INTEROPERABILITY IN THE INFOSPHERE – CHALLENGES, PROBLEMS, SOLUTIONS

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Annotation:

Future military operations presume Interoperability in the Infosphere. Technical, syntactic and semantic interoperability are three relatively independent, but interconnected levels of information interoperability. The article described basics of information interoperability, concetrate to interoperability models (elementary, complex, global) and to infrastructure. Solutions of information interoperability are challenges and also problem of the armed forces for future.

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Introduction

One of the fundamental concepts in NATO and national military strategic visions, and plans is interoperability. Future operations will be increasingly complex and multidimensional, so planning and execution of operations should be a joint and multilateral effort requiring truly interoperable forces. These forces must be fully interoperable with other military forces, and capable of interacting seamlessly with civil authorities, non-governmental organisations and other agencies in the joint operations area. Interoperability will be a key enabler to achieve decision superiority. The challenge of ensuring interoperability goes far beyond matching equipments, interoperability should be achieved not only in the physical, but in the information, and cognitive domains. Information interoperability is a mutual capability of different actors necessary to ensure exchange and common understanding of information needed for their successful cooperation. Technical, syntactic, and semantic interoperability are three relatively independent, but interconnected levels of information interoperability. The problem of interoperability on the first two levels can be solved relatively easily, but much more difficult to ensure the common interpretation of data transmitted in messages, stored in, and accessed from databases. There are different interoperability models of cooperating

actors, with different interoperability solutions. One way of ensuring information interoperability is to create an information interoperability infrastructure.

1. Basics of information interoperability

Fundamental condition of successful and efficient operation of complex organizations, organizational systems, groupings is the sufficient level of information exchange between components, the sharing, and coordinated exploitation of information necessary for cooperation. In case of heterogeneous components there is an additional condition, the information interoperability of the cooperating forces that is, in our opinion, a mutual capability of different actors necessary to ensure exchange and common understanding of information needed for their successful cooperation. In its broader sense information interoperability includes the common understanding of environmental phenomenons, effects.

Information interoperability requires different components, and capabilities, that are almost uniformly classified into three groups, into three (technical, syntactical, semantical) levels. Technical level information interoperability is the collection of capabilities to handle material (physical) representations carrying information, that is the foundation, essential prerequisite of successful, and efficient information exchange. Syntactical level of information interoperability includes capabilities to handle intermediary (non-physical) representations related mainly languages, message, and data formats used during information exchange. And finally semantical level information interoperability is the group of capabilities related to exchange of different representations preserving their intended meaning.

Information interoperability can be interpreted between persons; persons, and technical systems; and between technical systems. In the Information Age the most important, but at the same time the most difficult is the third: information interoperability between information systems (devices), or broadly between systems with information capabilities. Information storage, and processing devices obviously are not able to interpret data stored, or processed, they ‘do not know’ their meaning. So only an intended meaning, planned interpretation can be assigned to knowledge components stored in information systems, and it should be connected to users of these systems (devices), or to information providers. The intended meaning, agreed intentions, and interpretation of the primary users are usually determined in the purpose and functional requirements of the given system.

In information systems, or applications knowledge, and information is handled in the form of syntactical representations. In different systems identical knowledge pieces, information can be represented in different syntactic formats. From the point of view of information exchange three representations should be distinguished: the (inner) representations of the systems, and the intermediate representation used during information exchange.

Purpose of information exchange between systems is actually the exchange of the meaning of data stored, handled by systems, in other words the exchange of semantic representations carried by data. In case of homogeneous information systems, the inner representations are identical, so the information exchange – unless the limitations of the information transfer services doesn't influence it – is possible without essential transformations, the intermediate representation can be the common representation of the two systems. On the contrary, in case of heterogeneous systems information exchange could only be realized with the help of transformation(s), that preserve the meaning carried by the representations used. Information exchange between two systems can be basically done in two ways: using the inner representation of one of the systems, or using a third (intermediate, mediatory) representation.

2. Interoperability models, interoperability infrastructure

Depending on the characteristics of the information exchange between actors, and the supporting information interoperability environment, information interoperability solutions, and ideas can be classified into three groups, can be described by three models. Elementary interoperability model characterizes an interoperable information exchange structure between/among actors who belong to the same functional area, or specialization, and who are in a relatively strong and permanent cooperation. Complex interoperability model is also connected with a relatively permanent cooperation, but it covers more, or all possible functional (cooperation) areas, and is usually supported by more intermediary representations. Finally global interoperability model is not restricted to a given cooperation, it describes interoperability structures, and solutions of information exchange in a dynamically changing cooperation and information environment.

Elementary interoperability model describes a scenario, that is typical of a given functional area in an organization, or among cooperating organizations. In consequence of functional similarity of partners, and the strong and permanent cooperation, they usually handle almost the same information, and information to be exchanged can be easily defined. Despite fundamental similarity in contents of information exchanged during functional area cooperation, usually there are differences among different actors: rather in representations than in concepts used. To handle differences, in the process of information exchange, intermediate representation(s) and contents-preserving transformations are necessary. This can be solved by bilaterally, or by using a common intermediary representation. The former means much more transformations, and the appearance of new actors usually affect the old ones, so if possible the latter is used.

A functional area cooperation usually makes possible to negotiate a preliminary agreement, and if required, to make negotiated changes, modifications on the scope of information to be exchanged, and the intermediary representation used. So it is possible to define a common intermediary representation ("common language") that is appropriate to exchange of all essential information necessary for efficient cooperation in a way that preserves meaning. In elementary interoperability model the transformation

between inner representations, and the agreed intermediary representation is responsibility of the actors themselves. This ensures the autonomy of the actors, and makes easy to extend the cooperation. Having agreed about an intermediary representation theoretically it would be possible that actors adjust, modify their conceptual systems, and inner information representations to the common representation, but in practice this usually neither feasible, nor economical.

Elementary interoperability model is the basic, and minimally necessary solution to resolve heterogeneities between cooperating partners, but its extensive implementation has serious limitations. One of the problems is that a preliminary agreement on an intermediary representation is always connected to a given group of cooperating actors, and even on the same, or similar functional areas there can be more, or several agreements, different intermediary representations. Because of the essential sameness of the functional area, these representations usually differ only in format, not in the concepts used.

Despite of standardization efforts on several application areas (e.g. engineering, public health, bibliography, or meteorology) there are different interoperability solutions, exchange languages, formats. In military application, examples of parallel solutions are the exchange formats used on the same functional area, but in different military forces (e.g. USMTF, ADatP-3), or in different armed services of the same military force (USMTF, OTHT-GOLD), and the different versions of tactical data links with similar, or identical purpose (e.g. Link-1, Link-11, Link-16, and Link-22).

Complex interoperability model is connected with complete organizations, and organizational systems, and characterized by more intermediary representations. In this model the different representations form a harmonized system, all of them have special role – to support definite actors, and a definite part of the complex information exchange. In a broad cooperation environment elementary representations, used on basic functional areas, usually significantly overlap each other. So to support information exchange between different functional areas, higher level intermediary representations are needed to resolve heterogeneities between elementary intermediary representations. In a complex cooperation environment this requires a multilevel, usually hierarchical system of representations.

In complex interoperability model individual actors use a basic intermediary representation in their own functional area, and a higher level representation to exchange information with actors of an other functional area. This can be implemented either by direct, or by indirect transformations. In the first case actors are capable of communicate in different exchange formats, so they have to transform their inner representation to many intermediary representations. While in the second case actors know only their basic intermediary representation, and transformations between basic, and higher level representations are done by other, independent components.

In practice only elementary interoperability solutions for individual functional areas appeared so far. Even the theoretical analysis of the complex interoperability

model has just begun. One of the most elaborated discussions can be found in a paper of Lasschuyt, who analyses interoperability questions based on multiple intermediary representations from the point of view of a highly complex cooperation environment, the NATO C3 systems.

Global interoperability model uses a fundamentally different approach. While the previous two models were based on a group-, and organization-oriented approach, this third model describes the interoperability problems, and solutions from the point of view of individual actors in the infosphere. In our days an actor has to cooperate with a lot of such other actors with whom there is no real possibility to preliminarily agree on the information to be exchanged, and its representation, and whose conceptual systems, and native representations are significantly different.

In such a situation it is necessary, that a given system should be capable in a dynamically changing way, and in relatively short time to exchange information using previously unknown representations. This dynamic interoperability capability obviously can not be absolute, but within some limits it can be realized. Since the number of representations on the syntactical level is relatively small, and grows slowly, a capability of transformations between the possible representations on this level can be implemented in advance. As a consequence of individual conceptual systems, and points of views the harder task is to realize semantic level transformations, that is actually not a development-oriented task requiring first of all (software) technical knowledge, but an application-oriented task requiring mostly domain knowledge.

Ensuring dynamic interoperability necessary for actors of the global interoperability model can not be efficiently implemented as part of the affected IT systems, since it would require continuous modification, development of this systems, but not in their basic parts. So the required transformation functionalities should be realized in form of independent application components, built especially for this purpose. This leads to the concept, and questions of information interoperability infrastructure.

Information interoperability infrastructure is a coherent system of methods, means, and services, that's purpose is to support information exchange between cooperating actors in a meaning preserving way. Two fundamental tasks of this infrastructure are transformations between different information representations, and transmission of intermediary representations between actors during information exchange.

Transmission of different representations is traditionally done by communication systems. So concept of information interoperability infrastructure can be defined in two versions. In a narrower sense information interoperability infrastructure, and communication infrastructure are independent each other, the former is built on the services of the latter. In a broader sense information interoperability infrastructure includes communication infrastructure. From the point of view of persons, and systems, who make use of interoperability services, this difference has no any significance.

Traditional task of communication systems is to receive a given information representation on a determined connection point, and to transmit it in a reliable, and secure

way to one, or more other (determined) connection point(s). In case of "information exchange" between IT systems, or devices this means exchange of data (syntactical level representations) "carrying" information, that usually includes transformations between physical (material) representations. So the fundamental task of information interoperability infrastructure, or of its upper level(s), is the meaning preserving transformation between different semantical and syntactic representations used, or known by different actors.

Transformations between inner, and intermediary representations today usually implemented as an integrated part of a given IT system, or device. So when a new intermediary representation appears, a new interface application component needs to be developed for every system. The main disadvantage of this approach is that the same, or very similar functionality need to be implemented more or less independently, in a hidden, not reusable way in many versions. The main role of every infrastructure is to collect, implement, and provide every usable function, or service for a wide user community. In practice every infrastructure was born from individual solutions: separated from existing systems; redesigned, generalized, and reimplemented in a unified, centralized manner.

An information interoperability infrastructure should be implemented as a complex network of different components with well-defined functions. This is not only because we live in an increasingly network-oriented, network centric world, but also because almost any traditional infrastructure is, and was essentially a network of serviceprovider, and communication components. Based on the mission of an information interoperability infrastructure, and on the characteristics of information exchange, components of the infrastructure should be organized into semantical, and syntactical levels, and classified by the subject of information they can handle (transform).

An information interoperability infrastructure can be populated with different, freely accessible components, that are responsible for transformation between different representations of the same information (e.g. geographical positions, dates, quantities, names or codes of persons, objects, etc.). These components could be considered as an "expert" of the given type of information ("date expert", "unit-name expert", "person-code expert", etc.), because they usually embody a special part of sometimes high level knowledge. Using services of an interoperability infrastructure IT systems need not know any intermediary representation, they can use their own, native representation.

3. Summary

Successful execution of different – military, disaster relief, humanitarian assistance, etc. – operations of our age requires strong cooperation of the participating actors (organizations, persons) with different capabilities, and coordination of their activities. Fundamental condition of successful and efficient cooperation is the sufficient level of information exchange between components, the sharing, and coordinated exploitation of information necessary for cooperation. Military forces are heterogeneous in many dif-

ferent areas, so information interoperability is a prerequisite of successful information exchange.

Information interoperability is a mutual capability of different actors necessary to ensure exchange and common understanding of information needed for their successful cooperation, that has a basic requirement: to preserve the intended (planned) meaning carried by information representations used in information exchange. Information interoperability can be divided into three levels: the physical (material) level of mediums used; the syntactical level of languages, message- and data formats; and the semantic level of content, and meaning to exchange. In our days interoperability on the two first levels can be realized relatively easily. Much more difficult to ensure the common interpretation (semantic interoperability) of data transmitted in messages, stored in, or accessed from databases, and functions, services provided by information systems.

Information interoperability structures and solutions can be classified into three groups, described by three models. Elementary information interoperability model is connected with strong permanent functional cooperations, and characterized by one preagreed intermediary representation. Complex information interoperability model describes wider interoperability structures in organizations, organizational systems, and characterized by a harmonized system of different intermediary representations. Finally global information interoperability model has a different, actor-oriented approach. It describes the point of view of an autonomous actor in the dynamically changing infosphere. In the two latter models interoperability functionality can, and efficiently should be implemented in independent application components, that can form an information interoperability infrastructure.

References

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