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ADAPTATION OF C2IEDM FOR CIVIL CRISIS MANAGEMENT
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Abstract

Civil and military systems interoperability is an open topic for research and development, especially in case of C4ISR systems.

The proposed solution is focused on the mitigation of big disasters (e.g. terrorist attack or big flood/tsunami) by performing an effective crisis management due to the adaptation of C2IS to the civil environment. Core of any C2IS is its data model, which specifies the type and characteristics of each data and the way the information is stored, exchanged and shared at database level.

In this paper is proposed the adaptation of the C2IEDM (Command and Control Information Exchange Data Model) military standard for its utilisation in the civil environment.

As a first step to achieve this objective, a detailed analysis of C2IEDM has been performed. As a second step, a prototype of the C2IEDM physical schema has been implemented in order to be used as a logical base to encompass the data models (where available) of the different actors involved in a big civil crisis management operation (police, firemen, sanitary staff, civil authorities) C2I systems. We are working now to build, over the adapted C2IEDM, an interoperable C2IS for real civil emergency management and for coordinated simulations.

Introduction

Some lessons learned from recently declared big civil crisis (massive terrorist attacks, big forest fire, big floods/tsunami, etc.) reveal the necessity of improving the coordination and the information flows among the different civil/military commanders involved in the crisis management. The fact of achieving reliable situation awareness at commander level can optimize the effectiveness of the forces on the field, their effort and the assigned resources. Some of the main detected weaknesses in the management of this kind of crisis are on the one hand the lack of civil command and control information systems (C2IS) and on the other hand, the lack of continuous and normalized information flows among the different commander centres involved in the crisis management.

The current information flows established for managing a big civil crisis are mainly based on telephone calls, radio communications and not normalized text file transfers. These information flows can be split in two types:

- **Vertical information flows**; among the forces on the field and their different commanders steps.
- **Horizontal information flows**; among the different units on the field and also among the different commanders of the different civil forces (police, firemen, sanitary staff, etc.) involved in the management of the crisis.

These current information flows have proved to be clearly insufficient since they can not provide clear situation awareness to the different commanders, which normally are placed at their headquarters. Moreover the above mentioned communications channels for sharing information (telephone, radio, etc) can be insufficient in terms of bandwidth for some kind of information (i.e. real time video) or being out of order in a big disaster.

The solution proposed in this paper in order to mitigate the effect of a big civil disaster and performing an effective crisis management would be the introduction and adaptation of interoperable C2I systems to the civil environment.

The base of any C2I system is its data model, which specifies the type and characteristics of each data and on the other hand, the way the information is stored, exchanged and shared at database level. To support unambiguous definition of data for information exchange among civil C2I systems has been proposed to use the Command and Control Information Exchange Data Model (C2IEDM) as a common reference model.

The C2IEDM has been developed by the MIP (Multilateral Interoperability Program) [1], initially was called Generic Hub Data Model [2], in 1999 the name was changed to LC2IEDM (Land Command and Control Information Exchange Data Model). The current version contains a lot of content related to multinational joint operations and as a result of this its name changed to C2IEDM.
The aim of the Multilateral Interoperability Programme (MIP) is to achieve international interoperability of Command and Control Information Systems (C2IS) at all levels from corps to battalion, or lowest appropriate level, in order to support multinational (including NATO), combined and joint operations and the advancement of digitization in the international arena. The main objective of the present work is to extrapolate the MIP objective to the civil environment [3], in order to achieve that the different actors involved in a civil crisis management act as a unique coordinate force in terms of data availability and information exchange.

1. C2IEDM OVERVIEW

A basic task in data specification is defining the universe of discourse. The first step in the universe of discourse definition is to select the objects about which information is to be held. For C2IEDM, the basic objects selected are either identified uniquely as *items* or used according to their class or *type* characteristics. A key concept in data specification is the entity. An entity can be defined as any distinguishable person, place, thing, event, or concept about which information is to be kept. Properties or characteristics of an entity are referred to as attributes. The attributes make explicit the data that are to be recorded for each entity or concept of interest. The 6.15c edition of the C2IEDM contains 194 entities. The entire structure is generated from 15 independent entities, that is, entities whose identification does not depend on any other entity. All other entities are dependent entities.

Once the main objects which compose the model have been identified, the following step is its classification. The objects have to be classified taken into account both who are the actors who use the objects and which objects are available for being used in each moment. The C2IEDM encompasses two object categories:

- **Item**: Objects what can be identified individually; (by name: i.e. Lieutenant John Smith, Second Armoured Division, by call sign or serial number or license plate or passport number, and so on).
- **Types**: Objects which represent properties of groups or classes; (a tank, a ship, an M1A2 tank, a helicopter, a howitzer, a rifle, an armoured brigade, a light infantry battalion, an infantryman, a refugee).

Both categories are used in parallel as basic structural elements of the C2IEDM. The two structures are related to each other. Data characteristics are entered either on the item side or the type side as appropriate. Any characteristic described on the type side also applies to the item when the item is assigned a type classification. The linkage from item to type is mandatory in the model.

C2IEDM structure labels class objects as OBJECT-TYPE and individually identified instances as OBJECT-ITEM. Implicit in the distinction between type and item is the assumption that data relating to OBJECT-TYPES will tend to be relatively static or persistent (i.e., the values of the attributes are not likely to change very often over time), whereas the data characteristics related to OBJECT-ITEMs are likely to be more dynamic. For example, if a characteristic is about a type (e.g., M1A1 Abrams Tank), it is an attribute of OBJECT-TYPE. Thus, calibre of main gun, track width, and load class are characteristics of OBJECT-TYPE. However, the call sign, actual fuel level, munitions holdings, and current operational status of a specific tank are characteristics of an OBJECT-ITEM. Yet, the mandatory classification of an instance of OBJECT-ITEM as an instance of OBJECT-TYPE assures that the item inherits all the characteristics of the type. The first level of both, OBJECT-ITEM and OBJECT-TYPE sub type entities are presented in Figure 1.
2. REFERENCE MODEL IMPLEMENTATION

The implementation of a prototype of C2IEDM, for serving as reference model for civil crisis management C2I systems, is the first task in order to start the study of its adaptation to the civil environment.

Two implementations of the C2IEDM physical schema have been performed by UPV. The first one has been implemented through Microsoft SQL Server 7.0 and the other one has been implemented through MySQL version 4.0.24 [4]. Both implementations include the 203 tables which form the C2IEDM with their relationships according to the 6.15c C2IEDM version [5].

It is important to note the difference between the two implementations of the C2IEDM physical schema in terms of notation. In the MySQL version the table names, attributes, data size and type of each data have been implemented following exactly the notation of Annex I of the version 6.15c of the C2IEDM MIP [6] specification. This version will be used for developing purposes.

In the Microsoft SQL Server 7.0 a more “didactic” version of the physical schema has been performed since such as the table names as the attributes have been written without abbreviations in order to be clearly understandable by users belonging to target groups (policemen, firemen, sanitary staff, civil authorities) and also for performing clear examples for them. In the figure 2 the Microsoft SQL Server 7.0 version of the reference model is shown.

Figure 1. First level sub type of OBJECT-TYPE and OBJECT-ITEM
In figure 3 the MySQL version of the reference model is shown.
In figures 4a and 4b the differences on notation are shown with the representation of the two versions (MySQL and MS SQL Server 7.0) of the same table, in this case OBJECT_ITEM table. Note the use of the corresponding abbreviations in MySQL version according to Annex I of the version 6.15c of the C2IEDM specification and the use of the whole names in the MS SQL server 7.0 version.

Through the table relationship representation visual tool provided by Microsoft SQL Server 7.0 the relationship among the 203 tables which compose the C2IEDM physical schema can be shown. These relationships encompass 315 indexes 203 of which are unique. All these relationships have been represented through 18 diagrams which correspond with 18 of the 21 chapters which compose the 6.15c C2IEDM MIP specification.

In the following figures some examples of these diagrams are shown. Note that in some cases due the high number of tables included only the name of each table is shown, in other cases such as the table names as their attributes are shown in the diagram.
In figure 5 the whole sub type of independent entity OBJECT_TYPE is shown.

Figure 5. OBJECT_TYPE independent entity relationships

In figure 6 the relationships of independent entity LOCATION are show.

Figure 6. LOCATION independent entity relationships
3. ADAPTATION OF C2IEDM FOR CIVIL USE

The following step of the work described in this paper is the adaptation of C2IEDM to the civil environment in order to serve as a solid base for interoperable civil C2I systems for crisis management. The objective is to develop interoperable C2I systems for each actor involved in the civil crisis management in order to achieve a high degree of interoperability and coordination among them for optimizing their results. Through this kind of systems the commanders will be able to avoid misunderstanding or interferences due the lack of updated and relieved information during the crisis management.

Several meetings have been held with some of the actors involved in civil crisis management in the Valencia region, especially the Valencia Emergency Call Centre (112 Generalitat Valenciana) and Valencia firemen department. The 112 call centre receives the emergency calls from the citizens and informs the civil forces about the emergency characteristics, position and so on. Each actor i.e. the firemen department, evaluate the emergency based on the information received from 112 call centre and sends the resources they consider suitable. Once the units arrive to the crisis scenario they act coordinated by their commanders on the field and without any sort of coordination or information exchange with the other actors also involved in the crisis management. None centralized and interoperable C2I systems or something similar operates in any case.

After the description of the current situation the work now is to adapt the C2IEDM to the data modelling necessities of each actor and building over it an interoperable C2I application for real emergency management and for coordinated simulations. Through this kind of system the different commanders could either face realistic simulation scenarios of coordinated operations in a civil environment or act in a coordinated way in a real declared crisis. The proposed architecture, shown in figure 7, deals with the three DoD standard definition levels [7] operational, systems and technological.

![Proposed C2I system architecture](image)

**Figure 7. Proposed C2I system architecture**

The architecture will be used to evaluate command and control procedures by using multimedia information from individual elements. The blocking point of the dilemma (the non-availability of enough bandwidth in the combat and tactical networks) is solved in the civil environment by means of civil networks (e.g. GPRS, UMTS, WIFI) and systems following the COTS philosophy currently used in the dual development civilian/military environments.
On the one hand the system allows component reuse by means of an abstract object definition that can be replaced if interface specifications are fulfilled. It is important to point out that object-defined architectures are not silver-bullets, and every component reused must be carefully studied avoiding black-box philosophy, mainly for real-time and safety critical applications and systems. On the other hand, most of the architecture follows OSS (Open Source Software) philosophy [8], so source code is available. Due to this, existing software components can be reused, replaced or redesigned at any time to extend existing ones or to fulfil new needs and challenges.

A first prototype of the above described system has been developed by Universidad Politécnica de Valencia through the project C4ISR Multimedia for emergency management. (TIN2004-03588) founded by both the Spanish science and education ministry and EC-FEDER founds.

This prototype receives data from the units deployed on the field. The information received (real time video, vital signals from units, voice) is completed by the GPS situation of each unit in a GIS. In figure 8 the application main interface is shown. In this figure the video from one independent unit along with his vital constants and his position are shown.

![Figure 8. C2I System interface](image)

The major part of the system is based on the C2IEDM. In the following figures an example of independent unit location traceability is shown. The example shows the different GPS locations of a unit by representing a line on the GIS. The procedure is the following: The GPS records are stored in the table ABSOLUTE_POINT. The points under study are marked by the ellipse in Figure 9.
Figure 9. Different points represented by its GPS positions stored in the system database.

These points are marked as ABSOLUTE POINTS in the POINT table following the C2IEDM location entity structure. See Figure 10.

Figure 10. C2IEDM POINT table.

In order to create the line which will be represented by the system interface these points are included in the LINE_POINT table including its sequence order and the line id. See figure 11.

Figure 11. C2IEDM LINE_POINT table.
The line id is included in the LINE table and this line id is included in the LOCATION table and marked as a line. These tables are shown in figures 12 and 13.

Figure 12. C2IEDM LINE table.

Figure 13. C2IEDM LOCATION table.

Finally the line is represented in the interface of the civil C2I system developed by UPV. The C2I system user interface is shown in figure 14.
4. C2I INTEROPERABILITY; INFORMATION EXCHANGE

Once the C2IEDM primary structure and its application to civil environments have been analyzed, the information exchange methods defined by MIP for achieving interoperability among different C2I systems are going to be study in detail.

The MTIDP specification [9] (MIP Technical Interface Design Plan) performs a common interface and information exchange mechanisms. The common interface is the C2IEDM which model the information that the allied C2I systems need exchange in both directions horizontal and vertical.

The specification enables C2IS to C2IS information exchange and allows users to decide what information is exchanged, to whom it flows, when and over what communications medium. Thereafter no further interfaces are required to interoperate with any other MIP enabled system. The Message Exchange Mechanism (MEM) which consists of a suite of formatted messages derived from the C2IEDM that conform to AdatP-3 Part 1 [10], plus guidelines for their use. The Data Exchange Mechanism (DEM) is an automatic data push mechanism that co-exists with the MEM. When a C2 application changes the state of information that it holds, and which is recognised by the DEM, this information is automatically replicated to all other cooperating systems that have agreed to exchange this information. With both exchange mechanisms the meaning and context of the information is preserved and requires no additional processing on receipt to make it useful. The MEM and the DEM will be in-service during the period 2003 – 2005 and followed thereafter with biennial capability enhancements.
The DEM application is managed through the DEM database. This database is provided by MIP [11] in MS Access format and it is composed by 51 tables. Through these tables the whole interoperability process is managed. The database has been migrated to MySQL format by UPV for being coherent with the open source philosophy of our project.

In Figure 15 a vision of the DEM database is shown in MySQL format.

In the interoperability process which is being implemented by UPV there are two main modules which have to be taken into account.

The first one is the replication application module which manages the replication protocols to be used in order to establish a connection between the corresponding nodes and maintaining it during the data exchange session. This module has to manage the events launched by the C2I application and to process the protocol data units (PDU’s) received from other nodes. This module will manage the following tables of the DEM database: REPLICATION-NODE, TRANSFER-FACILITY, REPLICATION-NODE-ADDRESS, REPLICATION-NODE-LINK, REPLICATION-NODE-ADDRESS-LINK, REPLICATION-ORGANISATION, and REPLICATION-NODE-MANAGER.

The second one is the DEM manager module which is in charge to the DEM database managements which includes information ownership management, contract management and so on. This second module is composed by several sub modules which manage the different parts of the DEM database.

The first one would be the contract and C2IEMD management sub module. This sub module will manage the following tables of the DEM DB: REPLICATION-DOMAIN-COMPOSITE, REPLICATION-DOMAIN-COMPOSITE-ELEMENT, REPLICATION-DOMAIN-TYPE, REPLICATION-DOMAIN-TYPE-ELEMENT, REPLICATION-DOMAIN-COMPOSITE-FILTER, REPLICATION-DOMAIN-COMPOSITE-FILTER-ENTITY, REPLICATION-DOMAIN-COMPOSITE-FILTER-PARAMETER, REPLICATION-CONTRACT, CONTRACT-DATA-OWNER, REPLICATION-SUBSCRIPTION, REPLICATION-CONTRACT-FILTER-PARAMETER-FUNCTION, REPLICATION-CONTRACT-FILTER-PARAMETER-VALUE, and REPLICATION-DOMAIN-COMPOSITE-FILTER-ATTRIBUTE. Four additional entities are more related to C2IEMD: ENTITY, ATTRIBUTE, SUBJECT-VIEW, and VIEW-ENTITY.
The second one would be the management event sub module. This sub module will manage the following tables of the DEM DB: MANAGEMENT-EVENT, MANAGEMENT-UPDATE, and MANAGEMENT-ERROR. These tables are used to capture changes in the Replication Management and Contract Management Subviews as management events for replication to other nodes. Management updates contain the updated or created tuples of management tables with their attribute values; management event contains the associated management function and time information.

The whole interoperability process must to be completely automatic. When some data included in some replication contract was modified the whole process will start in an automatic way. The first step should be to detect any data modification at the DEM Schema (C2I EDM). The system has to check whether the modified data is included in any replication contract. In affirmative case the system has to establish the corresponding connections with the corresponding data receivers through the information provided by the network management view of the DEM.

Replication of user data can only take place if the following conditions are true:

- The REPL-NODE.status-code for the receiving node(s) is “AC”
- The NODE-LINK.dst-node-link-status-code is “AC” (for the source to destination node entry)
- The REPL-SUBSCR.status-code is “AC” where the providing node is the local node.
- The REPL-CONTR.status-code is “AC” where the providing node is the local node.
- Replication of management data can only take place if the following conditions are true:
  - The REPL-NODE.status-code for the receiving node(s) is “AC” or “MA”
  - The NODE-LINK.dst-node-link-status-code is “AC” or “MA” (for the source to destination node entry)

Once the system has checked that all the conditions are true the physical connection is established through the information stored in NODE-ADDRESS and NODE-ADDRESS-LINK tables. When the connection has been established the exchange of messages (PDU’s) between the corresponding data provider (DP) and data receiver (DR) will start in order to begin the replication session. The whole process is shown in figure 16.

![Figure 16. Replication process.](image-url)
The whole state diagram of all the possible events and PDU’s sent/received from both sides Data Provider (DP) and Data Receiver (DR) point of view are shown in figure16 and 17.

Figure 16 State diagram from DP point of view.
Figure 17 State diagram from DR point of view.
Explanatory notes for the state diagrams.

The first line in the text of each transition is either the primitive invocation (even) (if it is in minuscule) or PDU arrival (if it is in capital letter). The rest of the lines in each text are the system response to the previous event.

R_PDU shall be submitted to the ASSOCMAN using an A_Data_req, and R_PDU shall have been received in an A_Data_ind.

CLOSING by DR (respectively, DP): indicates that the initiator of the R_Close_req is the DR (respectively, DP) of this session.

If T1 expires, then assume the R_Abort_req that armed T1 has failed and proceed to abort the association locally.

2. Assumptions:
   The activities described in the state diagrams are unique to a session and the related association.

3. Predicates:
   P1: Positive response
   P2: Negative response
   P3: An association is already opened with this node

4. Actions:
   (1) Clean up context of session
   (2) Discard message
   (6) Arm timer (T1)
   (11) Clean up local context of related association.

The implementation of the interoperability application is currently in its test phase. The detected errors are being corrected in order to fully adapt the application to the MIP specifications.

5. CONCLUSIONS

The presented research has been funded by the Spanish government through the TIN2004-03588 project founded by the Spanish Ministry of science and education and FEDER funds. The following steps on that research will be to fine adapt the C2IEDM to the data modelling of the actors involved in the crisis management in order to profit fully all its data management features. To provide interoperability mechanisms to the developed C2I applications and simulation capabilities and providing the developed system with quick deployment and robustness features in order to optimize its quick deployment and reliability in case of civil crisis.
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