Integrating Human Terrain reasoning and tooling in C2 systems

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ABSTRACT TITLE

Within an operational staff the 'core business' of the Intelligence Cell is to initiate, collect, process, analyze and disseminate relevant information. This Intelligence Preparation of the Environment addresses the environmental evaluation, threat evaluation and results in an integrated overview of the relevant actors and factors. If done correctly the acquired information will greatly improve the Situational Awareness of (sub) commanders and staff members.

Traditionally, the environmental evaluation mainly addressed the physical aspects of the terrain (Physical Terrain information). However, in present day much more information is crucial for obtaining success. Examples of this new type of information are: sense of security, economic prosperity, political or cultural differences etc. This so-called 'Human Terrain' (HT) information could greatly enhance the ability to better understand the situation in a particular area or region. Although this new focus has now been integrated in doctrine, its implementation remains challenging not only because of the lack of knowledge about which type of information is relevant and what its relative importance is but also because current C2 systems generally don't support the visualization of Human Terrain information.

To address the 'gap' between presenting only factual information and also presenting its implications for the mission, we propose an approach that uses expert rules to derive implication information from facts. For the access, generation and visualization of HT information we propose an architecture for the integration with C2. The architecture is inspired by the approach used in the US Battlefield Terrain Reasoning and Awareness program where military relevant aspects of the physical terrain are (in an automated way) derived from physical terrain data.

1.0 INTRODUCTION

During the cold war, military operations were aimed at inflicting maximum damage to the opponent through overwhelming use of 'kinetic' energy. To enable this military victory a thorough understanding and optimal use of the physical terrain (PT) was critical and was given much emphasis. Other aspects like socio-cultural understanding of the environment were hardly addressed.

PT analysis is usually performed by experts at all organizational levels and by each for his own unit. PT analysis is a time consuming and personnel intensive process and its results vary with the proficiency of the expert, his mental fitness and the time available for the analysis. To remedy these issues US Army developed a promising system called Geospatially Enabled Battle Command (GEBC) [1]. GEBC works fully integrated with C2 systems and offers the expert automated support in analyzing and assessing the PT. This approach has several advantages; it guarantees the quality of the ultimate products, it enhances the speed of the planning process, it reduces the need for a large number of in theatre experts and computing power and it supports reuse of various intermediate analytical products. However, up till this moment GEBC only takes the PT into account.

Military operations are not primarily aimed at short-term military success, but are part of broader and long-term strategic objectives like restoring a failed or failing state. In counterinsurgency operations one of the military's main objectives is to influence the population through non-kinetic means such as economic development in order to support the host nation and to reduce support for insurgent groups. Understanding the dynamics of foreign societies is critical in order to identify flash points, reduce violence and promote peaceful economic and social development. Thus, in addition to the PT new types of information have become crucial for mission success. This additional information (that can mostly be portrayed in geographical context) is referred to as Human Terrain (HT) information.

In the US, the recognition of the issues mentioned above have led to the creation of Human Terrain Teams (HTT) [3], being specialized teams aiding the operational staff with socio-cultural knowledge. Basic HT information covers the so-called ASCOPE[1] factors [2]. A HTT will use map-HT Toolkit software, enabling visualization of and access to HT information. HT analysis is also a time consuming and personnel intensive process and its results vary with the proficiency of the expert, his mental fitness and the time available for the analysis. Moreover it also requires vast datasets and computing power.

Therefore, most currently used HT overlays are typically basic fact oriented – i.e. most maps with human terrain data focus on geospatial representation of relatively 'raw' data like ethnic groups, tribal leader, important places (churches, cemetery's), etc. Although visualizing this basic data already greatly enhances our ability to get a better understanding of a particular area or region, understanding the implications of this information for military missions remains difficult. For example, understanding the consequences of a particular distribution of ethnic groups from a counter insurgency perspective is difficult.

A system for accessing, generating and visualizing HT information is crucial to optimize the operational effectiveness and added value of military units. We will propose a possibly more effective way to address these needs, which may lead to a GEBC like approach that includes HT analysis and assessment.

This paper first describes the GEBC concept for the PT (section 2). Section 3 elaborates on the extensions that are needed for HT reasoning. Both sections 2 and 3 propose a possible architecture. Section 4 gives an in depth view on the HT reasoning possibilities. Conclusions are drawn in section 5. Sections 2, 3 and 4 use examples to visualize the concept/approach.

For the HFM symposium the paper focuses on the operational level and on the Provincial Reconstruction Team (PRT) scenario.

2.0 GEBC CONCEPT FOR THE PHYSICAL TERRAIN

2.1 Basics of the GEBC concept

In the GEBC concept, military relevant/tactically important aspects of the terrain can automatically be calculated in order to aid the military decision making process. These military relevant aspects are called Tactical Spatial Objects (TSOs). Two levels of TSOs are distinguished; foundational TSOs and mission specific TSOs.

Physical terrain facts, platform facts and meteo (meteorology) as mentioned in Table 1 are required for the computation of both foundational as well as mission specific TSOs. For mission specific TSOs more specific facts for the mission are required like the specific unit performing the mission and the recent, current and predicted weather. Table 2 presents some examples of foundational and mission specific TSOs. Some of these have already been implemented in GEBC and some need to be developed.

[1] ASCOPE Area, Structure, Capabilities, Organization, People and Events

- Foundational TSOs; an example is the maneuver network TSO which is a network of edges that are defined based on roads and cross country movement possibilities. For all edges the movement possibilities are calculated for all types of platforms (can the platform go there, at what speed? etc.) and for all types of meteo conditions;
- Mission specific TSOs; an example is a route from A to B that can be computed if the maneuver network, the specific unit, weather and the locations A and B are known.

Table 1: Example facts for Physical Terrain, Platforms, Meteo and Doctrine

Physical Terrain facts
Soil type (clay, sand, drainage, watersheds etc)
Height Slope
Waterways (width, depth, banks, flow speed,, bridges, dykes
(Rail)roads (width, surface, etc)
Built up areas (acreage, density, height, building materials, etc)
Woods (expanse, width trees , type trees, density trees, etc)
Agricultural areas
Cultural monuments (buildings, work of art, reservations, etc)
Power grids, Airports Seaports, Industrial areas
Meteo facts
Weather (temperature, humidity, wind...)
Climate
…..

Platform facts
Weight (per sq inch)
Dimensions (height, width, length,…)
Speed (relative to terrain/weather conditions)
Effective range
Traction
Obstacle management (height, width, slope, …)
Survivability (armor, art, etc)
Doctrinal facts
Type unit (armor, infantry, engineers, support etc.)
Scale of the unit (platform, platoon, coy, battalion etc.)
Mission types per unit level (defend, attack, anti-armor,
Doctrinal dimensions per mission type (width, length,…)
…..

Table 2: Examples of Foundational and Mission Specific TSOs

Foundational TSOs
Commanding Terrain
Fields of fire
Chokepoints
Obstacles (physical)
Battle positions (maneuver, art)
Coverage (against enemy fires)
Concealment (observation)
Maneuver network
Observation
….

Mission Specific TSOs
Attack by fire position
Defensive position
Axis of approach
Assembly area
Supply area
Casualty collection point
Maintenance location
….

2.2 PT System architecture

In figure 1, the system architecture for reasoning based on the PT is displayed.

In the proposed architecture the processes and systems are distributed using a data network. The geospatial capability is offered as a Network Enabled Capability (NEC). Currently in the US, a series of experiments and demonstrations (Joint Concept Technology Demonstration (JCTD) Common Ground) is performed where the GEBC concept is evaluated. In the concept NATO will provide the capabilities to the nations enabling a central access of information. One of the advantages of accessing central capabilities is that all nations are using the same basic data and reasoning mechanisms for PT.

National C2 systems need to be adapted in order to take full advantage of the PT capabilities. In the Royal Netherlands Army a wide range of C2 applications is used e.g. ISIS for battalion and brigade level and OSIRIS for combined arms teams level. The concept seems (in terms of level of detail) initially most promising for implementation in ISIS.

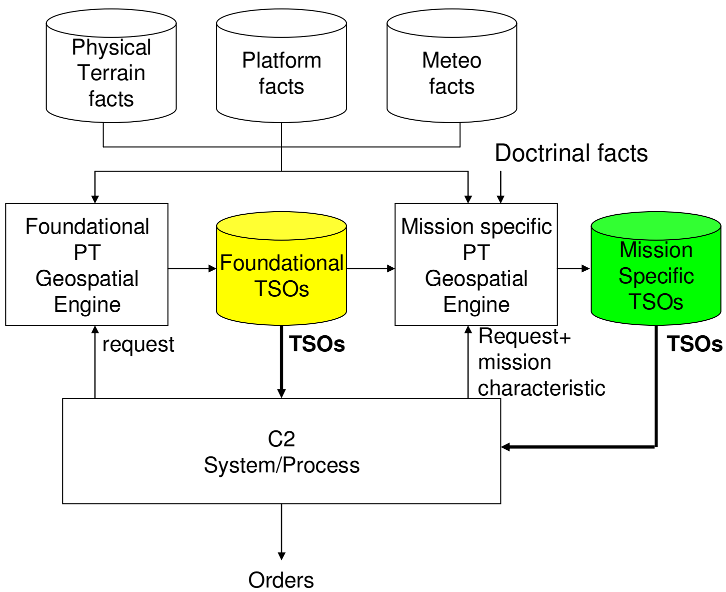

Figure 1: Physical Terrain reasoning system architecture [2]

From the C2 system, TSOs are requested by experts (step 1) involved in developing Courses Of Action (COA) during the decision making process. Foundational TSOs are generally computed (using foundation PT geospatial engines) beforehand since they consist of large datasets and require a long time to compute. Mission specific TSOs obviously can only be computed when information about the specific mission and has been entered into the C2 system. This computation takes place during the decision making process using mission specific PT geospatial engines. The requested TSOs (overlays) are displayed (step 2) on the C2 system thus visualizing the most promising possibilities to the expert. Experts then choose the most optimal combination(s) of possibilities (step 3) from the different TSOs they have requested. This information is then used to finalize the (OP)Orders to the (sub)units (step 4).

2.3 Example of PT reasoning

In this section an example is used to explain how mission specific TSOs depend on foundational TSOs and how these foundational TSOs depend on physical terrain facts, platform facts and meteo (figures 2 and 3). In this example we consider the following mission:

> ***Tank coy*** will prepare in ***Assembly Area A*** to move forward along ***Approach Route B*** and engage Enemy Taskforce in ***Target Area of Interest C*** from an ***Attack by Fire Position D*** by ***surprise.***

[2] the colors will be used throughout the paper to indicate foundational (yellow) and mission specific TSOs (green).

The mission specific TSOs for this mission are: Assembly area A, Approach route B, Target Area of Interest C and Attack by fire position D.

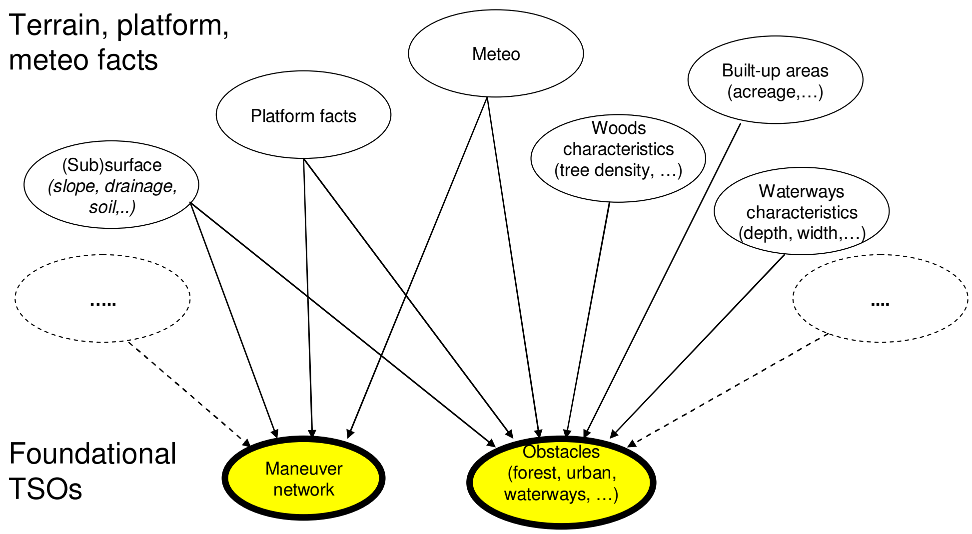

Figure 2: Example foundational TSOs and their dependencies on the facts

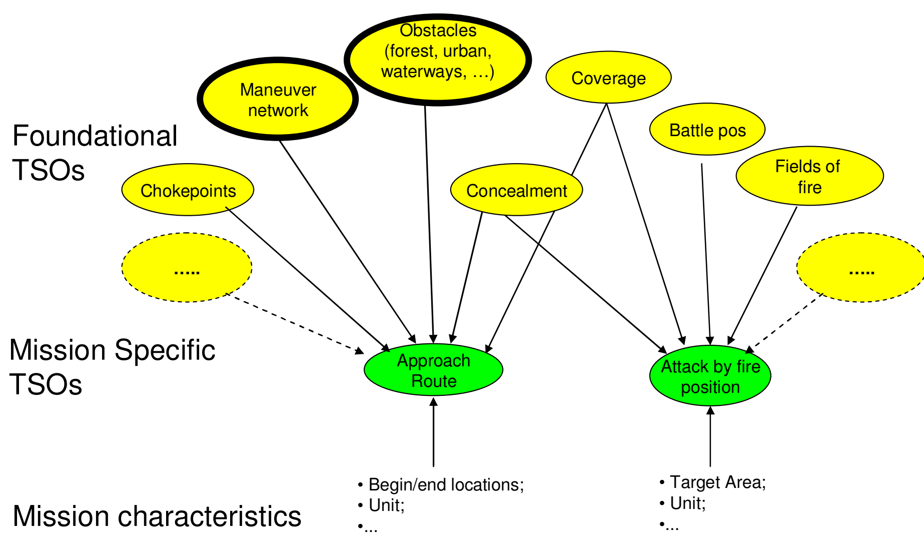

Figure 3: Example mission specific TSOs and their dependencies on foundational TSOs

The above figures only show dependencies. Actually calculating TSOs requires some algorithm. Below we give a high level description as an example. For instance consider the maneuver network foundational TSO and the mission specific approach route TSO mentioned above. Without going into too much detail, the algorithm will use:

- Platform maneuver characteristics (e.g. ground pressure (N/m^2) and dimensions);
- Begin and end position of the route;
- Maneuver network foundational TSO. This can be seen as a road network (represented by a graph with nodes and edges) where also cross country movement possibilities are transformed to edges with certain characteristics like allowed ground pressure or allowed dimensions;
- The unit characteristics are used to derive from the maneuver network an 'allowed' network dedicated for the unit under consideration. This allowed network is then used in a navigation algorithm like in normal car navigation systems to find the (for instance fastest or shortest) route between begin and end positions, taking into account the coverage needed for surprise also.

3.0 EXTENDING THE PT CONCEPT FOR HT

3.1 Extension of facts and Spatial Objects

Although analogies between the PT and HT do exist, there are also many differences when deriving HT TSOs. PT computations have a long and outstanding history of scientific knowledge about physics combined with practical experience. HT is all about understanding relations between humans and their social and physical environments. Many of these relations are complex and respond adaptive to changes, thereby leaving less room for quantitative approaches such as those employed for PT. HT (reasoning) information is therefore much more volatile than PT reasoning information. Exact computations with HT data are difficult to employ. Data might be unavailable, incomplete, at the wrong resolution or qualitative in nature. Another challenge is that, in contrast to PT, the precise nature of relations between facts and their higher order derivations are unclear and difficult to obtain. HT needs a new set of reasoning rules and also a new type of TSOs. We call them Socio-cultural Spatial Objects (SSOs). Table 3 gives an overview of possible SSOs.

Table 3: Example Socio-cultural Spatial Objects (SSOs)

Foundational SSOs
Criminal critical area
Political critical area
Leadership structure/distribution
Medical critical area
Cultural critical area
Economically critical area (Agricultural,Industrial,..)
Hostile population area
Optimal reconstruction locations
Religious critical area
Socio Cultural Maneuver Network
Socio Cultural Commanding Terrain
….

Mission Specific SSOs
Medical support area
Leadership support area
Reconstruction support area
Agricultural support area
Cultural support area
Security support area
Regional control site
Displaced persons support site
….

In order to derive SSOs, new types of facts are also required. Table 4 gives an overview of examples of required new/extra input that is needed for HT.

Table 4: Extending required facts for SSO computation

Socio cultural Terrain facts
Demographics (number, distribution, gender, language, literacy, ethnicity, religion...)
Communication (telephone, GSM, radio, TV, internet, newspapers...)
Economy (agricultural, commerce, industry, etc)
Medical aspects (pathogenic regions, mortality rate, facilities...)
Criminal records
Potable water
Energy supply (fuel, electricity, etc)
Displaced persons (refugees)
Regional conflict
Culture (festive days, festivals, etc)
Key leaders (clan, tribe, religion,(local) government, economy, etc)
…

Own Personnel related facts
Education
Experience
Background
Gender
Leadership
Nationality
Religion
….

3.2 PT and HT System Architecture

The architecture in figure 4 gives an overview of an extended system architecture for both PT and HT. The Human Terrain extension requires extra technical issues compared to the PT reasoning described in section 2.

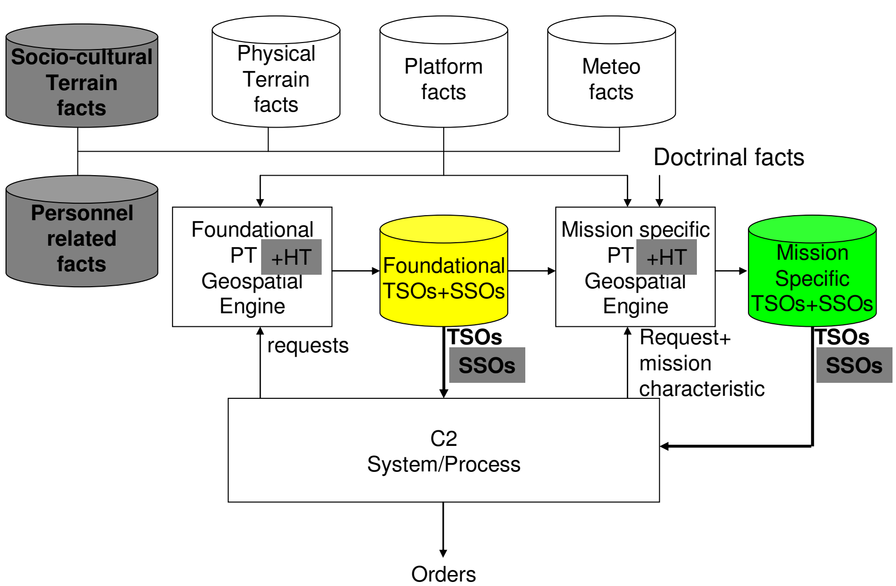

Figure 4: Extended system architecture for HT [3]

[3] in grey the extensions are given

4.0 HT REASONING

4.1 Derivation of SSOs

For the derivation of the required SSOs many different approaches are possible. Depending on the underlying datasets and desired outcome, different methods can be employed to process the data and make the necessary computations. Examples are the use of social network analysis to generate a variety of network measures, the use of rule based systems that capture expert knowledge into reusable rule sets, Bayesian methods or Fuzzy set theory to deal with uncertainty, etc. Most of these methods require high quality or large amounts of data and substantial understanding of the underlying processes. Except for a number of well-studied and documented examples, this information is often not available at a level or in a format required for (semi) automatic processing.

The use of indicators[4] may be a feasible first step towards fully functional SSO derivation where composite indicators [4], also called indices, (like foundational SSOs or mission specific SSOs) can be derived from basic indicators (like socio cultural terrain facts). In this construction process experts select a relevant set of basic indicators that make up the composite. After this selection process three additional steps are required to define the composite indicator. First a way to normalize each lower level (basic) indicator (typically involving basic fact data either physical or human) is chosen such that comparison between the subsequent indicators is possible; second, a weighting method is applied to express the relative importance of each basic indicator for the composite indicator and third; a method to aggregate the individual basic indicators into a composite index is defined.

The construction of composite indicators can be supported by using simple graphical methods like directed graphs that allow a visual representation of the different aspects of the indicator. For example, experts could use simple hierarchical trees to draw the structure of composite indicators, assess the value of particular lower level indicators for a given context or mission and assign weights to edges to express their judgments of relative importance of lower level elements.

The figure below shows the Human Development Index (HDI) derivation as an example of a composite indicator [5].

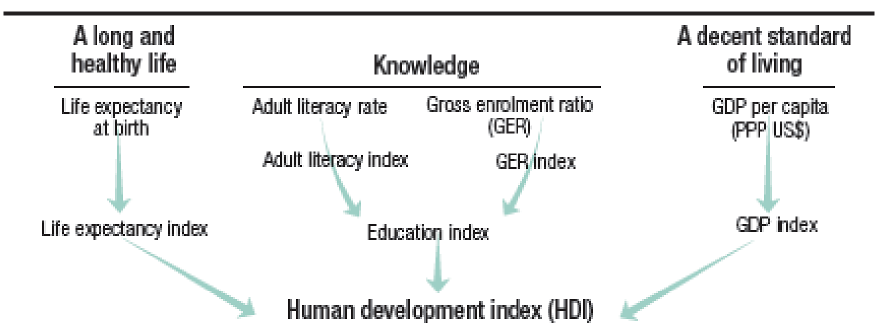

Figure 5: Human Development Index (reyadel.wordpress.com/2009/02/)

The figure below gives an example HDI for the country Brazil.

[4] Indicators give an indication about certain socio cultural characteristics like child mortality, life expectancy, etc. In general, socio cultural terrain facts and SSOs can be seen as indicators

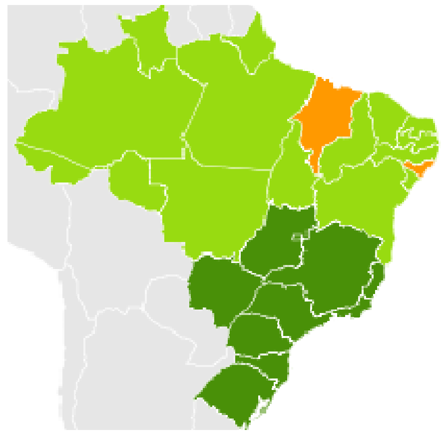

Figure 6: Human Development Index for Brazil[5] (wikipedia.org)

Typically, during the pre-deployment phase experts will define and develop the relevant datasets and develop the required reasoning to maximally support (largely) automated deduction of SSOs for deployed units in the operational theatre. During the operational deployment, as additional and more specific data and knowledge on the socio-cultural dynamics of the society in the theatre become available, datasets reasoning rules and algorithms will have to be maintained and updated on a regular basis as a consequence of adaptive changes in the population and their context. Depending on the C2-process battle-rhythm which may be of different timescale than the HT data management (collection and maintenance of HT facts) it is still to be studied if the HT concept is feasible for mission specific SSOs.

Besides this time aspect, also for HT there is a problem similar to the PT case with respect to the level of detail of the available information. Therefore we think that HT reasoning will require a C2 system for battalion and brigade level like the Netherlands' ISIS C2 system.

4.2 Medical Support example

In this section we will illustrate HT reasoning using a simple and hypothetical example. This example will be elaborated using the composite indicator approach described above.

We consider the following mission:

Medical Support Team will provide medical support in ***Medical Support Area A***

A medical support team, that besides medical support for own forces, has been commanded as part of a PRT to provide medical support to the local population, thereby gaining goodwill from these communities. Typical questions are: where will medical support provide highest gains in term of medical impact and goodwill for own forces. Other questions may address more deployment/logistical questions like where the medical team can best be deployed.

Each of these questions requires specific information like what is the mobility of the local population, what are their cultural or religious barriers for receiving care, what diseases are we dealing with?

[5] The colours dark green, light green and orange indicate high, medium and low development

During expert sessions all relevant facts are brought together in a basic graph as illustrated in figure 7. This figure gives some foundational SSOs relevant for the example mission and facts these SSOs depend upon.

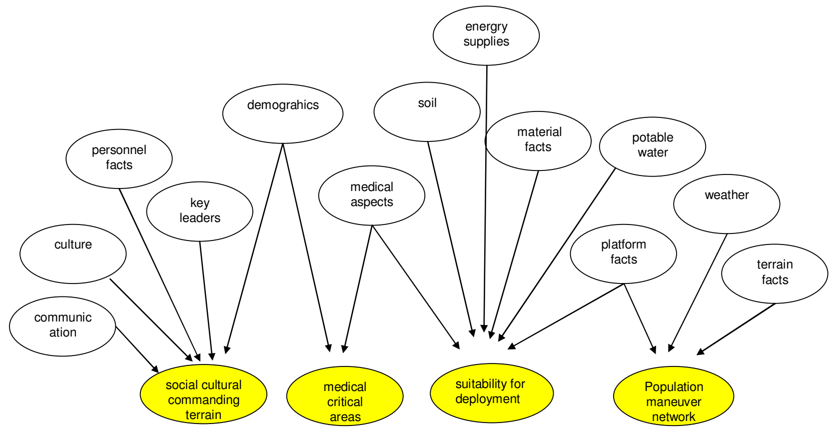

Figure 7: Example foundational SSOs and their dependencies on the facts

The figure below gives some of the relationships between the above foundational SSOs and the resulting medical support area mission specific SSO.

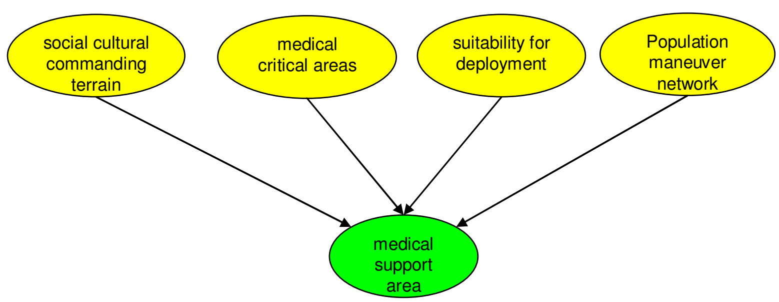

Figure 8: Example mission specific SSOs and their dependencies on foundational SSOs

In this example the goal is to find areas where (1) the need for medical support is high (*medical critical area*) (2) deployment is feasible (*suitability for deployment*), (3) goodwill for own forces (*commanding terrain)* and (4) which can be reached by the local population (*population maneuver network*). A further breakdown of this mission specific medical support area SSO into more aspects may give rise to more foundational SSOs and also TSOs! After some kind of normalization procedure (see table 5) that renders these indicators comparable, experts will assign weights to each indicator. These weights are based upon the relative importance of a given indicator within a set. For example infant mortality might be weighted much higher then life expectancy for determining how critical a particular area is for receiving medical care.

Using the composite indicator approach, finding medical support areas is done as follows. For each location in the terrain, the values for the foundational SSOs (like medical critical areas) are determined using the normalized values of the basic facts and the weighting and subsequently doing a similar calculation for the foundational to mission specific SSO transformation. After this process, all areas with high enough mission specific medical support area SSO value (depending on some threshold) belong to the medical support area. A part of this process is illustrated in figure 9 and table 5.

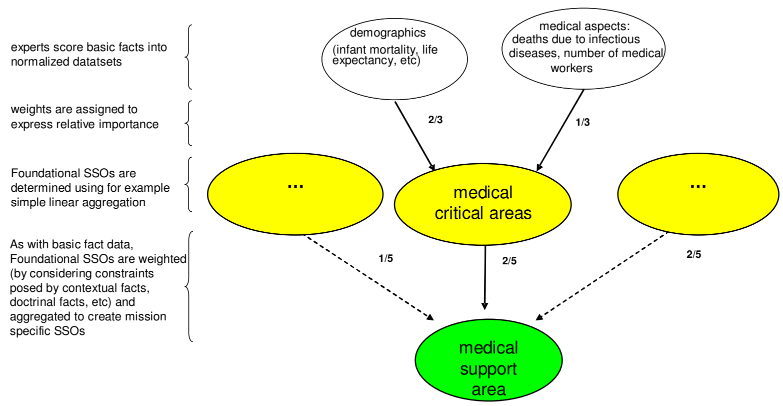

Figure 9: Example illustrating a simple diagram used to define the SSO "medical support area".

Table 5: A simple example of estimating a composite indicator

foundational SSO		basic facts	data	scoring	weighting	aggregation
medical critical areas						**92**
	demographics				***1/3***	***80***
		infant mortality rates	*63/1000 births*	*80*	*2/3*	
		life expectancy	*58 years*	*80*	*1/3*	
	medical aspects				***2/3***	***98***
		HIV deaths	*11000*	*95*	*2/5*	
		Number of physicians	*7 doctors/100000 people*	*100*	*3/5*	
	...other				***...***	***...***
		...	...	...	...	
		...	...	...	...	

In the above example SSOs were taken into account to find medical support areas, which are areas where medical support needs are high, that are suitable for deployment and which are reachable for the local population. The final decision for the location where medical support will actually be given will be done by the commander who would make a selection of these possible medical support areas. Obviously also TSOs may play a role in his decision, for instance when he wants to take into account other, more kinetic warfare aspects like coverage and concealment.

4.4 Enhancing PT reasoning with HT

The TSOs discussed so-far were based purely on PT facts and not on socio-cultural facts or personnel related unit facts. However also TSOs (not SSOs) that will be used for kinetic warfare situations can be enhanced when socio-cultural facts or personnel related facts for the unit performing the mission are taken into account. For instance, the example below takes the mission specific TSOs that were discussed in section 2 and explains how they could be enhanced using HT information.

Take for instance the original mission as was used in section 2.3:

> ***Tank coy*** will prepare in ***Assembly Area A*** to move forward along ***Approach Route B*** and engage Enemy Taskforce in ***Target Area of Interest C*** from an ***Attack by Fire Position D*** by ***surprise.***

The commandant has given the following additional planning guideline: 'I do not want the combat mission of the tank coy to interfere with the missions of the PRT in ***Agricultural Support Area E*** and ***Medical support Area F***.

This additional guideline may lead to changes in the course of TSOs: ***Approach Route B*** and ***Attack by Fire Position D*** which are initiated by taking into account the SSOs ***Agricultural Support Area E*** and ***Medical support Area F***

5 CONCLUDING REMARKS

Taking into account socio cultural issues is crucial for optimal operational effectiveness and added value of military units in military missions, whether these missions are peace keeping or full scale warfare. Socio cultural issues are usually terrain bound, these are summarized under the term Human Terrain (HT). Our vision is that automated systems in the HT area could help the warfighter in his military decision making process. However, these systems don't exist yet. In this paper we propose an approach for a first step in building such systems. The approach shows how, in analogy to an existing reasoning concept for the Physical Terrain (PT)

Elaborating this approach we have introduced the concept of Socio-cultural Spatial Objects (SSOs) analogous to so-called Tactical Spatial Objects (TSOs) in an existing Physical Terrain reasoning concept. We have given examples of relevant SSOs and indicated how the relations between SSOs and TSOs could be. Elaborating on reasoning mechanisms for calculating SSOs however appeared quite a lot of effort and was therefore not done in this project.

Reasoning with HT facts and SSOs is expected to be more time consuming and time varying than reasoning with Physical Terrain facts and TSOs. This means that careful consideration must be given to the timescale of the HT reasoning process in relation to the timescale (battle rhythm) of the C2 process which is expected to be faster. For a part of the HT data it is expected that this can be managed in the homeland via 24/7 reach-back. Given these facts it is expected that HT reasoning will only be feasible for the higher command C2 systems like the Dutch ISIS system. Besides the time factor also the expected available level of detail for some HT info is expected to be low indicating that HT reasoning will only be suited for the higher level command.

It is recommended to work towards a NATO wide capability, enabling warfighters to work with the same kind of information and have fewer ambiguities. Since it is expected that HT data will be quite difficult to acquire, sharing it in a NATO context can be a step in the right direction. NATO infrastructure should be used and standards should be aimed at. Think for instance about extending symbology (APP6A) or the Battle Management Language (BML) that is still under development.

Careful attention must be given to the future users of the HT reasoning capability. Without their support the concept will at best be sub-optimal. Think for instance about validity of the HT info, reach back advise by someone they don't know and robustness of the information.

It is recommended to take this concept a step further by using real data. Furthermore NATO-RTO should endeavor to initialize an international Task group to study and experiment with generic approaches to develop automated Human Terrain reasoning capabilities.

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