CRITIQUE SYSTEMS FOR GEOGRAPHIC INFORMATION AND GIS

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1 Introduction

Many decisions, not only in the field of military actions and emergency management, require and gain from a large amount of spatial or geographical information. If these data are handled in a Geographical Information System (GIS) we add possibilities to handle and analyse this type of information in a way that divert substantially from traditional handling of maps. A Geographical Information System is an IS with the capabilities not only to handle traditional digital maps in raster and vector format but further analysed Remote Sensing data and data from other sensors like GPS positioning and also real time intelligence reports. If combined with functions that can deliver critique to suggested decisions by pointing at impossible driving tracks or conflicting goals, the system can meet high expectations on civil as military C3 (Command, Control and Communication) systems. Such approach can also meet the fear of overload of information in such systems.

The development in society with globalisation and global dependencies, changing climate, changing demographic situation, more complex society and more complex systems also lead to a demand for more sophisticated information and information systems (Trnka et. al 2005a, 2005b). A research team between SNDC (Swedish National Defence College) and IDA (Department of Computer and Information Science), Linköpings Universitet, have experience in all forms of data capture and real time analyses and dissemination of geographically registered data through, among other means, mobile GIS. We have contributed to the development of GIS components for real time reporting of oil spills for the SRSA (Swedish Rescue Services Agency) and are working with similar questions related to GIS-based information provision in cases of crises for the Swedish Emergency Management Agency, and the Swedish Land Survey are engaging us for evaluation of geographical data as a strategic infrastructure. On the European level we are members of the eSDI-Net+ (Network for promotion of cross border dialogue and exchange of best practices on Spatial Data Infrastructures (SDI´s) throughout Europe) and were members of the European Network of Excellence GMOSS (Global Monitoring for Security and Stability). GMOSS was dealing with rapid data acquisition mainly from satellites and with other Remote Sensing techniques. On national and European level several initiatives are going on to build standardised and harmonised geographical databases that can be used in decision support systems. What is still on the agenda to be done is development of GIS based models making use of all those databases for prediction of potential hazards, for preventive work and action plans. The objective is to contribute with these models and data in rescue and relief work and to be able to update plans for better preparation etc.

Military Command and Control (C2) is nowadays often directed towards a "Network Organization" with less rigid structure of command and better suited to respond to changes in the environment than traditional, hierarchical ones. Network Organizations are characterised by fewer levels of control needed to perform the same tasks as before. Each level of control is believed to add to the rigidity of an organization and prolong the reaction time. However, one of the problems with this Network Organization is that commanders at all levels must process more information in order to exert efficient command and control over their units due to the

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Con formato: Fuente: (Predeterminado) Times New Roman delegation of responsibilities. Processing more information in stressful circumstances makes computer support even more important, both in presenting an overview of the current situation and for communicating efficiently with other commanders (Leifler & Eriksson 2004).

One attempt to develop such a Network based C2 structure is the Swedish Military ROLF project (Brehmer 2002a, 2002b, Persson, 2000 and Sundin, 2000). However, the first phases of the ROLF 2010 project when evaluated with behaviouristic studies (Artman and Persson, 2000) concluded that even though the system has been designed specifically to support equal interaction and making all staff members each other´s peers, the military code of conduct and traditions make it difficult to achieve discussions on alternative plans.
Some authors are worried about the possible information overload that could be generated by providing satellite images and maps (March, 1958 and Talbot, 2004). First of all we, in that case, have to problematize the difference between sequential messages as texts and spoken communication and images and maps. I here argue that maps constitute a certain kind of modality by which the user can make a short overview of a situation by just a glance or if time is available dig into details to make the refined analyses as to treat a specific question. In the design of printed maps it is a continuous debate on how to select and generalise the features that shall be presented in different scales and map editions. By introduction of electronic maps we have the opportunity to in a strict way select the features that are presented for the users not allowing them to by the way get a lot of other information that is not easy to formalise in a traditional inference engine. This is the case as such data are consisting of several factors and sometimes the knowledge they carry is depending on a life-long experience on how a certain situation will develop. On the other hand the electronic map in a Geographical information system is able to combine a huge number of different thematic layers and update these with new remotely sensed and surveyed information in real time or near real time. The stressing research questions today are related to how to develop and use this new modality, with its pros and cons and how to train the staff and organise the work with this new type of decision aid. The purpose with this article is to give an example on how geographical data can be used in advanced analyses that are pre-processed as to minimise the information stress but to make it possible to overlay and further process during a mission.

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This point on an interesting problem in introducing new technology – it will not be possible to give it a fair judgement if the evaluators are not appropriately trained and motivated and the working procedures not adopted to the new situation (Bach & Scapin 2004). Similar experiences have been drawn in a parallel project to this critique system in GIS - in a project where we have developed a head mounted mixed reality (MR) system for military logistic and other support. The system has huge theoretical advantages as it is able to aid, for example technical support persons in their work, regardless if they have detailed knowledge of the equipment that has to be repaired or not. Details of the equipment and it´s status can be sent to unit commander and further in the organisation giving detailed information about available resources. Through the MR system advanced instructions can be given about how to repair the specific equipment by providing a digital repair hand book, blue prints and spare part lists, in the language and in the detail that is required according to existing prior knowledge. The system can also deliver warnings if the repairman tries to do something hazardous or in the wrong order. It is easy to calculate the operative benefit for the organisation of introducing such a system. It means that it will be possible to provide a generally educated technician with detailed instructions how to repair equipment, unfamiliar to him, far away from any printed documents - perhaps during a mission in a foreign country.

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However, there will be a generation of users that perhaps will have problems to adopt the new technology and new working procedures and the system will probably not be suitable for persons with certain perceptual or other problems. We already have preliminary results that young students – the next generation of users – have no problems, as far as we can see, to adopt the new technology and make use of the new possibilities! (Gustafsson et al. 2004).

Figure 1. Spatial decisions through Mixed/Augmented Reality

This article is a presentation of a pilot study concerning methods to build GIS based models that can be included in a network based decision support system. As to reduce the amount of unprocessed and indexed data the user has to take into consideration we suggest that more stable and already existing geographical data are pre-processed into easy to adopt information that can be used together with dynamic data concerning development of scenarios – threats and resources. The model developed and tested here is aimed to predict trafficability through terrain – a task as relevant for military logistics as for emergency management and relief. The GIS is further supposed to work as a system that allows critiquing in the context of a C3 environment.

Critique systems and GIS

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From a philosophical standpoint it is often stressed that it is impossible to obtain all probable and correct data and knowledge to make a decision (especially in case of an emergency or dangerous situation) but further to support the decision makers with criticism on the different suggestions they are producing – perhaps telling what are the weak parts in them. This is certainly applicable in decisions that include several knowledge domains and areas of expertise. As a solution to the demand for data, perhaps aid with expert systems in the knowledge production, but primary to support the decision makers with data and information that they can turn into wise judgments, critique systems have been introduced. Silverman (1992) defined the concept of a critiquing system as (1) to recognize and analyze human error; (2) to form persuasive criticisms and feedback; and (3) to adapt to the situation and any lessons learned. Here we want to use the concept in a much broader scale facilitating critique and support in judgement of data, evaluation of (professional or partial) models and assessment of different possible scenarios as a result of combination of these partial models.

Plans in the US Armed forces are made by following a formal procedure, course of Action (CoA), that describes what information that shall be included. The CoA consist of a) general goal for the operation; b) The units and the material that are supposed to be used to reach the goal; c) The orders that have to be given by the units; d) Requirements in time; and e) A Terrain description. All these data are transferred into written plans and into maps showing the present situation, the threats, the resources and the goals. The situation is seldom static and that is why a dynamic GIS showing both the dynamic geographical situation and the forces is a very useful tool for decision making. The player that has the capability to forecast the development in all the involved space and time scales and have the ability to command and control his forces will be able to grasp the initiative and will possibly be able to solve his mission in the best way. However, this requires a thorough and common picture of the situation and with that as a base, a common understanding.

In cases with very fast decisions based on complicated topographic and other conditions it is crucial to have good maps (and linked data in a GIS), as well as interpreted remote sensing data completed with intelligence reports by humans and with other means of data capture. To facilitate this, military map agencies, sometimes in cooperation with civil surveys, have a huge mandate to provide relevant organisations with background maps and other data as well as real time updates. Being aware of the need for support to the data producers and end users DARPA have been funding several projects with the goal to create metadata bases and systems to inform the users of the quality of data, the timeliness, resolution, ontology etc., telling for what purposes it has been made, how reliable a (map) database is, how it can be used and where the weak points are. The data quality and metadata issues are well known problems that are easier than previously to observe with the help of the new spatial data handling and analysis technologies (GPS, GIS, RS etc). By training the users to compare the result from these different sources also, researchers can learn for what purpose the data can be used and what information obtained. Some researchers are stressing the problems that several data sources can add uncertainty to the final outcome. However, a more common opinion is that the different sensors and data sources with their special advantages and disadvantages, wisely used, can cross validate the information adding, for example spatial accuracy from one source to thematic accuracy from another. This has brought the traditional Remote Sensing and GIS communities together, trying to obtain benefit from each others advantages and overcome the built in disadvantages in the specific approaches.

In Europe the EU Commission together with national mapping, GI and remote sensing organisations are trying to build up similar capacity as in the US so as to provide data for military as well as emergency response organisations. Besides the ingoing data the models used to analyse the situation from different perspectives are of importance. Here the traditional approach is to use as simple models as possible with as few ingoing parameters as possible. This is probably a heritage from times when data were sparse and the computers as powerful as a common refrigerator today. Especially in developed countries databases are available that makes it possible not only to calculate the shortest path through a road network but further simulate possible areas under threat for flood, landslides, outcome of accidents with hazmat transports, possible areas for military actions etc. By the new high resolution satellites and sophisticated survey methods very few areas on the earth are white spots on the digital charts. At least they will be available if the areas have some economic potential as oil and minerals or a strategic location.

Some of these suggested GIS based models are possible to run in advance to simulate different outcomes and situations as training. However, the uses of real GIS based models are sparse and seldom integrated in the decision tools that are used in the daily work at responsible authorities and military agencies. If data are shared between civil and military organisations the telecommunications and networks are seldom dimensioned to really share the different views of the situation in a real emergency situation. To really evaluate the benefit of GIS supported decision making we have to develop laboratory environments that are supporting both the necessary analytical capacity and the demand for communication with complex digital GIS data sets. The staff must further be trained in both new working procedures for C3 (Communications, *Command*, and *Control*) and the different technical support systems.

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There is a common need to integrate models concerning different professions in the society (or in organisations) for physical planning and rescue functions in local and regional governments. Under the mandate in this study we are trying to develop such integrated models for military and other governmental organisations. We have as examples on such integrated models been working with hydrological models for flood prediction and maps and models for estimating risk for landslides that are induced by the flood and further impact on agricultural areas, on electricity and telecommunications, on transport networks, on population, on animal populations etc. The modelling of trafficability is a further development of this suggested development approach. Traditional model approaches are often just optimising or predicting for one task (like transports) and it is almost impossible to build a single (mathematical) model that can handle all the different factors that are playing their game in a real emergency or military situation. However, by harmonising the models so that they are able to integrate in the same information system, presenting the result of their outcome in a way that they are possible to combine or use as input into other models, it is at least in theory possible to see where the white spots are on the map. In this way we can identify where we don't have enough information, or identify the black spots where we can agree on the situation and have enough information to make a judgement. This needs several additional programs that can handle the time aspect, the status on all vehicles and other resources that are involved in the operation but it will have huge benefits if the GIS can act as a core information system combining the results. On the contrary it will be very difficult to achieve a common opinion about the situation without an information system that is able to handle dynamic and geographically represented data.

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Previous studies

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To try to define logical roles with critique functionality the US DARPA have funded several projects to support military decision support systems. Two such programs are - High Performance Knowledge Bases and Rapid Knowledge Formation (DARPA, 2003). Some of the supported projects within those programs are SHAKEN, CADET, SHAKER/KRAKER, ArCS, Mission Rehearsal Exercise (MRE) and EXPECT.

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In many of these studies where new technology and new working methods are developed present users are asked to contribute by defining the rules for the inference engines and the design of the information system. In some studies "High-ranking officers who have this important task of planning and monitoring military activities have to learn how to program a rule-based, distributed critiquing system in order to do their job" (Leifler & Eriksson 2004). This is probably not the best way to use their expertise.

I highly agree in this doubt as programming rules and implementing models should be a task for specialists both in military operations (or emergency management) and computer systems. We require that the persons that are supposed to fly airplanes are pilots. Why should we not require that decision makers have training in how to use new information systems and support for that? Several young candidates for the working life could in this way be trained to operate the system under supervision of experienced commanders that could contribute with their domain knowledge!

"Future research on decision-support systems will need to focus on the work process of the group in order to support them efficiently. We do not believe that traditional critiquing systems will be the primary tool for helping in the collaboration of a military staff in the future."

On the other hand the conclusion that "Those in control of an operation are also the ones who know best what information they need to share with others and how they need to cooperate to reach their goals. Therefore, they should also be in control of the computer system they use for their support" (Leifler & Eriksson.2004), is not always a valid statement. Why should a commander know the best new software and best new methods for decision making? My comment to this is that the prevailing decision maker is a valuable partner in the development process but there are so many other factors that have to be taken into account in developing a usable (computer) system. In Bach & Scapin (2004), was pointed out the problem in finding valid evaluators understanding the new technology and applications that are suitable to demonstrate the new technology! We have in such cases to find other ways than suggesting the current users to design the systems.

Methods and Techniques

Data acquisition

In some test applications developed we were using only open and available data sources. However, there are possible other sources that could be included in the future – perhaps after guidance from preliminary studies on a more general level. The test applications were performed to investigate the quality, possibilities and problems in data and existing models aware that these factors are depending on each other as models are requiring data in a certain format and resolution to be able to perform and be able to validate (also published in, for example, Gumos, 2005). See also Slocum et al. (2003) and Edlund (2004).

The factors that were investigated were situated in the test area equivalent to the northern parts of the topographic map 8FNO Linköping. The area is the northern slopes of a tectonic rift dividing the southern Östgöta plain with the shallow lake Roxen (+ 50 m above sea level) and the forest and "mountainous" areas north of the lake (round 100 m above sea level). There is not a dramatic difference in elevation but the landscape is divided with narrow valleys in the crystalline bedrock and in the investigation area a sub peneplane overlaid with clay that in its turn have been eroded by a creak forming the "Stjärnorp gulley". In non clay areas bare rock is mixed with glacifluvial deposits and partly areas with huge amounts of boulders. Vegetation is a mix of different aged coniferous forest and also parts with deciduous forest, including several hundred year-old oak trees impossible or hard to pass over also with very powerful vehicles. The trafficability analysis in the area corresponds to 625 km^2.

Constructing the Soil Knowledge Database

When trying to construct a soil database we have to investigate the ontological base for existing soil maps and comparing them with the needs when building a trafficability application. Soils with it´s complex physical, chemical and hydrological characteristics have been converted into a knowledge database including soil texture, soil grain-size distribution classification, soil strength and permeability properties, soil capillarity, frost activity of the soils, soil consistence and as a result of this - Soils trafficability. Soil strength is an index of suitability of the ground for the off-road mobility of vehicles (Mitchel C., 1991). The soil strength parameters have been prepared also to be a driving force for discreteness the

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Atterberg's Consistency Limits for the three different soil moisture classification levels (states): Dry, Moist and Wet (Saturated).

Hydrologic Modelling

There are several GIS based hydrological models for estimating the soil moisture like Andersson & Sivertun (1989) and Burrough & McDonell (1998). Watershed/drainage basins, the river network layer, the lake layer forming together a hydrological raster that has been prepared together with the enhanced Digital Terrain Model (DTM) and the Compound Topographic Index (CTI) also knows as Steady State Wetness Index, is an equation adjustable for computing the topographic moisture accumulation. The formula is defined as:

$$\mathbf{CTI = ln\ (\ As\ /\ tan\beta\ )}$$

where:

As - contributing catchment area per unit extent, orthogonal to the flow direction, and

tanβ -is the Slope measured in degrees with $\beta > 0$

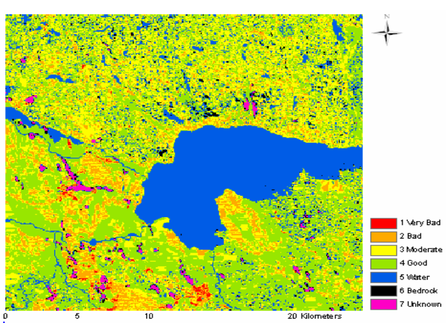
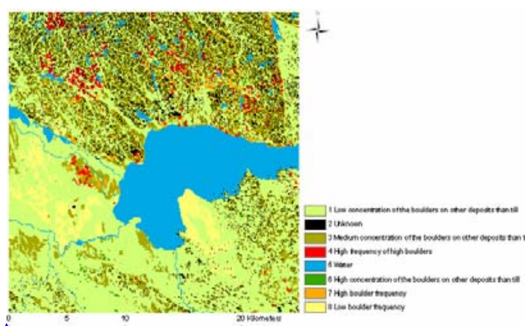


Figure 2 The Ground Condition Map



Fugure 3 Frequency of boulders in the area

Results

In the study was shown that available data sources are possible to use in a model for trafficability analysis in terrain. However, considerable work has to be done to prepare the data sets for the analysis and elevation data was found to be partly both unreliable and insufficient in the area of investigation. As data are in a GIS database it is further possible to add other factors such as precipitation, temperature and other dynamic factors of relevance. It is also easy to share the result with other users and to add intelligence reports both concerning own resources and development of the situation. Further in a GIS it is possible to analyse the situation with the scale or zoom factor desired as to see details or shift to a more general picture. It is also possible to show the result of the off road network analyse in a 3-D View for control of the reliability of the simulation. In the last example existing road network was added to demonstrate the possibility to combine traditional network analysis with the off road trafficability models.

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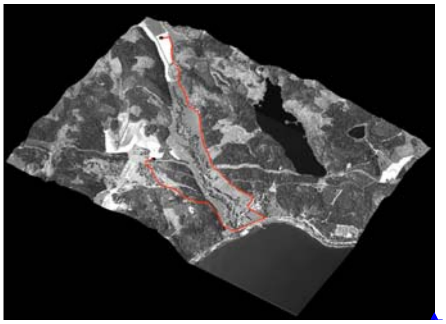

Figure 4 3D Scene of the experimental ground field

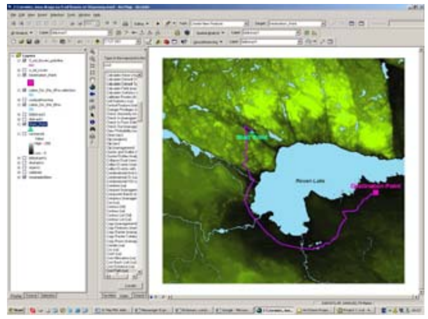

Figure 5 Secondary randomly chosen destination paths

Discussion

In this work it is shown that it is possible to get necessary data to make a quite sophisticated GIS based analyses in advance on the stable factors for trafficability in terrain. What is further needed are metrological data, data concerning present situation and dynamic and man-made obstacles as well as detailed knowledge about the own forces. By making this information available for those that ask for it (in the own organisation) it will, if needed, be possible to direct those units that are most suited through the most difficult paths but directing the others for tasks that they still have capacity for. In this way it will be possible to make better tactical and strategic decisions.

If remaining problems in implementation can be overcome (Uran and Janssen, 2003) the conclusion here is that a GIS can support in decision support systems – at least with criticism for suggested decisions that are impossible or less favourable according the roles formulated in the knowledge database used.

The Network based C3 structures will require other types of interaction supporting the members to share ready-made analyses, if time is restricted, or digging deeper into the data sources to find even more delicate solutions to the problems, if time and prior knowledge allows that. Here the staff are in full charge able to chose the sources and methods as they want depending on the situation and can share that with all members with few restrictions!

What Information Science can provide are the tools of highest perfection leaving to the persons that have to make the decisions. Also usability in this trafficability module is dependent on how accurate the model describes the situation and how valid and reliable the data are. By introducing a soil wetness index we contribute to this estimated value, however, depending on access to the soil and other databases we have used here. In the future new sensors like multispectral LIDARs (Airborne Laser Scanning) and a mix of sensors and databases can provide the user with all the necessary stable as well as dynamic variables.

LIDAR and InSAR (Interferometric Radar) techniques have been tested and compared in order to depict the forest canopy dimensions and terrain elevation models (Andersen H.-E., et al, 2004). For the concept of trafficability, the outcomes are of greatest importance in terms of accuracy improvement of the recorded earth surface features.

Acknowledgements

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No.	Datasets	Format	Scale / Resolution	Symbology	Source
1	The Topographic map	Vector	1:50K	8F NO Linköping	GSD
2	The Terrain Elevation Databank	Binary file	50m x 50m	-	GSD
3	The Quaternary Deposits Map	Raster	1m x 1m	8F NO Linköping (B) Ae 19	SGU
4	The General Map of the Östergötland County	Vector	1:250K	Combined from the following map sheets: 13. Stockholm 15. Norrköping 16. Nynäshamn 18. Oskarshamn	GSD
5	The Bedrock Geology Map of the Östergötland County	Vector	1:250K	Berggrundskarta över E-län Serie Ah	SGU
6	Watersheds of the Östergötland County	Vector	minimum 200 km^2 area size	Huvudavrinningsområden 67	SMHI
7.	Detailed Watersheds of the Östergötland County	Vector	average 35 km^2 area size	Delavrinningsområden for the map 8F NO Linköping	SMHI

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1. Datasets used for the Cross-Country Trafficability study

The maps that were used for Boolean analysis are as follows;

No	Factor map name	Genuine	Forma	Pre-processing	Boolean

.		File	t	1^{st}	2^{nd}	
1	The Land Use Map	Y18fno.shp	Area	Rasterization	Reclassification	0; 1
2.	The Area with Large Boulders Map	Y38fno.shp	Area			0; 1
3.	The Bog Map	Y28fno.shp	Area			0; 1
4.	The Human Made Objects Map	Ps8fno.shp	Point			0; 1
5.	The Road Network Map	V8fno.shp	Line			0; 1
6.	The Watercourses Map*	P8fno.shp	Line			0; 1

Table 2

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