3 categories. These are – application classes: canvas, render and control; information classes: styling, symbol, text placement, geometry, feature, application feature and feature collection; and service classes: data server and filter. This standardization will be based on many of the previously described standardization efforts. As well as providing direction for possible standard components for a common generalisation platform the initiative is also interesting in how it has laid out its interoperability strategy. |

Table 1. continued.

| Standard | Description. |
|---|---|
| GeoAPI (38) | GeoAPI is a defacto standardisation effort being organised by a consortium of developers working on different open-source projects (Deegree, JTS, GeoTools2). It has been initiated in response to a need for a common geometry model which would facilitate the integration of code amongst different open-source projects and reduce duplication of effort. The development is for a common geometry API defined at the interface level using the ISO 19107 standard. The work will be made in association with GO-1. It provides essential glue for a common generalisation platform since the most significant point of departure for many different tools is the geometry model. |
| Java Data Objects ((39), (40)) | Access to data storage resources must be in a manner that is independent of any specific database and using standard access methods. One approach is via a Web Feature Server which has the advantage that it is truly programming language independent. However, another possibility is to use Java Data Object specification, this provides a bridge between the data store world and the application world presenting data to developers directly as java classes (41), these java classes could also implement the GeoAPI to make them more interoperable. |

**4.2 Open source community**

A further boost to efforts to develop a common research platform could be the availability of related software tools to fast track development for different parties. A number of GIS open-source projects exist that are of interest to generalisation. Some examples of these are listed in Table 2.

Table 2. Relevant open-source projects

| | |
|---|---|
| Deegree (42), GeoTools (43), PostGIS (44), GeoServer (45) | These are different open-source projects hosted by Sourceforge (48). They follow roughly similar aims, which are the provision of open-source implementations of the OGC web services specifications. In general they are provided as modular Java frameworks allowing developers to pick salient modules for customised tools. |
| Seagis (46) | This is an open-source project that implements the OGC coordinate transformation service standard (49). It is now largely encapsulated within the GeoTool2 project referred to above. |
| JTS Topology Suite (JTS) and JTS Conflation Suite (JCS) (47), CGAL (18), Triangle (19) | These are various libraries that provide tools for spatial analysis and computational geometry. They have enjoyed a high degree of popularity amongst developers in the generalisation research community. |

**4.3 Summary**

The preceding discussion shows that significant effort has been made in the context of geo-spatial standardization and open source development. These efforts demonstrate the pertinence of launching an initiative to develop a common platform at this time. In addition, there is a clear research need to collaborate in order to pose questions that are to complex to be asked independently. Hence, there is sufficient momentum both from complementary standards and related development efforts and the research community itself to give such a project a reasonable chance of success.

## 5. EXAMPLES OF CURRENT RESEARCH PLATFORMS

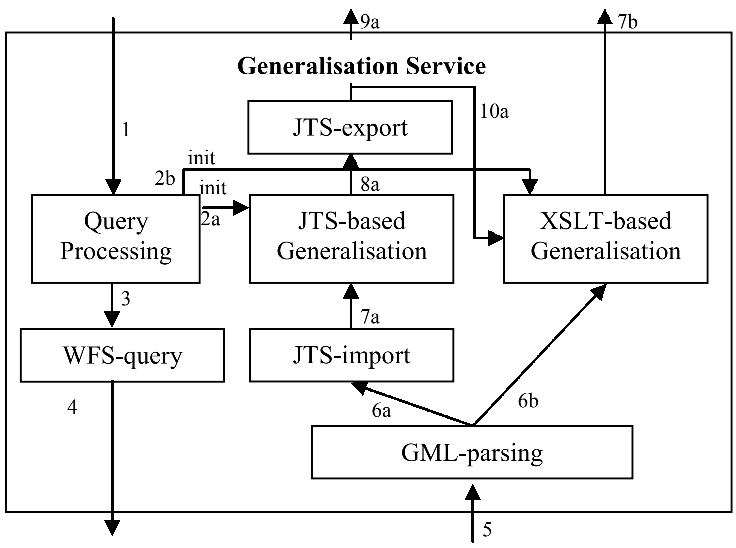


Figure 1a. Generalisation Service in GiMoDig, internal workflow, cf. Figure 1b (50).

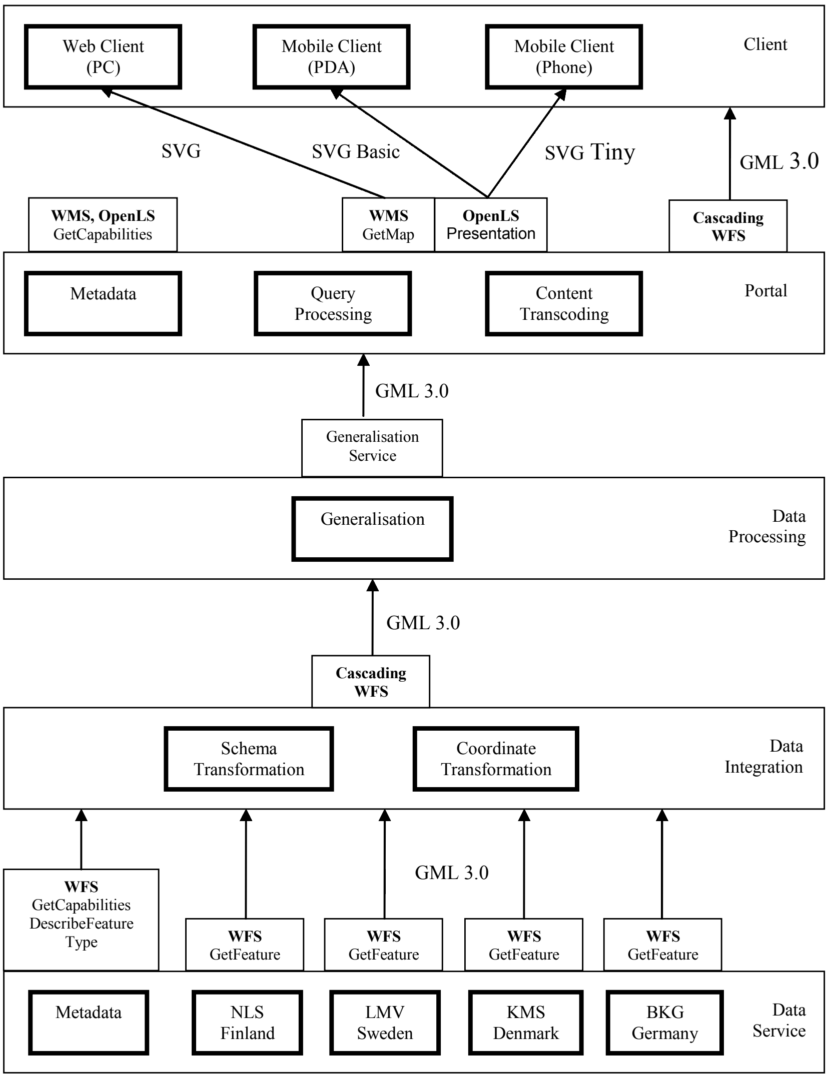


Figure 1b. Overview of the system architecture in the GiMoDig project (50).

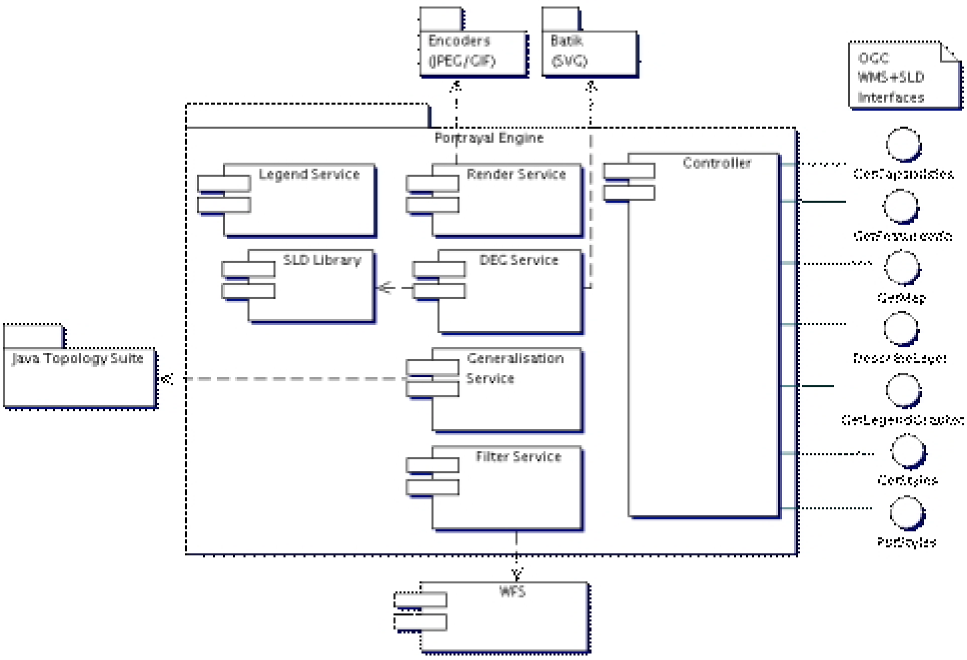


Figure 2. Overview of the architecture designs from the University of Zurich.

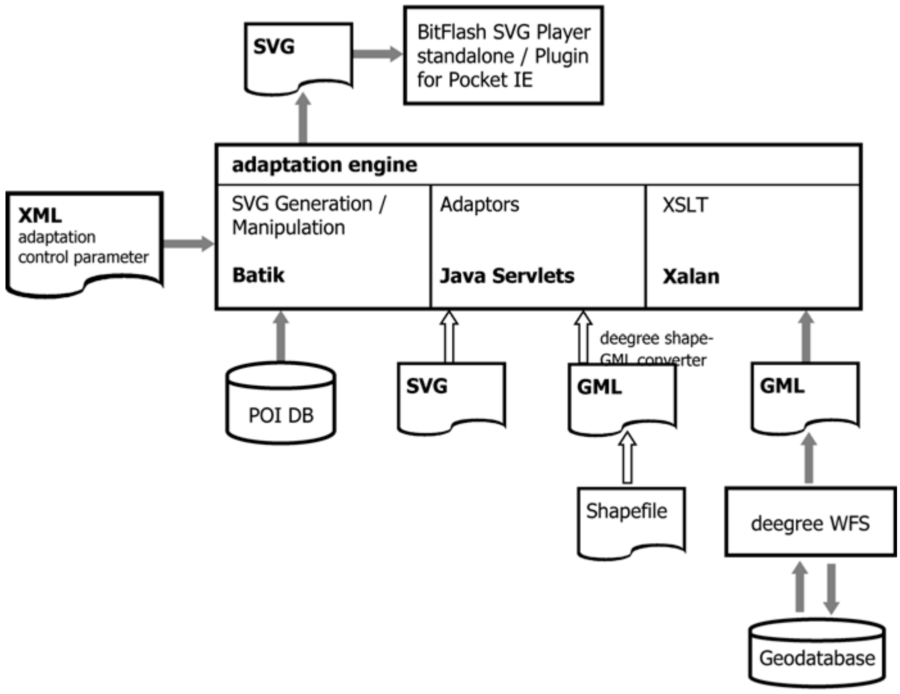


Figure 3. Overview of the architecture design from Technical University Munich (56).

Figures 1b describes the system architecture being used in the EU project GiMoDig (25). The main interest in this paper lies in the middleware called the data processing layer. In Figure 1a the workflow for the generalisation service is shown. There are two computing environments for the generalisation: XSLT and Java (JTS). Lehto and Kilpeläinen ((51), (52), (53)) demonstrated the use of XSLT (with some Java extensions) for real-real-time generalisation (e.g., selection and simplification). Harrie and Johansson (54) and Tuvesson and Harrie (55) used the Java class libraries JTS and JCS (47) for implementing some real-time generalisation and integration algorithms. The advantage of using XSLT is that it is computationally fast for "simple" generalisation tasks (that treats each object individually). JTS and JCS is not that computationally fast; on the other hand this Java environment provides tools for handling of complex relationships between objects in the generalisation process.

Figure 2 shows early design work from the University of Zurich for a research platform for portrayal which is to be used also in the EU project Webpark (24). Here again the approach of using a middleware component is favored. The design draws heavily on OGC standards and the decomposition of services and interfaces used by the OGC Web Map Server specifications (32). It inserts a generalisation service which provides three functions, using independent sub-modules; 1) model generalization - enabled through manipulations of filter requests and responses, 2) organisation of data into geographically meaningful groups relevant to a task e.g. clusters, alignments etc. and the formulation of declarative statements to direct their generalisation, and 3) graphical generalisation based on symbology conflicts and design constraints. The platform is to be configured dynamically using an XML schema that the developers have called the generalisation model language (GERML). This is intended to map an abstract view of generalisation process to classes implementing it. For each component in the generalisation GERML will provide an XML element. Within this a java class is declared that provides the actual functioning to realize the component. An example might be generalisation operators mapped to different generalisation algorithms. An interface level API provides definitions for methods of each of the abstract components that must implemented by concrete classes. This design means that functionality isn't hard coded into the framework but is instead bound dynamically meaning that it can be interchanged and extended independently. This modularity also provides allows the potential of code sharing to be maximized. It is intended to implement the design using the framework from Deegree (42) to supply basic infrastructure and JTS (47) to provide a basic spatial analysis tools.

Figure 3 shows the architecture partly in use for a research project on adaptive visualisation in mobile cartography at the Technical University of Munich (56). Like in the architecture from the University of Zurich, it is intended to use the Deegree WFS. So far Shapefiles are converted to GML using the converter classes provided by Deegree. The adaptation engine, which could also include generalisation functionality, either transforms the GML documents to SVG applying XSLT or generates SVG from scratch using Batik (58). The adaptation functionality is implemented in Java Servlets. The controlling parameters for the adaptation are encoded in XML.

The examples already show several commonalities:
- a middleware approach to the problem,
- the use of OGC standard web services components,
- the use of open-source tools for infrastructural support,
- the separation between data handling, generalisation processing and visualization layers,
- the use of SVG and JTS.

## 6. ISSUES FOR CONSENSUS

### 6.1 Basic needs
At the most fundamental level, a common platform needs to provide an infrastructure of basic GIS functions for example; data access, schema representation (e.g. geometry model and feature model), visualisation, user interaction, data structures and tools for spatial analysis, and tools for debugging. These basic needs provide the minimum set of requirements for research groups to collaborate effectively. From this point, a platform can be grown organically according to the research agendas of different groups, with different projects adding tools and functionality in a relatively ad hoc way. It needs to be agreed what these basic needs are, how they can be provided by existing tools, how these can be integrated together and what additional specifications are required. This process will need to identify the commonalities amongst the technologies in use by interested research groups and generate a consensus view of the platform from this. The components of this view can then be mapped to relevant standards and open software frameworks to determine what exists and where the holes are. This process to some extent mirrors that of the development of OGC initiatives, which might therefore act a guide.

### 6.2 Decomposition of the generalisation process
Having identified the basic infrastructure, the next level of collaboration is within the generalisation process itself. This requires a common view of the process and the concepts it involves, such as constraints, operators and measures. A decomposition of the information requirements and services for generalisation, which can be more formally specified, is therefore required. For example, should generalisation processing be viewed as a single service exposing an interface at a fairly coarse level, or should it be viewed as several different services e.g. a model generalisation service, a service for organisation of information, a service for graphic generalisation and adapted portrayal? As a single service it could encompass the needs of more people but at the cost of making it harder to share code at a lower level. With a more refined decomposition the research interests of different institutions need to be a strong influence. Another question is should generalisation operate on geometric information objects, simple features or on display elements that combine styling and graphical information? If there are different generalisation services then in terms of modularity and encapsulation it may make sense that they operate on different types of information objects, but pragmatically most spatial analysis algorithm libraries will probably work on geometries (e.g. JTS), so should design be shoe-horned to fit these considerations? It also needs to be asked if there are additional definitions required for information objects e.g. constraints and map specifications or can other standards be used to fulfil these roles?

### 6.3 Level of interoperation
It is also important to consider the level of cooperation that should be sought. Most research groups will not wish to abandon their current platforms but rather retrofit these to a common view. Definition of functionality and data types at the interface level captured in UML provides the most generic and inclusive approach to allow this. It allows research groups wrap existing platforms using various design patterns (59) e.g. “Bridge” and “Adaptor”. It also allows the model to stay free of language bindings, and therefore be more interoperable. An XML Schema definition similar to GERML, described previously, would also allow a language independent definition of the architecture and facilitate code sharing through dynamic binding of classes. However, developing a common implementation also has the advantage that it facilitates cooperation at a very low level. It also allows research groups without a platform to take part or to investigate research questions in new areas. Since it would have too reuse components from related open-source projects, it could draw on a wider body of experience and development assistance.

### 6.4 Summary
From discussion so far the favoured approach to cooperation would be:
- Definition of basic GIS needs,
- the description of a middleware model showing how a generalisation/adaptive portrayal engine can sit with other (largely OGC) standardised components,
- the design of an interface API consisting at the highest level of the description of a set of services and information objects for generalisation and at the lowest level generic interfaces for algorithms, measures, controllers etc. for generalisation,
- the definition of a XML Schema specification for describing the generalisation process at an abstract level,
- the generation of the captured interfaces in java and C++,
- implementations of the captured interfaces in java (and C++ if possible), and
- development of a java based reference platform using open-source components

Besides the functionality described above, which seems to be fulfilled by the systems and standards identified in section 4, there are also further needs for potential users of such a research platform: especially during the implementation and code generating phase, tools for a flexible inspection of data are needed, e.g. visualization, inspection of parameters and attributes – options that are generally provided by standard GIS.

## 7. ORGANISATION

The barriers to the creation of a common platform for generalisation need to also be considered.

### 7.1 Funding

Currently it is assumed that there are no available financial resources to support this work meaning that funding is largely through good will. However, since many research groups need to develop or redevelop platforms anyway, for example for specific projects, it is likely that some work can be subsidised indirectly. If sufficient momentum can be built up for development work it might also be possible to seek funding from a commercial sponsor.

### 7.2 "Coopertition"

The OGC use the invented term "coopertition" to describe the dichotomy between cooperation and competition embodied in such collaborations. Whilst the issue of competition is not so strong in, particularly academia, research it is still relevant. A level of cooperation needs to be determined that allows sharing of a common framework without making demands on the intellectual property of individuals. Likewise where an individual research group is happy to open up it research tools to the wider community methods to ensure relevant accreditation of intellectual property need to be provided.

### 7.3 Coordination for software engineering

If cooperation is to be made at an implementation level, policies need to be developed to ensure a level of quality of code both in terms of how it runs and how it can be maintained. This involves establishing guidelines for design of modules and reviewing, commenting and documentation of code. Systems for managing versions of code need also to be established. This includes not only code developed in house but also dependencies such as open-source frameworks used and their respective dependencies e.g. the version of the Java SDK they are based on. How new users can be supported needs to also be considered.

## 8. CONCLUSIONS

There is a broad agreement in the generalisation research community that a common research platform would be highly desirable. In particular, this is because of new research agendas related to dynamic portrayal of information for geographic services, often on small screen devices. Satisfying the platform and collaboration needs for this research domain is the goal of this project.

It appears from examples that the research platforms currently used in this domain share many similarities. This not only underlines the usefulness of sharing platform development efforts but also suggests that the concepts being used by researchers are sufficiently collective that consensus on the design of a platform can be achieved.

There are significant design barriers to the creation of a common platform. However, it is clear that the numerous open-source frameworks and relevant standards will help to overcome many of these barriers as well as alleviate the effort required to implement a reference platform.

It is realised by the authors that designing and implementing such a platform can be a time-consuming and ambitious project if it seeks to encompass all possibilities. It is instead hoped to evolve this platform in a more organic fashion, by starting from a framework meeting basic needs and allowing researchers to add functionality over time as research projects using the platform develop. The organisation of the project will follow a similar course, building from a base of a loosely-coupled group of researchers working to meet to common goals and using the ICA meetings (conferences and commission workshops) to discuss the progress of the project with the wider research community.

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# MAP GENERALISATION TECHNOLOGY: ADDRESSING THE NEED FOR A COMMON RESEARCH PLATFORM

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