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ROLE BASED INTEROPERABILITY APPROACHES WITHIN LVC FEDERATIONS

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ABSTRACT

The idea of the magic circle, frequently referenced in the serious gaming community, is explained and then shown to be a possible perspective to view live-virtual-constructive (LVC) simulation federations. This view opens the method of categorizing different roles and data capabilities for the various elements and actors within an LVC federation. The applicability of this view is shown in some explanatory detail, including a description of its applicability to simulations, the different types of roles, and the variety of knowledge (procedural and propositional) that can be qualified when the federation is viewed this way. Structured identification of the federation elements and the data they are exchanging is relied on to describe peculiar data interoperability issues that exist within current LVC federation architectures, and which may also affect future LVC federation architectures currently under development.

1 INTRODUCTION

Interoperability problems continue to be a problem for Live-Virtual-Constructive (LVC) federations that are relied on to generate synthetic environments representing the modern battle space, for purposes of training and analysis. Because of the wide variety of organizations and systems that are relied on to present a simulated scenario to the intended audience, interoperability between those systems is a constant goal for federation managers. Enabling such interoperability relies on a variety of different engineering standards for system alignment and data exchange. The amount of success enjoyed through employing these efforts varies widely, depending on a number of different issues.

One aspect of the interoperability problem, concerning data, is that there is a wide variety of different types of data, existing for different purposes, being generated and consumed by a wide variety of different federation participants (both human and automated), and performing the exchange of information and knowledge as part of different roles within the federation. A perspective on these differing purposes, participant types, and role types of data is presented here from the perspective of a compelling paradigm out of a research domain that is separate from, but related to simulations. That research domain is in the area of digital world design and development for games and serious games, and the approach is known as the magic circle.

Upon introducing the idea of the magic circle, along with a short history and explanation of its uses and implications, the perspective driven approach of identifying the different participants, purposes and roles of data within the federation are presented. Particular areas for interoperability mismatch for each of these are discussed, and finally possible strategies for addressing those mismatches are introduced. The ability to segment the data interoperability issues for a federation are one benefit from considering this perspective on the problem, but also the understanding of certain issues, and their solutions, driven from the approach of considering the synthetic environment generated by the federation as being the contents of a magic circle.

2 THE MAGIC CIRCLE

The idea of the magic circle, is that in any activity such as a game or sport, there is a cognitive space, where the "world" of the game is supported by accepted rules and laws. Participants in that "world" agree to abide by those rules, and as such, are participating in the magic circle. This section will describe the concept more fully, along with its history, and show how it is not only directly applicable to digital games, but also to the digital worlds that comprise simulations.

2.1 Origination

The concept of the magic circle comes from Johan Huizinga. The concept was originally described to enable understanding of how persons agree to be governed by different sets of rules and laws when engaged in some activity that they pursue for the sake of fun such as make-believe, or playing a game or sport (Huizinga 1955). For Huizinga, the idea of play did not only constitute games, but also included other activities were there are some defined rules of behavior, that can be engaged in, for the purpose of defining a winner or loser. This often is games or sport, but could also include business, the competitive marketplace or legal courtrooms. The term only appears a few times in Huizinga's work, however the concept appears throughout, and the idea has appeared in the literature of the serious gaming research community.

2.2 Applicability

The idea of the magic circle defining a cognitive space of interaction for actors can be thought of as a group of actors, agreeing to act according to, and constrained by, a set of rules. In a simulation game, where the rules are intended to be representative of some referent system, those rules are then further constrained by being tied to a series of resources. In a game enabled and enacted by only human actions – such as a tabletop simulation or roleplaying game – the understanding of the rules, and the appreciation of what resources are available, are done through understanding by the human actors.

The human participants – the actors – willingly subject themselves to the rules that define their particular behaviors, and agree to abide by the constraints that these rules put on them. This willful compliance with the rules defining the space of play (the game, the sport, or the competition), is how the magic circle is held in place, and maintained. The motives for this could be many, but the effects of those motives all collapse into "a desire to participate in the magic circle for some reason".

2.3 Specific use for Digital Worlds

A type of play space that exists is that of digital worlds. These can be simulated synthetic realities (of greater or lesser fidelity to an imagined real world), or they can be purely abstract. An example of the former might be the 3d world envisioned for a first person shooter type game, where rules of motion and the appearance of solid objects such as walls and obstacles mimic those same things in reality, and they are presented for the player's visual benefit. An example of the latter might be a typical platform game, where an imagine 2d world exists of platforms for the game character to run back and forth on, collecting coins and avoiding monsters. In either case, the constraints imposed on the player that create the boundary of the magic circle are those constraints that exist due to the definition of that synthetic reality. The player is limited by the types of motions and activities that are enabled, as their only ability to act within that world, but within those limits, the player cognitively decides how they will attempt to achieve the goal of the game (points, survival, treasure accumulation, or others). The attitude that a player adopts when entering such a play space, is referred to in (Suits 2005) as a "lusory attitude". Prior to entering that space, the player has some notion of what they mean to gain in the space – whether it be victory at the game, some side effect of engaging in play, or just the joy of entering another cognitive space. This is referred to (Suits 2005) as the "prelusory goal".

There are some differences in how the magic circle is applied, in this case of digital worlds, do exist – and also some similarities. The differences come from the fact that if the idea of the magic circle surrounding the play space is applied to a digital world, then it can be seen that significant software and hardware structure must exist, in order to enable and present the world in which the actors interact. The idea of applying the magic circle, to digital games, was proposed within (Salen and Zimmerman 2003). The concentration there is on the cognitive space that the game takes place in, the interactions of the player, and the design of the game, and not as much on the enabling technology. On the other hand, the similar application of the magic circle when it applies to a digital computer game is the same as when applied to a sand lot game of kick ball, because in either case, the player agrees to abide by the set of rules in order to participate in the play activity. In the digital world, they can escape from those rules only by acting outside – ending the game program, turning off the computer, or so on. In the physical world, where a magic circle construct is obeyed for some play (such as a kick ball game), once the players willingly break the defining rules, then they are no longer playing the game (and in fact, the game may end, or they may be asked to leave the play activity by others still willing to participate in the circle).

In considering a digital world as a play space, Figure 1 (Klabbers 2006) can suggest that the actors are not only those controlled by human players (in essence, avatars or extensions of the human into the play space), but also those actors that are controlled by computers. Also, the implementation of the digital computer that is making the digital world possible, is also enabling both the rules by which the actors (human or computer) can perform their actions in the magic circle. Finally, any resources that may exist inside the digital world, for the actors to act on through the rules, exist only because they are given digital "presence" by the enabling digital computer.

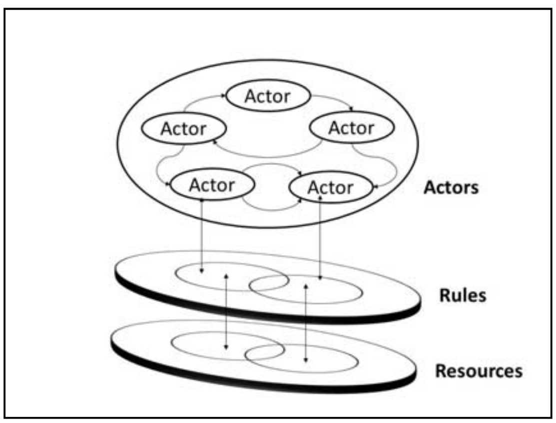

Figure 1: Actors, rules, and resources.

2.4 Elements Participating in and Enabling the Magic Circle

By focusing on the magic circle to understand the role that these different elements have to each other, we can see that there is a magic circle, or defined play space, that is constructed and maintained by computers that outside that circle. There are actors that can participate within that play space, but are themselves controlled by agents from outside the circle – either by enabling computers in the case of artificial actors, or in the case of humans who willing participate in the magic circle by controlling an avatar that represents their will to act within the circle. There is the digital world itself and the resources that exist within it, that are generated from without the circle by enabling computers, but which enable the definition and context within the play space that give the actors' actions meaning.

There are a number of different interactions happening here. If we rely on the magic circle to divide up the space into three regions, it becomes easier to describe those interactions. Those three regions are (1) within the magic circle, (2) the structured wall that enables the magic circle, and (3) outside the magic circle. For convenience these can be referred to, respectively, as the first region, the second region, and the third region. The computer systems that enable the digital world of the magic circle are providing content that exists in the first region. The computer systems (which may be the same that enable the digital world) that enable the game actions by human actors, are providing the structure that exists in the second region. Finally, the humans that are going to play the game participate in the third region.

There are instances where at least two of these project into other regions, however. The first instance of projection from one region into another, is human players, through their use of the computer systems that enable the game, are able to cognitively project their participation into the first region. They are not in that game world, however they can perceive it, and through the game system, exert their will over avatars to act within it. The second instance of projection from one region into another, is when the computer system that is aware of, and responsible for enabling, the game structure in the second region, is creating actions for artificial actors that are participating in the first region.

3 MAGIC CIRCLE APPLIED TO SIMULATION

Reliance on the magic circle for digital games can also be useful in the study of simulation studies, to help define the difference between the digital world contained within it (providing the play space), from the supporting structure that makes that digital world possible, and finally from the human participants that exist outside both of those, but projects their will onto avatars acting inside the magic circle. There are some differences, however, and these are described. The prelusory goal (Suits 2005) of a participant (user) entering a simulation is, for some motivating reason, that the participant in the magic circle (the "simulation space" rather than the "play space"), wishes to engage in a reliable representation of the referent that the simulation system is synthetically creating.

The selection of using the magic circle for this approach described in this paper, is based on the perceived utility of the magic circle description to help differentiate the different roles of LVC federation data – in terms of both origination and of intended use – for a simulation. The use of the magic circle appears to provide that utility, as described in the following sections. However, in spite of this, it is quite possible that additional findings from the serious gaming community could benefit the ongoing refinement and application of LVC federations, and should be further explored in future efforts.

3.1 Definition of Reliable Representation

In applying the magic circle to games, the boundary of the circle is the border of the play area. Within that border, actors willingly submit themselves to rules of behavior in order to engage in play. There are reasons to create a similarly bordered space with a simulation, where actors willingly submit themselves to rules of behavior in order to participate. With a simulation, typically, the reason is not play. This is true of LVC federations, when considering their use for training and analysis. The goal to be achieved, rather than a play space, is the ability for all actors involved to have a shared reliable representation (see section 3.2 consideration of a reliable representation) of what is being simulated. The actors involved in this simulation version of the magic circle can, as with their counterparts in a play space oriented circle, engage in behaviors defined by rules, and interact with each other, the synthetic environment, and resources of that environment, only through those rules.

Consider that the simulation (and system) elements of the federation that are going to interact with the synthetic environment are based on conceptual models in order to capture what they are representing. In order to measure that representation, it is informative to take a look at what (Pace 2000) has to say about conceptual models. Four criteria are presented for a good conceptual model, in order to judge whether or not it is useful at conveying the representation of what is being modeled.

- Completeness – all elements of the problem domain that the resulting simulation will address are included – objects, processes, and elements of control and structure.

- Consistency – all elements are in alignment with each other, with regards to structure, scope and resolution
- Coherence – all elements have function and potential
- Correctness – all elements of the model are valid representations of the referent

3.2 Model sensitivity to the Magic Circle

In evaluating the reliable representation of the synthetic environment, when described as the three elements supporting the magic circle perspective, then the three elements can be evaluated in the following way. These three elements help to judge the sensitivity of that representation in perspective of the magic circle approach.

- Systems enabling the synthetic environment inside the magic circle should enable it so that it appears reliably. This should be consistent from system to system that interacts with that synthetic environment, and of enough detail so that the desired actions can take place, and their results observable, within the synthetic environment.
- Systems enabling human or computer participants to direct actors in the synthetic environment to perform actions should have their directions interpreted reliably, so that an expectation of resulting actions can be counted on when the participants are making decisions or reacting to behavior programming. Sensitivity of directions to conditions within the synthetic environment should be reliably represented.
- Systems presenting a view of synthetic conditions inside the magic circle to (human or computer) participants outside the circle must present such a view reliably enough for those outside participants to be aware of the synthetic environment, and to perceive the results of their directions to actors inside the circle.

In all three of these cases, the systems involved are model based – they have their algorithms and programming based on models that are intended to support the reliable representation. As each system is typically developed separately, however, there is likely to be some mismatch between the individual models, and the implementation of those models. Depending on the relationship of the system to the magic circle, there may be more or less sensitivity and tolerance to the differences that cause the mismatch. When representing a visual depiction of the synthetic environment as a 2d geographical map to human observers outside the magic circle, the various systems responsible may adopt different methods to distinguish between grassland and forest on that map. As long as each method is understandable by the perceiving audience, and that the two areas (grassland and forest) are distinguishable from each other, then the differences in those representations are an allowed-for tolerance. However, when information about the location of moving entities on that 2d map are presented to computer systems, that are perceiving and perhaps controlling the movement of those entities, then there is much less tolerance in how that information is represented to those computer systems.

3.3 Evaluating Reliable Representation

The evaluation of the reliable representation of a simulation is measured through verification and validation. In considering the validation of simulations that are intended to interact with human users, a survey of validation approaches that have existed for training simulations may be instructive at this point. The reliable representation of the simulation is important, whether through valid presentation of the synthetic environment, through valid interpretation of the inputs to the actors within the magic circle, or assessing the validity of the synthetic environment that is enabled – although as we saw in the previous section, there may be more or less tolerance to that validity depending on which participant the specific component is interacting with.

When conceived of from the perspective of respecting the magic circle, the view of there being two types of validity – one which is based on the logic and structure of the systems enabling the simulation, and the second is based on the interface of the simulation with those that are participating in the simulation – is in agreement with earlier efforts at classifying validity. Initially this was referred to as internal validity and external validity (Campbell and Stanley 1963). Efforts referring to the use of serious games for educational purposes have referred, more recently, to external validity as representational validity (Feinstein and Cannon 2001), and to internal validity as algorithmic validity (Wolfe and Jackson 1989). A broad variety of approaches to validity, and classification into whether they address internal validity or external validity, has been presented in (Feinstein and Cannon 2001).

The military simulation community, of course, has a wide variety of approaches to checking both verification and validation of simulation systems and the models they are based on. Although the approach of viewing a federation as the construct that provides both enablers and participants in the magic circle is not common in that community, there are nevertheless a number of approaches that are useful for checking both the internal validity (of the enabling components) and external validity (for the participants). A number of these have been cataloged in MSCO (2006), and have been categorized and described in terms of their relationship to the conceptual model (reliable representation of the referent) in Turnitsa (2012).

4 LVC FEDERATION STRUCTURE AND ROLES

An LVC federation consists of a broad number of enabling and participating systems. The many different participating federates – which may be virtual or constructive – as well as any live role players are only the beginning. The interoperability infrastructure that allows the exchange of information between these different federates also make up a large portion. In addition, the number of systems, that the audience may rely on in order to be a participant, which includes command and control (C2) systems, visualization systems, messaging and communications systems, and others – all make up another large portion. If the federation, and the synthetic environment it produces for the purpose of the participating audience are the be considered from the perspective of being a magic circle, then these many different parts have to be identified, and their contribution to the whole should be classified.

4.1 Identifying Federation Elements

In considering the different federation elements that can take part in the three different regions related to the magic circle for the purpose of enabling digital worlds (for games), there were two different types of elements identified – those that "enabled" the digital world, and those that "participated" in the digital world. In an LVC architecture, there are those same categories of elements, but also a third is introduced – those that "control" the synthetic environment. This third category includes technical controllers and operators of some of the enabling systems, for the purpose of ensuring that the synthetic environment operates in a certain way to achieve the training (or analysis) goals of the particular scenario being simulated. These controllers have the specific job of ensuring that the synthetic environment that enables the training situation (scenario) simultaneously satisfies the conditions required for successful transfer of training, as well as retaining a degree of similarity to such a scenario that might arise in real life, or the operational environment (Hays and Singer 1989). What those elements bring to the federation (enable, participate, control) is the role of the element. Identifying what the different types of elements exist, and whether they are live or artificial, will assist in categorizing those roles.

In trying to categorize the many different elements that make up the federation, a problem arises. That problem is that while these elements, which are often digital systems, exist in a federation, providing a portion of the synthetic environment, or enabling the participation of a portion of the actors in that environment, many of these systems were designed as commercial (or government) products that can stand alone. In that case, they often perform as almost all of the artificial participants listed here. So, rather than identify specific products (JCATS, GCCS, etc), instead the types of elements are listed. As an example of how many possible systems do participate, an overview of the just systems in the US JLVC Federation that receive data at the time of federation initialization, for instance, numbers in excess of 30 simulation systems (EDD 2013). The types of elements enumerated here are broken down into type based on what type of system they are, and whether they are live (human) or artificial (computer). These elements are based on the federation being used for training, if it were to be used for analysis, these elements might be slightly different.

- Trainees – Live element, generate (actor) input into the federation and receive output from the federation.
- Role Players – Live element, generate (actor) input into the federation alongside the Trainees, for the purpose of providing a more believable training experience.
- Instructor-Controllers – Live element, generate (actor and non-actor) input into the federation, for the purpose of ensuring that the scenario of the simulation proceeds in accordance with training objectives.
- Scenario Control – Live element, ensures that the required (non-actor) scenario elements are injected into the synthetic environment according to a schedule, typically a military scenario event listing (MSEL).
- C2 Systems – Artificial element, allows live elements to generate input to and receive output from the federation, and that the input and output are in the format they would be in an operational scenario, rather than a simulated training scenario.
- Federation Control – Live element, ensures the starting, stopping and synchronization of all federation elements, and also that the exchange of data between elements is available.
- Federation Network Infrastructure – Artificial element, the data network that allows traffic of synchronization data, input data, and output data to and from the federation elements.
- Tech Controllers – Live element, operating the many different artificial elements in the federation, ensuring that they function as required.
- Simulators – Artificial element, the state machine that takes the (actor and non-actor) input into the synthetic environment and turns them into output.
- Constructive Behavior Generators – Artificial element, generate (actor) input into the federation, based on some modeled or scripted behavior.
- Virtual Cockpit/Vehicle Interface – Artificial element, translating the physical actions of a trainee into (actor) input for the federation.

The distinction between live and artificial here is somewhat arbitrary, as in most cases live elements require artificial systems to interact with the federation, and artificial systems require live operators to allow their functionality. However, this list are those types of elements identified in the OVs and CVs of the JLVC2020 Architecture.

4.2 Identifying Roles

The roles that an element can take, with regard to the synthetic environment, are that it may enable that environment, it may participate in that environment, or it may control that environment. Enabling the environment means that the element, in some way, makes the synthetic environment possible. Participating in the environment, means that directions are sent to some actor (avatar) that exists in the synthetic environment, directing its actions. Controlling the environment means ensuring that Enabling and Participating elements are doing what they are required to do, and when they are required to do it, in order that a specific scenario is presented by the synthetic environment.

In addition to identifying their (enable, participant, control) role, an identification of how that role exists in regards to the three regions related to the magic circle, as they are describe above in section 3.1.

- Trainees – Participant. Trainees are in region three.
- Role Players – Participant. Role players are in region three.
- Instructor-Controllers – Participant and Controller. Instructor-controllers are in region two.
- Scenario Control – Enabler. Scenario Control personnel are in region two.

- C2 Systems – Enabler. C2 Systems are in region two.
- Federation Control – Controller. In region two.
- Federation Network Infrastructure – Enabling. In region two.
- Tech Controllers – Controller. In region two.
- Simulators – Enabling. In region two.
- Constructive Behavior Generators – Participant. In region three.
- Virtual Cockpit/Vehicle Interface – Enabling. Exist in region two.

As described earlier, participants (both live and artificial) have to operate across different regions, and this is assisted by enabling elements. The means that elements use to communicate with each other, and to exchange information (input, output, synchronization, control) is by transferring data from one element to another. Depending on the type of element, and the role that it is performing, that data exchange can be a source of different sorts of interoperability issues within the federation.

4.3 Sensitivity to the Circle for Data and Knowledge

If a participant in a simulation has, as a lusory goal, the desire to participate in the reliable representation of that simulation, and if that desire is to gain some information out of the experience, then the participant should have some expectation of having access to output from the synthetic environment, and also some expectation that the output data can be interpreted as information. If the setting is training, as is the case often with an LVC federation, then that information is desired to be the basis for knowledge (the results of the training, when the information that derives from the training experience can be interpreted into such a way that it can be applied generally, and not only to the scenario of the training simulation). This progression is the standard data-information-knowledge progression according to (Ackoff 1989). For this to happen, however, the various elements, of different types and different roles, have to participate in the federation, and help to create the reliable representation within the simulation scenario of an operational scenario.

The interoperability between different elements in the federation can have their potential for conceptual exchange of information described according to the levels of conceptual interoperability model (LCIM), which provides for a descriptive metric for how much conceptual value a data exchange can convey (Tolk, Turnitsa, and Diallo 2008). In looking at the various elements that were described as having interaction, and data exchange, then the LCIM can prove to be valuable.

5 FEDERATION ELEMENTS AND INTEROPERABILITY

As described in the preceding section, the requirements for interoperability efforts between different elements of a federation should follow techniques that allow for an adequate amount of conceptual expressiveness, so that the proper information can be interpreted from the data being exchanged. This becomes a requirement, based on the live participants lusory goal of reliable representation, to insure the ability to perceive information that can become knowledge. With that in mind, making application of the LCIM in order to support the data-information-knowledge progression, especially for command and control, can be seen in (Turnitsa and Tolk 2006). According to that, the presentation of knowledge generally requires systems to be interoperating via data that can be conceptually expressive at least to the semantic, if not pragmatic level. If that is not possible, then it may be helpful to understand why not by consider the dimensions of difference that a multi-model solution, such as the multiple elements of an LVC federation, might be experiencing.

An in depth understanding of the applicability of the LCIM model to interoperability issues can be gained from other sources (Tolk 2008), however as an aid to the reader, a brief explanation of the levels is presented here. The different levels are characterized as follows:

Level 0 Stand-alone systems have No Interoperability.

Level 1 On the level of Technical Interoperability, a communication protocol exists for exchanging data between participating systems. On this level, a communication infrastructure is established allowing systems to exchange bits and bytes, and the underlying networks and protocols are unambiguously defined.

Level 2 The Syntactic Interoperability level introduces a common structure to exchange information; i.e., a common data format is applied. On this level, a common protocol to structure the data is used; the format of the information exchange is unambiguously defined. This layer defines structure.

Level 3 If a common information exchange reference model is used, the level of Semantic Interoperability is reached. On this level, the meaning of the data is shared; the content of the information exchange requests are unambiguously defined. This layer defines (word) meaning.

Level 4 Pragmatic Interoperability is reached when the interoperating systems are aware of the methods and procedures that each system is employing. In other words, the use of the data – or the context of its application – is understood by the participating systems; the context in which the information is exchanged is unambiguously defined. This layer puts the (word) meaning into context.

Level 5 As a system operates on data over time, the state of that system will change, and this includes the assumptions and constraints that affect its data interchange. If systems have attained Dynamic Interoperability, they are able to comprehend the state changes that occur in the assumptions and constraints that each is making over time, and they are able to take advantage of those changes. When interested specifically in the effects of operations, this becomes increasingly important; the effect of the information exchange within the participating systems is unambiguously defined.

Level 6 Finally, if the conceptual model – i.e. the assumptions and constraints of the meaningful abstraction of reality – are aligned, the highest level of interoperability is reached: Conceptual Interoperability. This requires that conceptual models are documented based on engineering methods enabling their interpretation and evaluation by other engineers. In essence, this requires a "fully specified, but implementation independent model" as requested in (Davis and Anderson 2003); this is not simply text describing the conceptual idea.

The LCIM shows that a layered approach to support composable services is necessary. The WS standards described earlier are not able to manage all levels, in particular not with the M&S specific upper layers. It is worth mentioning, however, that the LCIM focuses on technical support by information systems, such as command and control information systems in the military context. As has been shown by others (Alberts and Hayes 2003), the organizational and social aspects are often even more important.

Composability of models (Page, Briggs, and Tufarolo 2004) is defined as the realm of the model and interoperability as the realm of the software implementation of the model. In addition, their research introduces integratability coping with the hardware-side and configuration side of connectivity. The author supports this categorization and recommends the following distinction when dealing with issues of simulation system interoperability, to include meaningful simulation-to-simulation system interoperation:

- Integratability contends with the physical/ technical realms of connections between systems, which include hardware and firmware, protocols, etc.
- Interoperability contends with the software- and implementation details of interoperations, including exchange of data elements based on a common data interpretation, etc.
- Composability contends with the alignment of issues on the modeling level. The underlying models are purposeful abstractions of reality used for the conceptualization being implemented by the resulting simulation systems.

This idea complements the LCIM. The LCIM has been successfully applied not only in the domain of Modeling & Simulation, but generally in model-based interoperability challenges.

5.1 Interoperability Issues for Heterogeneous Types of Elements

As the two different types of elements that have been introduced here are live and artificial, whenever there is interoperability between heterogeneous types of elements, it means that a human element is attempting to interoperate with an artificial element, or the reverse. The issues for interoperability here range from issues that are central to human-computer-interaction topics, all the way to issues that are central to natural-language-processing topics.

Some of the approaches to deal with interoperability at this level exist. They consist of ways to have the artificial system present information in a way that is meaningful to the live system, or the reverse. One example of an artificial system presenting information to a live system in a meaningful way, is for the system to display map information concerning military units using standard unit iconography, such as from the U.S. icon standard MIL-STD 2525B, or the NATO icon standard APP-6A. Another example, is for live systems that wish to communicate information (such as actions for actors in the synthetic environment), to formally organize that information via a data model that can be symbolically understood by the artificial system. This is done, experimentally, with systems such as Coalition Battle Management Language (CBML) and the Military Scenario Definition Language (MSDL). Yet another example is to devise some language that is symbolically understood by an artificial system, to be able to interpret artifacts that are employed by live systems. An example of this is to use an interpretive system such as Business Process Modeling Notation (BPMN) to describe live system work flow processes, such as doctrinal staff activities, so that those processes become actionable data for the artificial system.

Addressing such interoperability problems, against the scale of the LCIM, depends on which type of element is receiving (interpreting) the exchanged information. If a live element is receiving the element, then the exchange is likely to reach the (level 4) pragmatic level, especially if the live element is familiar with the normal behavior of the artificial element – the context of the exchange elements can be knowable by the live element, and therefor pragmatic exchange is possible. This is the basis for many cognitive models concerning human computer interaction. An example, intended as a single sample, and not necessarily superior to other such cognitive models (such as belief desire intention models, and so on), is the GOMS model (Card, Moran, and Newell 1983). The GOMS model relies on four elements in order to describe how the live element interacts with the artificial element. GOMS is an acronym, and consists of the following elements:

Goals – users goals, or in a more expansive definition, agent goals (allowing for artificial participant elements). This, if known by a partner element in some interoperability gives the frame, or context, in which to address the valuation of a semantic level item exchanged. If that valuation is done correctly, then pragmatic interoperability is achieved.

Operators – the individual user (or agent) actions that are done in order to interact with another element. These are the atomic activities that the element can perform, with another element. This may be, in our case, either directly for another element that is a system, or projected by use of a supporting element in an enabling role. Knowing what the operators are that a user selects, is essential to building a predictive model, which leads to pragmatic interoperability.

Methods – an individual user will likely choose some path towards achieving a goal. When that path includes using a system, for instance to direct actions for an actor in the synthetic environment, the sequence of individual operators selected together become a method. In such ways, pragmatic interoperability can be achieved by the correct application of predictive (stochastic prediction models, Bayesian prediction models, etc) techniques. As with operators, there is the possibility that the methods may consist of direct element – to – element interactions, or it may be supported by an enabling role element in between (such as a live participant choosing to enter a sequence of operators as actions to an actor in the synthetic environment), or some combination. If the total method sequence of operators is known, and if it is also know (or knowable through techniques) how it may change through the sequence in response to changing conditions in the synthetic environment, then dynamic interoperability can be achieved.

Select – A user may have a number of different methods available, and based on understanding of the current state of the synthetic environment (which is perceived, again, either directly from the elements enabling the environment, or via supporting elements that are translating such information from out of the circle, to where the receiving element is), they will make a selection of those methods. Understanding which of the methods may (or will) be selected, can be done with predictive models, however as with reaching dynamic interoperability at the methods stage, making such predictions enters a very large (perhaps unsolvable) solution space, when non-deterministic (such as live) elements are in play, or when the interaction of elements leads to complex situations.

5.2 Interoperability Issues for Heterogeneous Roles of Elements

As different elements also interact with the relative regions of the magic circle following different roles (enable, participant, control), there exist interoperability situations where there are challenges to the data being exchanged, but also some solutions that may already be applied. In considering the possible heterogeneous arrangements of the different element roles, if the exchange of data is directional, then there are six possible combinations (only three if the direction of the data is of no concern, or if it is assumed that both directions must be solved in each of the three cases). Of these, the most likely (those that are explicitly called out in the enumeration of element roles) are (1) the case where a control element must send and receive data with an enabling element, and (2) the case where an enabling element is sending and receiving data from a participating element.

In the case where a control element must send and receive data with an enabling element, if both elements are artificial, then the different roles do not matter, the ability to exchange meaningfully requires only a syntactic or (at most) semantic level of conceptual expressiveness between systems. An example solution that already exists for this case are the interoperability technologies that allow for the exchange of system control data, such as the High Level Architecture. Other technologies that allow for exchange of information between artificial elements for the purpose of supporting simulation architectures include the Distribute Information System (DIS), and the Test and Training Enabling Architecture (TENA). In situations where the elements are either themselves discrete event systems, or could be mapped to discrete event systems, then a number of different techniques exist to allow the DEVS formalism to support distributed interoperability exchange (Zeigler, Praehofer, and Kim 2000).

Recent developments, seeking to come up with an enabling architecture that accommodates, and perhaps eventually replaces, this wide variety of different enabling technologies for the exchange of semantic level interoperability information, is the Live Virtual Constructive Architectural Framework project. It has been underway, including a number of different spinoff projects, for a number of years now. An initial description of the goals can be found in Lutz (2009).

6 SUMMARY

The technique investigated in this paper begins with considering the literature describing the elements of play and participation in the play space of digital games. The name given to the cognitive play space that a player enters when engaging in play is the magic circle. Applying that concept to LVC federations, in lieu of traditional games played for fun, grants a different perspective, for the purpose of considering the various elements making up that federation. This perspective can be relied on to understand a variety of different aspects of those elements, such as the type of element and the role of element. Considering the interactions of those elements and how they can participate in relative regions of a magic circle for the users of an LVC federation simulation, helps to define and describe the required levels of conceptual expressiveness required for interoperability.

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