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Concept for a Web-based Information System for Flood Management

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Abstract. Recent emergency flood situations at European rivers have revealed the demand for better and in-time information for citizens in flood prone areas about flood development, as well as better coordination of resources and actions during pre-flood phases and its critical stage. Information and Communication Technology (ICT) has a large potential to improve the situation. Decisions may be supported by information about resources available at the region and national level, by information about means and access to critical locations at the prevention as well as the evacuation phases, and by including citizens as well as managers into one common information and communication process. The paper outlines the potential of ICT for these aspects.

Key words: ICT, Web based flood management, Web applications, Web services, document management, waterlevel forecast, neural networks, SMS warning, XML schema

1. Introduction

Decision support is based on information which has to be generated, ordered, presented and disseminated. For management of risk in flood prone areas, information concerns knowledge about development of high water situations, about availability of resources and means for prevention and rescue and about logistics and processes of actions. Since long primarily the forecast of water level development by means of ICT based models has been considered and little attention been given to the administrative management and information processes during crisis situations involving citizens at all stages of crisis development. Both aspects will be considered in more detail within this paper.

Forecasting water level has at all times been a challenge to water engineers. Statistical and mathematical methods tools have been developed to calculate the run-off and flood wave propagation in rivers for planning purposes and to identify which regions might be affected or should be protected. ICT started to play a role within modelling only since 1960. Different kinds of models are in use.

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The early water level forecasting systems were based on statistics, idealised analytical calculations and heuristics. Much depended on the experience of a few engineers who had become familiar with the local system over a number of years. The situation improved when discrete numerical models became operational. First those models had been a domain of universities and research centres with access to mainframe computers. Studies and expertise were provided from these institutions for planning purposes on river developments and their impact on high water situations. Only in the 1980s did governmental regional organisations in charge of "official" forecast begin to build their own numerical model dedicated to particular river basins. These institutions then became authorised centres for warning services and crisis management. Their job was – and in most cases still is – limited to the physical-hydrological-engineering view of the problem. For the main European river basins they are collaborating in international commissions.

Numerical modelling entered into water engineering practice during the 1980s on a large scale after the appearance of the PC. As mainframe computers were no longer a prerequisite for building regional flood forecast models, even specialised small institutes and companies became builders and users of software for flood simulation systems. As such systems are based on the shallow-water equations and with features to cope with flooding and drying, they can be applied to a variety of problems from river to coastal and tidal systems. This wide range of application pushed the development of numerical methods and software dramatically. Many forecast and flooding scenarios models have been developed since then for most flood prone areas at rivers and coasts.

Online forecast and flooding calculations, however, were still rare and under operation of institutions with big mainframe installations. The first only PC based simulation system had been installed in 1987 in the city of Hamburg in Germany. It may serve here as example for developments at other places too. It consisted of four car battery buffered PCs operating independently at four distributed crisis centres. The forecast was driven by data on water level development at the North Sea (Cuxhaven) and was calculating 2-dimensional flooding situations in the city area in the case of a dike breaking (Holz and Kroker, 1987). On installation this system already showed the potential of ICT for decision support in crisis management. It might provide useful information about roads accessible at high water for dike repair and evacuation work of people, for displaying infrastructure and factories to support decisions about where help is needed most urgently, about sensitive goods and their risk potential etc. This visionary outlook of those days becomes reality with the appearance of the Internet since 1995. Decision taking is based on information and information on communication. The utilization of this technology in the context of flood warning and management is at the centre of this paper. The approaches and solutions have been elaborated within the EC funded project OSIRIS (Operational Solutions for the Management of Inundation Risks in the Information Society)[1] and the German Research Network Natural Disasters (DFNK)[2] funded by the German Federal Ministry of Education and Research.

OSIRIS focused mainly on the ICT aspects. It aimed at the dissemination of information in the critical situations of catastrophic flood events to increase the awareness of the citizens, to prepare citizens and crisis managers for efficient protection and rescue measures, to improve the quality of information made accessible to all flood crisis stakeholders before, during and after the crisis period, and to increase the rapidity and flexibility of information access (Holz and Erlich, 2003). Target of the DFNK funded project was the numerical simulation of instationary flooding processes on river banks and in polder areas after sudden dike breaching. This project served for illustrating ICT based decision support solutions and testing new methods for flood forecast by neural network methodology.

2. From Closed to Open ICT

Numerical flood forecast modelling started on mainframe computers 40 years ago. Since then the computer performance increased according to Moore's law which still holds. Numerical power, disk capacity and transmission rates on an average are doubling every 18 months which means they are growing by a factor of 100 over 10 years, and respectively a factor of 10,000 over 20 years. So, nowadays any forecast model may be run on a PC at any location. So models became as open and mobile as PC's are, provided input data are available.

Networking between computers became everyday practice due to the appearance of the Internet, only 10 years ago. "The net is the operating system" as proclaimed by the CEO of Sun Microsystems, has become true. The PC has changed its role completely. Nowadays it should be considered even more as a "communication engine" than a "computation engine". This change makes the net based PC ideally appropriate to handle forecast and crisis management related "information" of any kind. Performing numerical calculations for flood forecast has become just an "added value".

Modern cell phones, designed as "communication engines" turned into mini "computation engines" by processor power and memory. Connected

[1] http://www.ist-osiris.org

[2] http://dfnk.gfz-potsdam.de

to the Internet and running the Web browser as a general operation system, they are offering, together with PC's available everywhere and therefore accessible to everybody, an open and mobile environment for information and communication. Moreover, as cell phones are "detectable" by position, they are ideally supporting rescue and crisis management demands.

So in summary, closed and static and centralised approaches have to be reconsidered. The new paradigm of working "any place – any time" ideally supports management during a flood crisis. Distributed residential people, distributed means and material, distributed monitoring, distributed information and distributed actions can be managed and co-ordinated from a distributed, eventually even "virtual", headquarter at any time. Distributed communication to and between citizens and acting professionals during crisis situations support coordination of actions, dissemination of instructions and help creating confidence in measures taken.

3. From Equation to Data Driven Models

Improvement in hardware goes along with the potential for new approaches. Forecast models have been based on deterministic differential equations to be solved numerically by discrete methods. These models, if covering areas on the scale of river basins, even within a modern hardware environment, take quite some time to compute. More severe, however, is the fact that they can produce reasonable forecasts in actual situations only if, besides the hydrology, all geometric data (bathymetry, riverbank, structures etc.) are at any time representing the real situation. This can hardly be achieved in practice due to the amount of data necessary to be monitored and updated continuously due to unexpected occurrence of extreme high water events.

An alternative to this approach has been emerging for a few years. It is based on the consideration of using self adaptive black box systems, which are driven only by recent hydrological/hydraulic data. Some data are representing driving forces of a system and some data can be interpreted as the corresponding reaction of the system. The correlation, even if it is represented by a non-linear function, can be represented by a particular artificial neural network (ANN). Such networks, having an architecture similar to the human brain, have to be trained from continuously incoming monitored data. Once trained, they are able to predict system responses when finding similar data patterns according to which they have been trained for. The applicability to forecast of water levels has been shown in literature and the validity tested within the project (Bazartseren *et al.*, 2002).

It is evident, that this approach – as any – has its limitations. A model can forecast only what it memorises and it will hardly memorise the 1000-years-return period situation because the river basin most likely will have totally changed by natural evolution or human made interactions over time. However, valuable support for warning and planning may be expected for short term periods such as 10–30 years, no human made changes assumed.

This approach is particularly interesting for high-water forecast when looking from an ICT perspective. The only input required for a neural network model are data from different stations over time giving precipitation and/or water level and/or discharge. If sensors are being equipped with small processors and these connected to a computer (data acquisition) network, small programs may perform the monitoring and training automatically without human interaction. More attractive, however, would be an Internet based approach. Assuming the measurement devices being equipped with a computer interacting with the Internet, intelligent agents may travel through the net, collect all data automatically and train the neural network. Even the artificial neural network, once trained, may travel through the net to do a forecast on a PC at any location. No central data acquisition system would be needed anymore.

4. From Forecast to Information in General

Conventional flood warning and crisis management systems do not exploit the full potential of ICT. Generally systems are "computation oriented" rather than "communication oriented" supporting management of information of all kind relevant to high-water management at all stages before, during and after a crisis. "Information" then refers to "actors" such as organisations, administrations, interest groups, stakeholders, persons, automatically operating equipment for monitoring etc. as well as to activities initiated and performed by "actors" as "actions" together with the "means" needed to fulfil these actions and the "objects" on which the actions apply under given "constraints" defined by regulations and standards. All information has to be communicated (information exchange/sharing) for keeping control on the state of the system it is representing. Generally speaking an "information management system" for flood management has to contain "information" from all areas concerning population and rescue, physics and engineering, technical standards and risks, regulations and law, technology and socio-economic aspects, actions and objects, means and communication together with the information on water level development within one integrated environment.

For system design abstraction has to be made on “information”. There are various definitions around which are all more or less useful. Here a definition might to be chosen which is appropriate for software development. Information consists of “information elements”. A generic information element is described as

Information = Information (syntax, semantic, pragmatic).

A simple example may serve for illustration. A water level gauge is delivering a signal in terms of data (electrical current, number etc.). Its representation is described by the syntax giving number of digits, transformation rule, origin etc. This signal can be interpreted only if some dimension and physical meaning is added. For this purpose, the semantic identifies the data as a water level value. To understand what this value is going to be used for, the pragmatic has to be added, for instance the boundary value for a numerical value or warning level for crisis management.

This generic approach is powerful. Imagine, having three information elements, an actual water level measurement, a forecasted water level and a water level representing a warning level. All these information elements may have different origin, from a measurement, from a numerical model and from a database. They are independent according to syntax and semantic. Pragmatic, however, tells them that they are elements to be shown within one warning notification to citizens. So pragmatic is defining the relations between information elements.

Within an “information management system” tools have to be applied which act on the “information elements”. A typical tool might concern the way how to present the information. Water levels might for instance, dependent on intended use, be given in the form of lists, tables and graphs (of various kinds). The same holds for communication tools transmitting information between actors as well as for documentation tools which control the output to media (paper, chart, electronic document etc.). It is obvious that such actions may only be performed on clearly structured information elements with clearly defined relations between each other. The theory of sets and relations/graphs provides the mathematical background for a formal description necessary for software design. The feasibility of such an approach has been shown in research (Brüggemann, 2000) for generating interactive dynamic documents and for working in semantic modelling environments (Brüggemann, 2002).

5. From Complexity to Software Design

One of the key issues for building complex software systems is the aggregation of numerous elements mapping structured information and the operations to be performed upon information elements by actors. Software engineering provides corresponding specification approaches such as the Unified Modelling Language (UML)[3]. This is based on diagrams enforcing the specification in a clear manner. An example is given to show the basic idea for the simplest case of "water level forecast".

Within an information management system there are "actors" performing "actions" on "objects". Taking the "water level" as an object (information element) the users (actors) and their actions have to be described. This description is represented within the "use case" diagram as given in Figure 1. It describes the process and the actors.

This "use-case" diagram represents actors in terms of their "role" they are taking within the information management process. It does not tell anything about their position, organisation, party etc. This information has to be specified by relations in separate tables.

The diagram does not tell anything neither about the means by which the actions are to be performed nor about the presentation of input and results to the different actors groups. In the diagram these functions are hidden within the communication layer contained in the presentation layer, which have to be specified separately. Moreover, it should be noticed that within Figure 1 no difference is made between human actors and devices and models. This underlines the generality of the approach.

The given UML methodology has limitations for describing event handling that is a typical feature of high water crisis management. If actions have to be taken in the case of a flood event and if these can be defined in advance, they can be described. In case of unforeseen situations such as breaking dikes, however, measures have to be taken *ad hoc* according to the actual development and needs of the situation. This can hardly be modelled within the given UML methodology. Further mathematical methods will be needed for formal description such as Petri-networks (Petri, 1962).

The true value of UML specification within software design is that this methodology allows the specification of object classes thus keeping software design down to the end of implementation. It is beyond this paper to go into further details.

6. From Granular Information to Documents

The previous chapters show that starting from clearly defined "information elements" and a process description by means of the Unified Modelling Language, all technology is available for designing a flood management

[3] http://www.omg.org/uml/

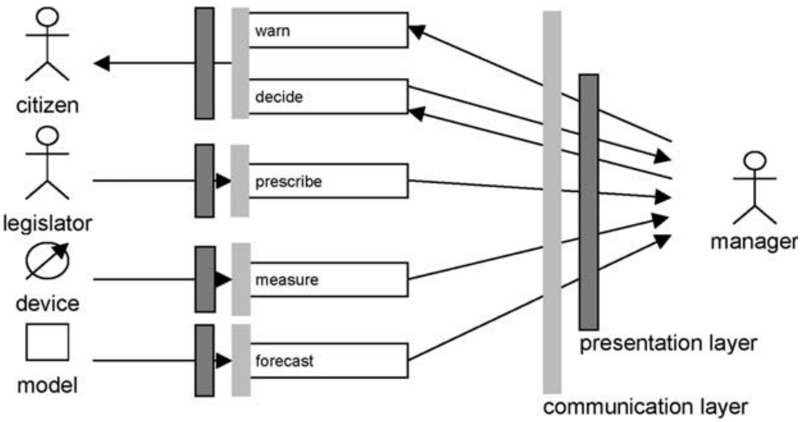

Figure 1. Unified Modelling Language, Use-Case Diagram "water level"

system in reasonable generality. The question, however, comes up what is reasonable and up to which level details have to be resolved.

Within the generalised approach an "information element" is representing the lowest level that can be described. For example this might be simply the datum of the water level at a given location and time. Assume this is to be compared with a water level contained and prescribed within a regulation for warning. Then the regulation itself has to be analysed and mapped into an information model itself. This, for sure, would lead to software of extreme complexity and be beyond the needs. The objectives of the system should be kept in mind and the information be specified down to a reasonable level of granularity only.

Most often information carriers may be considered as documents. A typical example is the textual version of a law or regulation. This is a text document. It contains numerous "information elements" and their relations as well as a description of processes to be followed. Picking up each element as an independent unit and describing all relations between them and the processes to be initiated would result in an "information model law" by itself and be beyond the needs.

Information is also contained in maps and charts. It is obvious that in a city map there is information about the position and direction of streets, their names, schools and hospitals marked etc. All of this information may be useful for crisis management. Some information, however, may be lacking for crisis management, such as the information on geographic height with respect to sea level and the actual condition of accessibility in case of construction work. This doubtlessly is the most crucial information for planning evacuation and rescue during inundation events and it has to be added in an appropriate manner. Typically information from digital terrain models has to be superimposed and notes about accessibility implemented by converting from textual to graphic information.

Pictures, plots from model results and videos/animated result presentations are information carriers as well. It would be a considerable task to extract the "information elements" contained concerning for instance high water level automatically by ICT tools. Mostly it is even not necessary as much information is picked up intuitively.

So, in summary, the approach taken was not going as far as the granularity of an information element, rather than to the assembly of information within a document. The analysis and judgement is left to the user. It is anticipated that only such documents are used and provided which are directly relevant to flood management. This is a pragmatic solution.

Nevertheless, within the software solution the way how to cope with granular information elements is demonstrated for water level information in the context of software generated electronic documents. Their content, as well as a way of presenting the content, is described by extended mark-up language (XML) descriptors. By software the descriptors may be identified and used for treatment within other ways of presentations in different context.

7. From Information Access to Reproducibility

Crucial aspects of any information management system are online access at any place and any time, redundancy, actuality, version control and reproducibility.

Access to documents containing the relevant information at any time and from any place is supported by Internet technology applying the Web browser as common operating system. The Web supports archiving and accessing the documents on any computer worldwide, no central computer serving as document base is necessary. Documents are stored by their authors on their computer installation embedded in the Internet. So they clearly remain within the responsibility of the person providing the document. Redundancy is avoided, actuality supported and version control is in hand of the information provider.

Management of crisis is no routine. So after crisis analysis of what had happened and why decisions have been taken this way reveals much insight and aspects for improvement. As ICT based system are recording all accesses to documents, reproducibility of processes run during crisis phases is given.

8. From Sequential to Object-Oriented Implementation

The potential of modern ICT is based on the Internet and the object-oriented paradigm represented by structured programming languages as Java and C++. Java[4] is fully embedded in the Internet; it supports all communication and networking processes provided within this environment and thus ideal for implementation.

The object-oriented approach is completely different to former software architectures 10 years ago. The former architecture was oriented towards fast execution of numerical algorithms as used in deterministic discrete numerical forecasting models. Data and the algorithm, operating on the data, were kept separately. The algorithm was loaded into the computer memory and started executing sequentially the methods while loading the required data and returning the results produced. Actions and communication with the algorithm was not possible directly unless foreseen and coded.

The object-oriented approach is different. It starts from the consideration that all physical, material and conceptual things we use are objects. Objects are thought of as having state. The state of an object is the condition of the object, or a set of circumstances describing the object. An object consists of attributes for modelling parametric properties (state) and methods for modelling functional properties (behaviour). The definition of an "information element" as used before is close to this approach. By its self descriptive parameters on syntax and semantic and pragmatic it "knows" everything about itself. It even knows the methods to be applied to itself. Data and methods are integral part of the object. They are not separated as in the sequential approach where data and algorithms might be contained in different data-/program-bases.

Objects being self-contained may travel through the Internet. They may be transferred to any computer worldwide and be treated or adapted there. Generally they are independent from their local environment. They may be assembled in to major units referencing objects on different levels and communicating with each other.

Transfer and communication between objects is supported within the client/server model. In the common client/server model, one server is activated and awaits client requests. Both client programs and server programs are generally part of a larger program or application. Relative to the Internet, the Web browser is a client program that requests services from a Web server on another computer somewhere on the Internet.

A special type of client/server model consists of three well-defined and separate processes, each running on a different platform:

[4] http://java.sun.com/

- The user interface, which runs on the user's computer (the client).
- The functional modules that actually process data. This middle tier runs on a server and is often called the application server.
- A database management system that stores the data required by the middle tier. This tier runs on a second server called the database server.

The object-oriented approach is implemented rather effectively in the Java environment. The Java code is portable in the net and can run anywhere in the net on a server or client that has a Java virtual machine as a Web browser plug-in or runtime environment. The Web browser supports the execution of any code on nearly all computing platforms from PCs to cell phones. The advantage of this approach is evident. In the view of users the Web browser may be considered as the "operating system" on which everybody is working worldwide. The architecture is outlined in Figure 2. So former difficulties, resulting from different practices and operating systems at local computer centres are overcome.

Objects may be rather different in size by either data and/or behaviour. To make the object-oriented approach feasible in all environments from PCs to cell phones with different data-storage and computing capacities, objects may be treated on the client-site or server-site. Server based computing is essential for operating with handhold devices (e.g. PDAs) or cell phones in the Internet, and also PCs benefit from low network traffic and fast response times. The server with high computing capacity sends only the presentation of the result for an object execution to the Web browser of the requesting device. The advantages are seen immediately. Any PC, any cell phone, even any measurement may be connected to the Internet forming a comprehensive environment with which an integrated software solution may be built.

9. From Theory to Practice

After considering general aspects of modern ICT its potential will be demonstrated within a few implementations done within the OSIRIS- and DFNK-project.

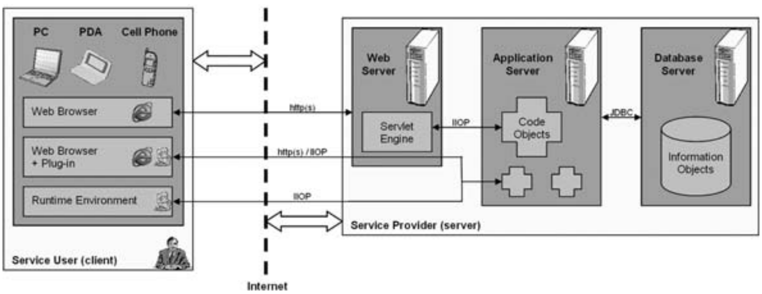

Figure 2. Client/server model, three-tier design, Java environment.

9.1. WEB BASED DOCUMENT MANAGEMENT

Information resources in the form of electronic documents are generated and remain within the responsibility of different authorities. These may reside at different locations. Thus information resources are available on a decentralised networking server as identified by their URL (uniform resource locator). The resources remain physically where they are generated. Thus maintenance and legal responsibility for the information content remains with the originating unit.

These external information resources provided on third party servers are integrated into the flood crisis management system through a Web based information resource management system called "DCMS" (Hildebrandt *et al.*, 2001). The DCMS[5] is a Meta database and manages an arbitrary number of heterogeneous information resources over the Internet by reference and classification. The resource classification is done by semantic markup using a single domain ontology for the description of implicit and hidden knowledge. The semantic markup consists of a flexible task-related set of attributes, which are summarised in a resource entry and stored in a database. These attributes are determined according to the classification of the information content. This allows a fast retrieval of the necessary information. The access, exchange and sharing of the information resources is facilitated using XML. A determined global query schema facilitates the search for the information content.

DCMS consists of a net based server component to manage the integrated resources of a certain domain by an administrator and a Web based front-end accessible by crisis-managers and citizens (see Figure 3: Web based document management). Decision support is offered to crisis-managers through exclusive information resources with restricted access. For educational purposes the DCMS also provides material on historical events. This material is presented in the form of text, pictures and movies, and supports awareness about the danger of flooding events.

Due to the flexible architecture of the DCMS new information resources can be easily classified and added to the repository, and become immediately available. The flexible architecture also allows the adaptation of the system to any kind of document based project in research, education or others. Today more than 30 installations for several independent projects from very different disciplines are running worldwide.

9.2. WATER LEVEL FORECAST AND PRESENTATION

A forecast of a high water situation is one of the most essential hydrological tasks for river basin management and is mainly performed by means of

[5] http://dcms.bauinf.tu-cottbus.de/

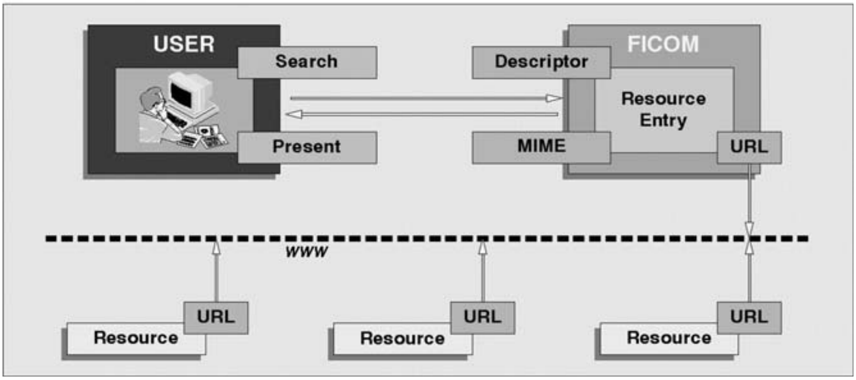

Figure 3. Web based document management.

traditional conceptual and deterministic models using forecasted precipitation. Due to ever-increasing urbanization and the consequential shorter hydrological response in the river basin, the information on prevention or restoration measures in the case of a flood ought to be accessible faster and more flexibly to the general public.

A Web application and a Web service for water level observation, processing, presentation and short-term forecast has been developed within OSIRIS (see Figure 4). The water level forecast has been implemented by cost-effective and rapid-responding artificial neural network (ANN) models. The water level presentations, as well as the forecast models are implemented as a Web application using Java Servlet technology[6]. The presentation of the collected and forecasted water level data is implemented in Scalable Vector Graphics (SVG)[7]. The Simple Object Access Protocol (SOAP)[8] has been used to deploy the water level forecast as a Web service (Hildebrandt and Holz, 2002).

The system contains functionalities for raw data collection from several federal hydrologic public data servers, the extraction of relevant data for the river Odra to which it had been applied into a local database, the processing of the user's requests and the presentation of results in tabular and graphical views.

The ANN has been operating since August 2001 and was trained for high water situations up to the alarming level 2. The online response time after request for the water level forecast is less than a second (Bazartseren and Holz, 2001).

[6] http://java.sun.com/webservices/

[7] http://www.w3.org/TR/SVG/

[8] http://www.w3.org/TR/SOAP/

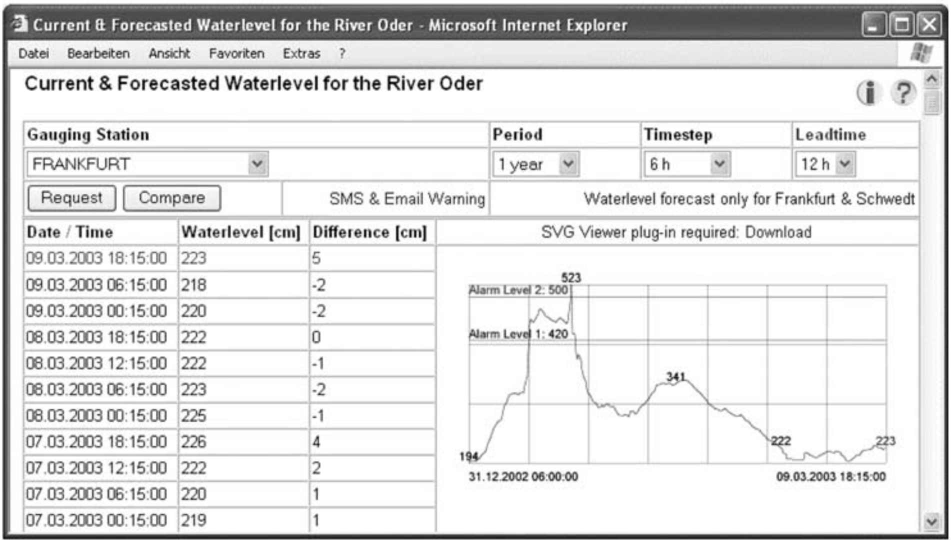

Figure 4. Water level forecast and presentation.

The system can be accessed as a real-time dynamic and interactive Web application by any person via a Web browser as front-end[9] also selected methods have been exposed as Web services by adding SOAP interfaces[10] to these methods. Web services are accessible as remote procedure calls (RPC) from any other software, subsystem or server independent from platform, operating system, object model, or programming language. This allows other software developers to integrate easily the OSIRIS Web services into their own software solutions.

9.3. SMS & E-MAIL FLOOD WARNING SERVICE

For citizens information on the water level forecast system is supplemented with services on cell phones. Everybody may register via the Web browser to be informed by SMS on his cell phone or e-mail as soon as some relevant water level exceeds a given threshold[11]. This additional service demands a fast forecast on the water level to be expected within the next few hours. Commonly this task of water level forecast is accomplished by numerical models. Because of computing time they generally have many restrictions when applied under real-time conditions. The ANN within the water level forecast system delivers the actual forecast within a second of reaction time.

[9] http://www.ist-osiris.org/ffoder/op/
[10] http://dcms.bauinf.tu-cottbus.de/wsm/
[11] http://www.ist-osiris.org/ffoder/sms/

There is a need for a publicly accessible Web based system to help citizens, as well as informing the decision makers at any time, who then may plan emergency and restoration measures during high water situations. The system enables citizens with an Internet access or a cell phone to monitor the flooding events likely to occur in their area of interest and to take prevention measures suggested by the relevant authorities. The forecast based only on hydrological conditions upstream has produced a satisfactory accuracy for practical purposes.

9.4. XML SCHEMA DEFINITION FOR HYDRO-METEOROLOGICAL DATA

XML is a standard, simple, self-consistent way of encoding both text and data so that content can be processed with relatively little human intervention and exchanged across diverse hardware, operating systems and applications.

In brief, XML offers:

- a widely adopted standard way of representing text and data,
- in a format that can be processed without much human or machine intelligence,
- exchanged across platforms, languages, and applications,
- and used with a wide range of development tools and utilities.

XML is a meta language which can be used to describe the logical structure of a wide variety of documents and data in different ways according to the application. This universal, flexible and extensible approach opens up an almost unlimited range of uses for XML, from word processing through electronic business to data archiving.

Within the OSIRIS-project an XML schema definition[12] has been developed by the consortium to support the exchange of hydro-meteorological data between different users and applications.

A typical application is the presentation of hydro-meteorological data (Figure 5). The tool for hydro-meteorological data presentation is accessible for crisis-managers as well as citizens as an interactive Web application[13] via the user's Web browser. The Web application produces at the user's request an HTML / SVG presentation of the user's XML data source. The user has to specify the URL of his XML data source and then receives the presentation after a successful validation of his data source against the defined XML schema definition for the hydro-meteorological data.

[12] http://www.ist-osiris.org/osiris.xsd

[13] http://www.ist-osiris.org/extern/wlp/

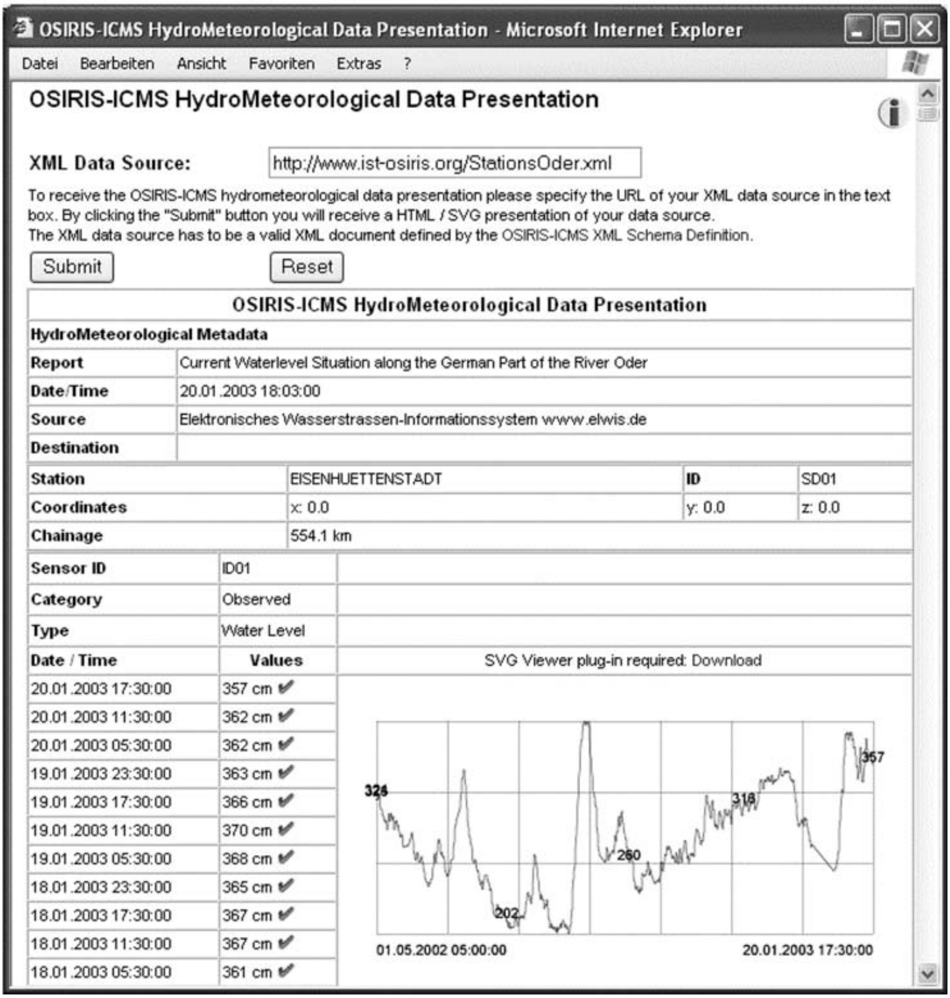

Figure 5. Hydro-meteorological data presentation.

9.5. GEOGRAPHIC INFORMATION SYSTEM INTEGRATION

The awareness of citizens and stakeholders to the risk in flood prone areas is important for flood management. This awareness can ideally be supported by visual information about high-water situations taken from the past or computed for scenarios. The past is best captured by pictures, photographs or videos contained as documents. Access is provided through the Internet, supported by plug-in software for video presentation.

Future danger and damage potential is best identified by numerical simulation of flooding processes. The results may be animated and superimposed by layers representing the streets, familiar locations, waterfront

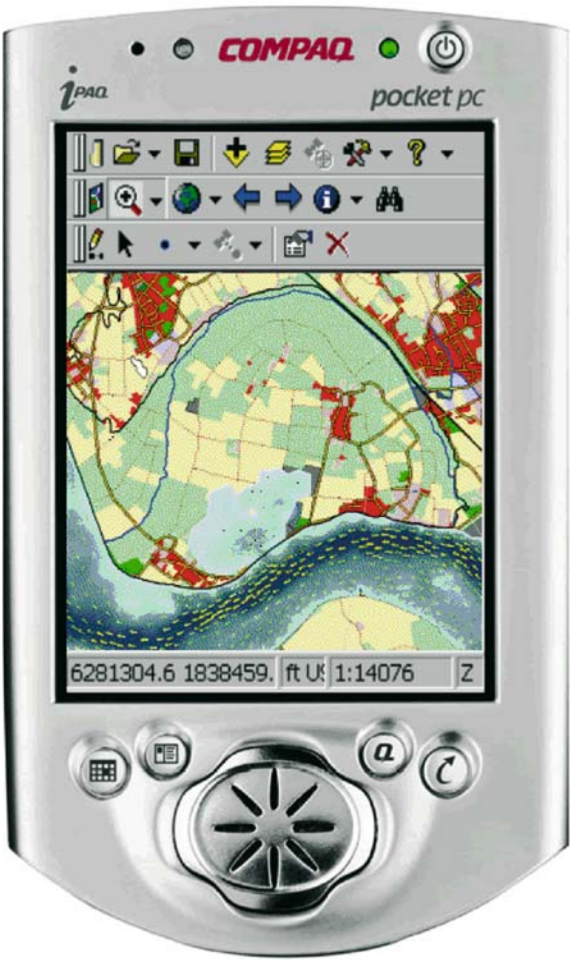

Figure 6. GIS presentation of flooding after dike break.

propagation and depths. Such graphical presentations are supported by geographic information systems (GIS) that even offer Internet access down to handhold devices and cell phones. Figure 6 shows an application for polder flooding after dike breaching as simulated within the DFNK project. The Arc Internet Map Server (ArcIMS) from ESRI had been used. Houses, streets, fields as well as flow velocity in the river, dike breaching point and flooding behind this location can be seen. As the locations can be identified where such devices are operating, this technology ideally supports observation of local developments by mobile observers in the field as well as for rescue purposes.

9.6. IMPLEMENTATION OF SOFTWARE SYSTEM

The software had been designed in a manner to be portable and easy to install. The document management system basically consists of two components, one for referencing information resources and one for finding and presenting them. This part is small and runs on any client under the browser. So basically only a browser has to be implemented to make any client a user of the crisis management systems. For presentation and communication some few features have to be added to the browser that are available without charges in the Internet.

9.7. PRACTICAL EXPERIENCE

A prototype of the flood management system has been implemented in the city of Frankfurt (Oder) as being partner of the OSIRIS project. It is in use by the fire brigade responsible for crisis management. It is linked to Internet services provided by the federal and local authorities on high-water monitoring and warning. Advertising for the technology is done by the city which runs an open-access terminal in the city hall. School classes have accessed the system as well as many private Internet users. The system is integrated in all further Internet services the city is providing on its website. Thus it really happens that citizens and stakeholders are sharing information, improve confidence to public measures and understand their city and river in view of its natural environment much better.

10. Conclusion

ICT has revolutionised the approaches that are possible to utilise in modern flood management and decision support. Systems have developed from former "engineering oriented" systems for water level forecasting into real "administration oriented" systems. The PC has turned from a "computation" into a "communication" engine. In combination with mobile networking, handhold devices and Internet accessible cell phones the PC represents an environment for working and communicating "any place – any time". Information and communication systems for flood management and decision support are just beginning to exploit this potential. The project OSIRIS is only an example.

11. Glossary

Java: Java is a programming language expressly designed for use in the distributed environment of the Internet. Java can be used to create complete applications that may run on a single computer or be distributed among servers and clients in a network. It can also be used to build a small application module or applet for use as part of a Web page.

Java Servlet: A Java Servlet is a program that is specified in a Web page and runs on a Web server to modify a Web page before it is sent to the user who requested it. The term was coined in the context of the Java applet.

Ontology: An ontology is a way of describing a relationship between different words and phrases of a certain domain or discipline. In other words, an ontology is an explicit formal specification of how to represent the scientific objects, concepts, and other entities that are assumed to exist in a certain discipline, and the relationships that hold among them. The most powerful relation in a domain ontology is the 'is a' relation, as it follows the natural way of thinking.

RPC: Remote Procedure Call (RPC) is a protocol that one program can use to request a service from a program located in another computer in a network without having to understand network details.

SOAP: The Simple Object Access Protocol (SOAP) is an XML based lightweight protocol for the exchange of information in a decentralised, distributed environment. SOAP defines a messaging protocol between requestor and provider objects, such that the requesting objects can perform a RPC on the providing objects by specifying the envelope structure, encoding rules, and a convention for representing RPCs and responses. SOAP is used as the glue in connecting a Web service with the application calling it.

SVG: Scalable Vector Graphics (SVG) is the description of a two-dimensional vector graphic in XML. Any program such as a Web browser that recognizes XML can display the image using the information provided in the SVG format. Vector graphics is the expression of an image using mathematical statements rather than bit-pattern description. Scalable emphasizes that vector graphic images can easily be made scalable. Thus, the SVG format enables the viewing of an image on a computer display of any size and resolution.

Web service: Web services are a set of technologies that allow application programs to communicate with each other using widely deployed protocols (SOAP) and languages (WSDL) based on XML. Web Services publish interfaces for use by other services as a RPC via the Internet and support the loosely-coupled Service Oriented Architecture paradigm by encapsulating implementation details like platform, operating system, object model, and programming language.

XML: The Extensible Markup Language (XML) is a simple and flexible text based format derived from the more complex SGML and is today the most important language for the exchange of a wide range of data in nearly every discipline via the Internet. XML is not really an independent markup language at all, but rather a meta language – a definition tool that enables users to build their own markup languages. XML merely provides a linguistic framework that permits the extremely diverse applications constructed with it to understand one another.

XML Schema: The XML Schema (XSD) language is used to define the constraints like the syntax, the structure, the content and the semantics of an XML standard. An XML Schema is by itself an XML document and expresses a shared vocabulary, enables to encode complex data structures and allows computers to carry out rules made by humans.

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