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Interoperability questions of perceptual information in military IT systems

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Perceptual (visual, acoustic, etc.) information play an important role in human information acquisition, and in a lot of application areas. In the globalized, dynamically changing information environment of our days interoperability questions related to perceptual information, and necessity of their solutions more and more considerably arise. This is especially true in case of military application, where the successful information exchange, and the efficient exploitation of available information services have important role in ensuring and maintaining of information superiority, and as a consequence in operational superiority. This publication summarizes conceptual basics of perceptual information, introduces their typical application areas, presents changes in their application, determines basic concepts of their interoperability, and finally, based on the analysis of the existing interoperability solutions, draws conclusions about appropriate solutions in a changing information environment.

Introduction

IT systems from the appearance of the computers support the handling, and processing of in narrower sense "data-like" (numerical, logical, and textual) information. Later the development of information technology gradually made possible the efficient processing of line drawings, then still images, finally motion pictures and other kinds of digitally represented information. Direct primary perceptual (first of all visual, and acoustic) information, acquired by human perception, always played a highly important role in human information acquisition, and exploitation. These perceptual information play an important role in a lot of application areas, so in the military application too.

In our world of globalization successful and efficient operation of different actors (persons, organizations) practically inconceivable without extensive information exchange between/among actors, and broad exploitation of different information sources, information services of the infosphere. This is especially true in case of military application, where these activities have important role in ensuring and maintaining of information superiority, and as a consequence in operational superiority.

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This publication summarizes conceptual basics of perceptual information, their basic characteristics; introduces their typical application areas, in detail the military application areas; presents basic formats, types, and characteristics of perceptual information representations; presents the changes in the application of perceptual information; determines basic concepts of their interoperability; analyses the existing interoperability solutions; and finally draws conclusions about appropriate solutions in a changing information environment.

Concept, role, and application of perceptual information

Concept, types, and characteristics of perceptual information

Human knowledge i.e., the different information components appear and are handled, processed and used in the human brain in two different mental representations: in analogue and in propositional (judgment based) form. Mental visual pictures, sound, smell and taste impressions are represented in analogue form. These arise as a result of the perception of the external and internal environment by our senses. Conceptual propositional representations are results of higher level sensing (e.g., form recognition) and of conceptual cognition and thinking.

Personal knowledge and information is partly gained from one's environment, and partly as a result of his or her thinking. The two basic sources of environmental information are the naturally predominant environmental influences and the representations of information generated artificially by people or devices. External representation may similarly to internal, mental representation be also divided in two main groups: the first comprises of the perceptual information corresponding to the analogue mental representation, the second contains the abstract external representations corresponding to the propositional mental representation.

Perceptual representations include both perceptible environmental effects and artificial representations that record and reproduce these in relatively unchanged and true form. The sensings of our environment themselves do also represent characteristics of the objects and events of this environment. Artificial representations include traditional drawings and paintings, and also recordings made with the help of different devices, such as still and moving pictures and sound recordings. In a broader sense, also those forms of environmental effect not sensible by humans (e.g., radioactive radiation, magnetic field, etc) which are transformed to the humanly perceptible domain belong here. Sensing and observation (play back) of perceptual representations convey to all of

us the impression of the original environment, and ensure the recognition of a certain aspect of reality.

Abstract representations in contrast to perceptual representations do not contain characteristics similar to reality; their relationship to the objects they represent is arbitrary (based on conventions). In this category belong first of all traditional written texts, systems of symbols, but also different numerical, logical etc. data. The perception of these does not automatically ensures the recognition of the represented information, since for this step it is necessary to know the rules of the representation, to know the "language" applied.

One of the main characteristics of the external perceptual representations, in the following called perceptual information, used to gain knowledge, is that they dispose of modality connected to human perception. Material effects of our environment (objects, phenomena, events) all carry potential information about different characteristics of this environment or of its components and parts. Senses of all creatures are able to detect given environmental effects (stimuli) and convert these to a certain neural impulse pattern. In the process of cognition as a result of further processing the human brain synthesizes higher-level information concerning environmental object and events: analogue and propositional mental representations.

Depending on the senses human perception may have one of the following modalities:vision, hearing, touch, smell and taste. Vision detects light of diverse light sources and light reflected by environmental objects, i.e., light of secondary light sources. Hearing is the perception of mechanical oscillations created by sound sources and forwarded by some medium (in most cases by air). Touch is the detection of shape, size, weight, surface texture and mechanical consistence of objects. Finally, smell is the perception of volatile substances emitted by objects; taste detects solute substances in saliva. For humans the first two modalities – vision and hearing – play the most important role, so in the following we will deal with these.

One further characteristic of perceptual information is their complexity. They carry information regarding not only single objects and events of our environment – except in artificial cases – but concerning their certain complexities. In case of vision and hearing perceptual information are images and sound.

An *image* represents characteristics of a part of our environment preserving its spatial distribution: humanly detectable distributions of light intensity and pattern, i.e., the humanly processable visual stimulus. An image represents characteristics of a part of the environment according to the nature of human eye as differences in shades and colours.

An image (pattern of light) may be created in natural ways, as a result of light emitted by different light sources or as a product of secondary light sources: reflections

of diverse objects of our environment; but also with help of devices (recording and play-back of original images, artificial creation of light effects, or by transformations of other types of environmental effects and characteristics to brightness and/or colors). Among these latter images of radar, temperature, X-ray, ultrasound, radioactive radiation or magnetic fields may be listed.

Images and *visual information* is an external information representation – describing light distribution or a certain material effect in two dimensions – that may, sensed directly or projected with the help of suitable devices, create visual stimuli and inner visual images. A basic characteristic of visual information is that the potentially higher level – e.g., textual or symbolic – information carried by the image may be acquired only by further processing. According to this – though represented as images – textual information, tables, pictures based on symbolic characters, maps and diagrams do not belong to the category of images.

Visual information (information representations) may be subdivided into two main categories: still images describing light distribution (or material effect) at a certain point in time, and moving images representing the change and flow in time for a certain period. The represented light distributions continuously and parallely change in space and in time. There is no possibility to create different representations for these two aspects, but this is not necessary either. Human vision is neither continuous in time, nor in space. Spatial resolution is determined by the number and position of the receptors on the retina. The illusion of sensing continuous motion is created by the succession of still pictures (at least 15 per second) perceived.

Sound is a mechanical oscillation created by a vibrating object, travelling in a suitable medium, a mechanical wave perceivable by the human ear. Aural stimulus is the sum of the sounds representing the state and changes of state of the environmental objects. Sound represents the state and changes in state of vibrating objects by pitch and volume, or by the change of thereof.

Sound may be created in natural ways, by oscillations of sound sources of the environment, but also artificially by recording and play-back of original sound sources, artificial creation of sound effects, or by transformations of other types of environmental effects and characteristics to sound. In this latter category belongs for example the representation of the level of radioactive radiation by different pitch and volume.

Sound (acoustic, audio) information is an external information representation – describing sound vibrations – that may, sensed directly or projected with the help of suitable devices, create aural stimuli and inner audio images. Among audio information speech, music and singing possess special positions. Speech is essentially the audio

representation of abstract, conceptual information; music and singing are the sum of sound elements of constant and predetermined frequencies (one keynote and its harmonics).

Visual information also plays a major role *in military applications*. In case of the NATO and its member states basic notions are first of all 'imagery' (image or spatial representations) 'visual information'.

'Imagery' according to the NATO Glossary of Terms and Definitions is "collectively, the representations of objects reproduced electronically or by optical means on film, electronic display devices, or other media".[1] So 'imagery' includes "images" created by the means of photographic, radar, electro-optic, infrared, thermo-sensitive and multispectral devices (sensors).[2] According to the US military interpretation, 'imagery' is the visual representation of persons, places, objects recorded and stored on some physical carrier.[3] As it can be seen in these definitions, the both interpretations of the notion of 'imagery' may be regarded the same as visual information.

According to the US military interpretation, 'visual information' is the visual or image information representation of persons, places, objects with or without sound.[4] In this sense visual information includes photographs, digital (still) images, moving images (movies), analogue or digital video recordings, manual and computer graphics and animations of real or imaginary persons, places and/or objects, including subtitles, additional data (textual, or in form of tables) and other data facilitating understanding.[5] This above definition of visual information is a broader definition containing also audio information, called audiovisual representation. This is justified by the fact that moving images are almost always accompanied by sound recordings.

Handling, role and application areas of perceptual information

Handling of perceptual information is basically very similar to the handling of other types of information basing on the need of organizational, work or personal functions and activities. For a given activity perceptual information is needed, if it is not provided, cannot be acquired directly – by human sensing – and the necessary information content may not be acquired in other abstract forms of information.[6]

So the required information has to be acquired from other sources, or has to be created from existing (perceptual) information. Creating primary perceptual information representing the environmental effects on a suitable level is practically only possible with the help of devices.[7] Real representations, recordings may only be created in case of image and audio information. Smell and taste may only be sampled, and other environmental effects measured (which are in this sense and form no perceptual representation).

The desired primary perceptual information representation may be created with help of sensor units out of the environmental effects they are based on. These representations

created by sensors may be displayed with the help of suitable functional units; they may be recorded and transmitted. These functional units may be turned into different technical devices – image and sound recorders, cameras, microphones, image displays, speakers, sound and image conveyor systems – to create still and moving images and/or sound recordings. With help of all these devices the desired perceptual information (recording) may be created and transmitted if necessary or earlier recordings may be played back anew.

The next figure demonstrates the different representations used, and the appropriate functions (functional units) applied during perceptual information handling. Representations drawn with broken line border are inner representations used in different devices.

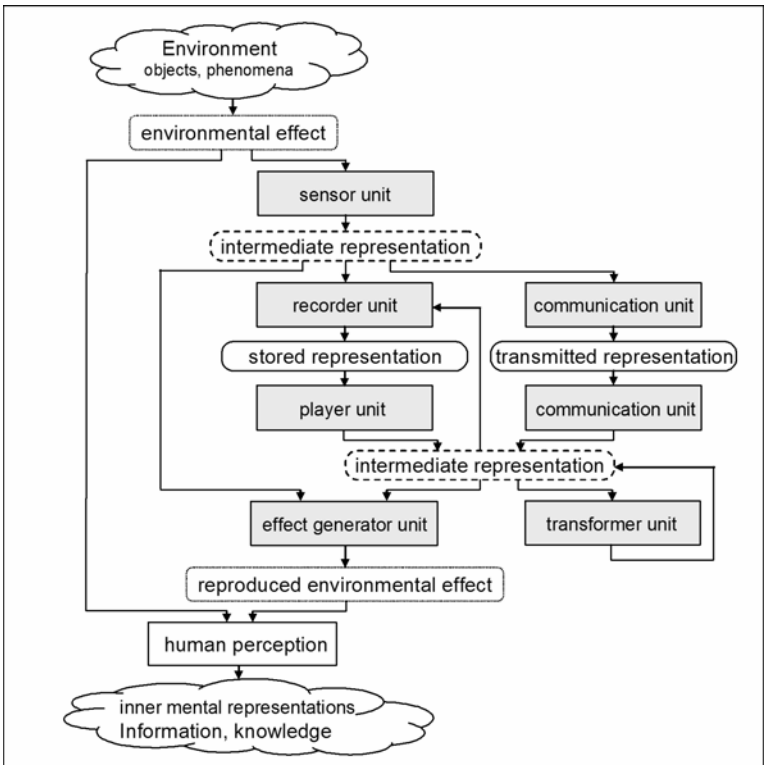

Figure 1. Model of perceptual information handling

It may happen that the given need for information may not be satisfied by actual or earlier recordings, but the transformation or comparison, synthesis and integration (fusion) of different pieces of perceptual information is necessary. On perceptual information several different operations not affecting its perceptual character may be performed. Among others in this category belong the improvement of quality, special or time transformations, modification of basic characteristics (shade, colour, volume, pitch, and tone), exclusion of redundant pieces, fitting of different information next to each other or their superposition. Most of these operations may already be performed manually and with help of traditional image and sound editing devices.

Final activity of handling perceptual information, assuring use is the displaying of the acquired, or created information. This is achievable with the help of directly viewable, traditional carriers of information (in case of visual information), but also with help of play-back equipment to display conveyed or recorded information. All three methods create an environmental stimulus very similar to the original, or an artificial effect.

The *role of perceptual information* is significant in numerous fields of applications. To these belong fields of applications closely related to the natural or built environment, or concerned with their forming or observation (e.g., agriculture, architecture, environment protection, and meteorology). Besides, perceptual information related to the actual and future state of our environment bear basic importance to all applications, where certain components of the environment (e.g., relief, flora, certain landmarks, weather, and state of the sea or ocean) bear influence to be considered for that given activity. Further characteristic applications: medical diagnostics, media, broadcasting, and production and distribution of movies, and such special applications as personal identification.

Characteristic military applications of perceptual information include imagery intelligence, cartographic support, meteorological support, terrain classification, target identification and evaluation of operation efficiency, and visualisation of situational information.

Imagery intelligence is one of the methods of acquiring information for reconnaissance and intelligence purposes. Its aim is to create accurate and timely information from different sources and from the exploitation of imagery resulting from the different devices mentioned earlier. So this field of application is obviously based on perceptual information and its handling.

Purpose of cartographic support is the supplying of necessary cartographic information (maps, aerial photographs, etc.) to military organizations for performing their tasks. Maps today are essentially created based on aerial photographs or images taken from outer space (i.e., perceptual information) and are regarded as abstractions of

primary perceptual information enriched by additional information. According to this, also military cartography is one of the basic applications of perceptual and mainly of visual information.

Task of the meteorological (in a broader sense, meteorological and oceanographic) support is the determination and evaluation of the current and expected influencing characteristics of aerial and oceanic environments. Beside the data acquired by ground, marine and aerial sensors and instruments, images taken by meteorological satellites play a prominent role. Diverse satellites take images in regular intervals of specified parts of the Earth in the visible, infrared and thermal radiation portions of electromagnetic radiation.

Terrain classification and analysis is one of the basic components of planning of ground operations. Its aim is the evaluation of effects of natural and artificial landmarks on a given operation. Terrain classification includes most of all evaluation of visibility, possibilities of fire and movement, and concealment and deffendability. Based on this it becomes possible to determine the landmarks, regions, directions, routes and positions matching different criteria. Terrain classification, based mostly on cartographic information, is only possible with suitable accuracy if actual perceptual information concerning relief, flora and built environment is acquired.

Target acquisition and evaluation of operation efficiency is a basic component as well. Target acquisition is basically the selection of regions, facilities, means to be occupied, seized or destroyed. For this the detection and identification of potential targets and their positions is necessary. In a dynamically changing operational environment this is based on reconnaissance and intelligence, and most of all on perceptual information. Then during execution of operation it is necessary to determine and evaluate the results of the given activity (manoeuvre, strike, etc.), which also requires acquiring and evaluation of perceptual reconnaissance and intelligence information.

Visualization of situational information is – if necessary – accompanied by textual, tabular, and other forms of information. This is explained by the essentially spatial character of military operations: targets to be reached are usually determined in spatial form; military organizations, groupings are based on spatial manoeuvres; finally position and movement of participants of military operations essentially influence their possibilities, activities and results. Visualization of military situational awareness is still based on maps, but with the development of information technology photography-based (ortophoto) and close to reality synthetic two and three-dimensional image visualisation gains in importance.

Changes in the handling of perceptual information

Representations of perceptual information

Perceptual information may be subdivided, based on their state of processing and content, into three groups: raw, primary and processed (secondary). *Raw information* (representations) contain only the recorded, original environmental effect, so carrying little information for the end user. A single image or sound recording, for example, without the information on what, where and when has been recorded, may – if it may at all – only be interpreted and used in possession of additional knowledge. In case of many applications for successful and effective use beside the above mentioned also other additional, descriptive information is necessary.

Primary perceptual information are representations created directly by the instruments, devices (recorder, sensor) acquiring information. In sensors already elementary processing steps may take place, the representation created may already contain additional information.[8] In civil and military applications this primary information is forwarded (directly or after recording) from the ground, aerial, marine and space sensors for further processing, or distribution to the information processing and utilization units. In some fields of application sensing and processing are not necessarily separated, are realized in the same device (e.g., medical diagnostics).

Processed (secondary) perceptual information are representations created from primary and further secondary information – according to a specific or typified need – after processing (or further processing).[9] Processed information is usually created from primary information via substantive modifications, changes, enrichment by further additional information, or by integration of several types and pieces of perceptual information. Processed perceptual information so usually already consists of several components: it contains next to the basic perceptual information also additional descriptive data, symbols, graphical and textual components.

Traditional representations of perceptual information include first of all analogue negative or positive films (transparencies), pictures, paintings, records (LPs and such), but also transfer forms of images and sounds utilized in telecommunication and broadcasting. Raw, primary and processed information exist and are utilized also in case of traditional representations. Primary information is created out of raw information by application of titles, subtitles, and superimposed storytelling. Written additive information may have appeared directly on the carrier itself, but also on its cover or container. Processed information includes beside others retouched, cut, edited, and modified image and sound recordings, image and sound assemblies, montages.

Digital representations of perceptual information appeared in connection with the development of information technology in the mid 1970s, and became the dominant type of representation today. In the course of the past years in case of still and moving images, and sound information many different standards, manufacturer-specific format appeared, became widespread or disappeared.[10]

Still image representations, according to human vision, base on representations by image elements. Here, the light distribution to be represented is described in form of characteristics of some finite elemental parts of the image surface. The format and arrangement of these elemental parts theoretically may be arbitrary, but in practice arrangement of rectangles (pixels) in rows and columns became established.[11] The whole picture is described by the shades and colour characteristics of the individual elemental parts. In practice there are several different representations of different detail and construction.[12] Moving image representations are based on a sequence of still images (frames). Earlier, in the era of analogue technology also half-frame (alternating row) representations have been used.

Analogue sound representations usually utilized for the description of sound waves surface furrows or changes in the magnetic field. Digital representations realize this by sampling and quantification of the characteristics of the sound wave at given time intervals.[13] Beside this, in order to achieve surround sound effect, the given representation may contain two or more (stereo) recordings originating in different spatial positions.

High quality representations require as well in case of still and moving images as for sound recordings a considerable amount of information. In case of today's dominant digital technology, this results in requirements for high storage and data transfer capacities. As a consequence, in case of all three types of information, compressed representations appeared. Part of these preserve the entire amount of information of the original (uncompressed) representation, while others minimally (in some cases unconceivable) diminish image or sound quality in order to ensure higher compression ratios.

Changes in technology and application

Due to the development of information technology and thus the domination of digital representations a major change concerning the handling – creation, processing and use – of perceptual information occurred. These changes, which in many cases are interconnected, concern as well the users, systems and devices of perceptual information as the perceptual information itself.

The development of information technology and microelectronics based sensor technology results in an increase in the quantity, diversity and ability of imaging

devices. This calls forth the development of even newer devices with new sensing methods, with higher sensitivity and resolution, which – due to their lower prices – are attainable for an ever increasing circle of users. Due to the application of a larger amount of high quality sensing devices a larger amount of high quality perceptual information is created satisfying more user needs more effectively.

The dominant role of digital representations of perceptual information also resulted in certain consequences to be considered. The digital format together with the increased functionalities of information devices expanded the possibilities of recording, storage (search), forwarding, processing (modification), and display of perceptual information in an extraordinary way. Thus all functions of handling of perceptual information, except for acquisition, may be realized without special equipment, mostly with "average" information devices and configurations. All this facilitates the design of system components dealing with acquisition, processing, synthetisation, storage and release of perceptual (visual, audio or sensory) information suitable for a given user need. Further on, it also enables realization of simplified system components with lower functional abilities and capacities for end-user needs.

Due to the easy accessibility of primary and process perceptual information and systems necessary or their handling perceptual information is applied in many fields it has not been applied earlier. This may be explained by the fact that the lack of applications did not result from the lack of demand but from the constraints posed by technical barriers.

Parallel to the increased amount of information, due to the improvement of possibilities of data transfer and creation of global networks, networks of users and system components concerned with handling of information underwent vast expansion, too. Information of certain sources are utilized by an increasing number of users and applications, and certain applications utilize information from different sources, often not even intended for use for that given field.

Basics and solutions of perceptual information interoperability

Concept and interpretation of perceptual information interoperability

Expansion of sources and applications of perceptual (above all visual) information raises the necessity of investigating questions of their interoperability. Interoperability usually means the ability to work together. Information interoperability is the mutual ability to effectively exchange information based on a common understanding. Accordingly, interoperability of perceptual information signifies interoperation of

systems and devices handling – creating, processing, storing and releasing primary perceptual information, but also using and utilizing it – such information.

Two systems or devices handling perceptual information are interoperable if they are able to exchange (receive or send) perceptual information ensuring identical interpretation of content (meaning) sufficient in the context of the interoperation. The notion of interoperability makes only sense, if cooperating systems are characterized by differences, incompatibilities, or heterogeneities regarding content, representation and exchange of perceptual information. In this sense, problems of interoperability do not arise in case of homogeneous systems. Here, information may be exchanged based on content, representation and transfer without difficulties.

Information interoperability needs the existence of different components and subcapabilities built-up on each other. The basis is the technical interoperability of systems handling the physical carrier of representations. This means that one system is able to receive and use representations and/or physical carriers (data transfer format, data carriers) created by another system. The second level is made up of syntactic interoperability realizing handling of intermediate representations, meaning the knowledge and ability to use data and message formats, and languages (data exchange protocols) during exchange of information. Finally, semantic interoperability is the ability to preserve and interpret the intended meaning accompanying the given information-representation on a necessary level for cooperation.

For the traditional handling of perceptual information interoperability of recording, transferring and play-back (releasing) devices has been ensured by technical and syntactic standards. In the interest of broad applicability size and basic physical characteristics of picture strips, records and tapes, rules and parameters of recording perceptual information, and ways and forms of transferring this information (transfer of speech, radio broadcasting, television broadcasting, video-conferencing, etc.) have been standardized in one or some few ways.

Due to the basic identity of human sensing raw perceptual information displayed arises the same mental impression practically in everyone. So there are no interpretation problems here. For the types of environmental effects however, which are normally not perceivable by human senses but have been transformed in the range of human perceptibility (like radar, temperature or ultrasound) the lack of common mental impression acquired during training and usage of these information can create mental incompatibilities. Substantive differences occur during further processing of this information: here by objects, phenomena, processes seen on the image, by speech and signals in audio information abstract (notional) information is created – but these already belong to the borderland between handling of perceptual and abstract

information. Since in traditional handling of information hardly any additional (primarily textual) information has been attached, semantic interoperability of perceptual information has been practically narrowed down to lingual interoperability.

In case of modern, digital representations of perceptual information interoperability on a technical level may be regarded as solved, but on syntactic and semantic level their amount and complexity grew enormously. Technical interoperability is based on the possibilities and the general interoperability of digital data transfer and storage, independent of perceptual information. Thus, problems and tasks of interoperability in case of perceptual information concerns representations applied (data format) during data exchange, and realization of representation transfer between internal representations of individual systems and intermediate representations.

Interoperability solutions in case of perceptual information

Basis of the realization of interoperability between systems handling perceptual information today are the standard or manufacturer-specific data formats. These, according to their function and the information represented, may be subdivided into three groups: formats representing raw data only, primary information containing also additional data, and formats describing complex groups of information.

Data exchange formats carrying raw information contain theoretical representations (pixel matrices, frame sequences, acoustic wave patterns, etc.) of perceptual information in a predefined structure with predefined data elements, using compression if necessary. Different formats contain beside the data describing elemental structures of the environmental effect represented only syntactical characteristics[14] regarding the method of representation.

In the course of history many different formats for the representation of perceptual data evolved, but only a few became widespread. Due to the differences in the demand of diverse applications (closeness to reality, size, etc.), and because of data already accumulated in different formats no uniformly accepted and applied standard format developed, and it cannot be expected in the near future either.

In case of raw information interoperability is ensured by general or task-specifically developed (image, sound, etc.) conversion functions. Conversion between different formats basically takes place on a syntactic level, a problem to be solved by IT specialists and not requiring application-specific knowledge. Users are at most required to specify parameters of the target format.

Demand for additional data enriching raw information lead to the development of new information exchange formats, or in some cases to the expansion of already existing formats. Additional data tags attached to the raw information appear in form of

type values. The list of possible types and formats of their values are determined by the given data exchange format. Part of these complementary characteristics, which are absolutely necessary from the user's point of view, may be used in all fields of application while others are application specific. Examples for the first are date and place or description of the recording, for the latter geoinformatics-type characteristics used in GeoTIFF[15] or medical diagnostic-like data used in DICOM.[16]

In case of primary information enriched by descriptive characteristics, in order to realize interoperability, the exchange and – if necessary – modification of both raw and additional information has to be ensured. Knowing a given data-exchange format, take over or setting of different characteristics is a syntactic level task, but their interoperable use already poses problems on the semantic level.

The meaning of individual characteristics are, independently of the actual representation, defined in the description of each data exchange format, usually in form of a denomination or by a brief definition in a text format (e.g., exposure time in seconds, altitude above sea level, velocity of platform, radar mode, etc.). In case of classification characteristics format descriptions also anchor the range of possible values and their meaning. All this entails that the modifications necessary for the application of a data exchange format are usually "wired" into a system on the software level.

Problems in interoperability may – among others – emerge, if a given system interprets and uses a certain characteristics not in a proper way or differently from other systems. This may be caused by a simple programmer error, but it is also possible that the given format description does not define the intended meaning of that characteristic sufficiently, thus leaving a certain freedom of interpretation for each system.

Another problem may arise, if the characteristics or their available values are not suitable for displaying the descriptive information used by the other system. In such cases information may not, or only inaccurately exchanged or transferred. The solution in this case, as it can be seen in everyday practice, is the expansion or refinement of the given format. Newer versions of different formats are usually backward compatible, meaning that representations according to the new version may also be handled by older versions (but sometimes in limited ways), but in order to be able to utilize the new possibilities, conversion component and systems of applications interested in the refinement have to be modified.

A further interoperability problem may arise from individual characteristics[17] of data exchange formats intended to ensure broader application. The amount, content and meaning of such is usually determined by a narrow circle of users fitted to their own needs regarding data exchange. Thus their definitions are not available to the broad public, and are so not usable. Also different, non-standard characteristics are indicated by different

representations in different fields of applications, working against interoperability as well. In such cases, it is of course possible to expand the original data exchange format, but this also affects all users who have applied the given format earlier.

The next family of solutions supporting the interoperable exchange of perceptual (most of all image or image-based) information is composed of the data exchange formats designed to represent processed, in most cases complex information (information products). In military applications these include among others the NATO Secondary Imagery Format (NSIF), and the US National Imagery Transmission Format (NITF).[18] These two standards are in most parts identical. The international Basic Image Interchange Format (BIIF) has been developed based on these standards.[19]

The essential designation of the information exchange formats mentioned above is to exchange and transfer information between systems as one entity, components integrated into a standardized structure, instead of files in different formats. Unified presentation is ensured by a common coordinate system, which is the basis of relations of all components to be represented (image, drawing, symbol, text) to each other.

Main structures of information exchange formats are beside the header information the segments carrying different information, based on image, drawing (composed of lines), and text segments. Information representation occurs within different segments according to different standards and broadly applied formats. Thus, these formats describing complex information may also be regarded as higher level "container"-standards based on earlier standards. The same applies to many other standard formats belonging to this group.[20]

The reviewed information exchange formats contain many incorporated possibilities for individual development, in form of optional data elements and segments. Segments carrying certain types of information may be extended individually by optional descriptive data, and information that cannot be represented by existing segments may be indicated in these segments.[21] Most of these may only be applied based on central registration, but among the individual descriptive data also some may exist, that are only used and applied by a certain group of users.

As it has been already observed in case of the previous two categories, there is no one exclusively applied standard format used for the exchange of complex groups of information. This cannot even be realized within one field of application, since even within NATO NSIF is not the only and exclusively used format. Also the installed extensions built in by tight groups of users have to be regarded as a characteristic partly rendering interoperability more difficult.

Summary, conclusions

In summary, based on the previous findings, it can be stated, that in our days handling of perceptual information is characterized by the growth of the quantity, assortment, and quality of available information, and information sources; by the extended availability of information processing capabilities and possibilities; by the broadened application of perceptual information and by a more complex system of relations between actors involved in handling of perceptual information. All these more and more intensively raise the necessity of the analysis of perceptual information interoperability questions.

It should be repeatedly emphasized, that interoperability problems related to modern digital representations of perceptual information, on technical level can be solved relatively easily, while on the syntactical and semantical levels their quantity, and complexity have significantly grown. So essential interoperability problems and tasks are connected to representations (information exchange formats) used in information exchange, and to necessary conversions between inner representation used in the individual systems, and the intermediary representation.

It can be also summarized, that there are many standardized exchange formats for perceptual information on different levels, and actually there is no single version among them, that is used exclusively, or even in significant majority. As a consequence of different requirements of various application areas, and different formats of existing, highly valuable information representations, appearance of a unique, full-scale standard interchange format cannot be expected. So systems, devices handling perceptual information should interoperate, exchange information in such an environment, where the other systems, devices use more different formats.

In case of heterogeneous systems, handling perceptual information, transformations between inner and intermediary representations today usually implemented as an integrated part of a given IT system, or device. According to this kind of solution, when a new intermediary representation appears, a new interface application component needs to be developed for every system.

In a dynamically changing information environment the adaptation based on a continuous development neither sufficiently efficient, nor flexible, and in some cases even cannot be accomplished. Even a minor information system upgrade, limited in range and volume, requires a significant amount of time from the formulation of the requirements to the implementation of the new software or hardware version (solution). Moreover an additional time is necessary to do the modifications on all of the working implementations of the given system. What is more, in case of “legacy” systems usually it is not possible to upgrade the system, to extend it with new interface functionality.

One solution of the problem described above could be the separation of conversion application components from the individual information systems. This means the implementation of an interoperability infrastructure, where autonomous application components, intended to resolve heterogeneity between different systems (mediators), belong to the group of so-called middleware components.

Implementation of interoperability infrastructure will probably according to service-oriented architecture widely spreading nowadays. In this architecture different components implementing interoperable transformations appear as autonomous service-providers that can be used to build a complex transformation. This kind of implementation, in case of missing interoperability subfunctionality, makes possible to extend the infrastructure with application-side interoperability components, even to provide this functionality to other applications, and later to build into the infrastructure. All this ensures dynamic, application-requirement oriented extension of infrastructural services.

Several components of an infrastructure, ensuring interoperability of perceptual information, are already available in form of independent applications, application components (still image, sound, and motion picture format converters), and only conditions of their wider availability should be ensured by placing their services at users' disposal in form of infrastructural services. The next task is the development of other components, ensuring interoperable conversion of the additional descriptive information, and the container-formats supporting representation of complex perceptual information. In addition the foundations of a general interoperability infrastructure should be laid down.

Notes and references

1. AAP-6 (2005), *NATO Glossary of Terms and Definitions* [p. 2-I-1]
2. NATO Land ISTAR (Study draft 1), Section 4 *Categories of Intelligence* [p. 3-12]
3. DoD Instruction 5040.02, *Visual Information* (2005), Enclosure 2 Definitions [p. 9]
4. ibid. [p. 10]
5. ibid. [p. 10]
6. Required information may not be conveyed at all or not with necessary detail, is not quantifiable.
7. Partial exception is visual information created as drawing or painting. In contrast, there is practically no possibility to reproduce sound, smell, taste and other effects without devices.
8. See e.g. STANAG 4545 NATO Secondary Image Format (NSIF), *Terms and Definitions* [p. A-11]
9. See e.g. STANAG 4545 NATO Secondary Image Format (NSIF), *Terms and Definitions* [p. A-11]
10. In case of still pictures e.g. BMP, GIF, TIFF, JPEG, PNG; for moving images, e.g., H.261, MPEG-1, MPEG-2, DivX, H.263, WMV; for sound recordings, e.g., WAV, MP3, WMA, AAC.
11. One of the NATO image format standards (NATO Secondary Image Format) defines the notion of image as two dimensional, rectangle arrays of pixels indexed by rows and columns.

12. 8, 16, 32 (maybe 48) bit, RGB (red-green-blue), YUV (shade-colour1-colour2), CMYK (cyan-magenta-yellow-black), HSI (hue-saturation-intensity) representations. These latter are adjusted to the characteristics of human vision.
13. Sampling in a range of a few to 96k per sec. (characteristically 44100); or 8, 16, or even 24 bit description.
14. Amount of rows and columns, colours, palette information, amount of frames per second, sampling frequency, accuracy of data, compression method applied, etc.
15. The widely used TIFF formatted complemented by geographic/geodesic characteristics.
16. Digital Imaging and COmmunication in Medicine.
17. E.g. individual fields in TIFF, individual "keys" in GeoTIFF.
18. STANAG 4545 NATO Secondary Imagery Format (NSIF), MIL-STD-2500C DoD Interface Standard, National Imagery Transmission Format (NITF).
19. ISO/IEC 12087-5 Basic Image Interchange Format (BIIF).
20. E.g. Hierarchical Data Format 5 (HDF5) used for the exchange of technical-scientific information; or Grid in Binary (GRIB) applied in case of meteorological data.
21. Tagged Record Extensions, Data Extension Segments, Reserved Extension Segments.

Bibliography

AAP-6(2005), NATO Glossary of Terms and Definitions (English and French). – NATO Standardization Agency, 2005.

Digital Imaging and Communication in Medicine (DICOM), PS 3.1. – National Electrical Manufacturers Association, 2004.

DoD Instruction 5040.02, Visual Information (VI). – Department of Defense, USA, 2005.

ISO/IEC 12087-5, Information Technology – Computer Graphics and Image Processing – Image Processing and Interchange (IPI) – Functional Specification – Part 5: Basic Image Interchange Format (BIIF). – International Organization for Standardization/International Electrotechnical Commission, 1998

MIL-STD-2500C, DoD Interface Standard, National Imagery Transmission Format 2.1. – Department of Defense, USA, 2005.

NATO Land ISTAR (Study Draft 1). – NATO Land Operations Working Group, 2002.

STANAG 4545, NATO Secondary Image Format (NSIF). Edition 1, Amendment 1. – NATO Military Agency for Standardization, 1998.