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AN ARCHITECTURE TO SIMULATE DIFFUSION PROCESSES IN MULTIPLEX DYNAMIC NETWORKS

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ABSTRACT

Dynamic Complex Systems have been analyzed using diffusion processes in multiplex networks, nevertheless, there are no well-established modeling and simulation (M&S) mechanisms for these applications. We present an architecture based on Network Theory, Agent-Based Modeling, and Discrete Event System Specifications (DEVS) to simulate diffusion processes in dynamic multiplex networks. The proposed architecture provides rigor and formalism to the study of diffusion processes in multiplex networks.

1 INTRODUCTION

Diffusion processes are models to represent the mechanisms by which a given object (i.e. a virus, an idea, etc.) is spread out in an environment from an area with a high concentration of the given object. The study of diffusion processes is useful in different domains. For instance, they can be used to understand how a disease spread through a population or how political ideas can be spread through the Social Networks.

There are different ways to study diffusion processes, most of them based on using different types of networks. They were initially modeled using networks with a single type of connection between entities, which could lead to misleading results. Generalizing diffusion processes from simplex to multiplex networks is not trivial and it is an open research field.

Generalizing the study of diffusion processes is important for studying Complex Systems. Many dynamic Complex Systems (such as Social Networks) have been analyzed using diffusion processes in multiplex networks, there are no well-established modeling and simulation (M&S) mechanisms for these applications, which poses some problems. For example, sometimes the model definition, its implementation, and the experiments conducted on the model are defined as a mix of software applications without clear separation of concerns, making it difficult to think about the models and validating the results.

In order to address these issues, this research provides a solution applying a formal M&S methodology to the study of dynamic Complex Systems: DEVS. We provide an architecture and a development process to study diffusion processes in multiplex dynamic networks based Network Theory, Agent-Based Modeling (ABM) and DEVS (Bouanan et al. 2016; Ruiz-Martin et al. 2016).

2 ARCHITECTURE

In figure 1a, we present an architecture to simulate diffusion processes in multiplex dynamic networks. Over this architecture, we define a development process for the whole modeling and simulation process.

The **Diffusion experiment data collection** is composed of all the requirements, the specifications, and all the data available from the problem or system we are interested in studying.

The **Network model** provides a formal representation of the relations among the components of the system. This model is formalized using Network Theory, and it can be implemented and stored in different formats (table, graph, XML). There is different software available to analyze properties of the network model: Gephi, Pajek, MuxViz, R, which includes a package for network analysis called igraph, etc.

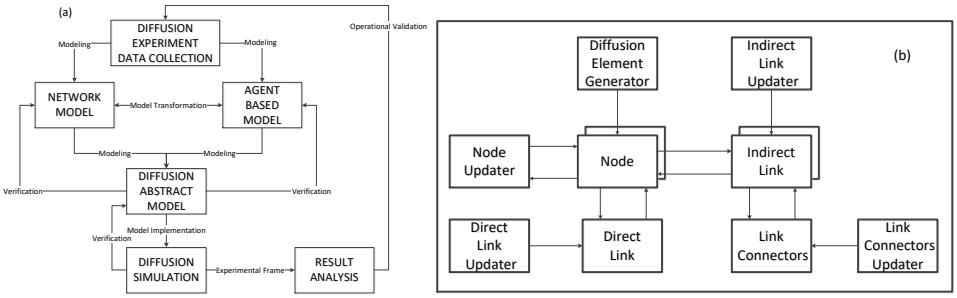

Figure 1. (a) Architecture to simulate diffusion processes in multiplex dynamic networks. (b) Diffusion Abstract model architecture

The **Agent-Based model** is a representation of the behavior of those ones in charge of the diffusion process, the objects they use for diffusing the element and the properties of the relationships among these objects. It is formalized using ABM concepts, and it can be implemented using different methods: DEVS, an XML file definition, or specific software platforms such as NetLogo, Repast, etc.

The **Diffusion Abstract model** is an abstract and formal representation of the diffusion experiment data that matches the elements in both the Network and Agent-Based models. It is formalized using any mathematical specification (in our case, DEVS). The Diffusion Abstract model is a generic container that follows the architecture depicted in figure 1b. The architecture is generic and it could be used to study different diffusion problems. The number of components used in the Diffusion Abstract model would depend on the type and characteristics of the problem we want to study.

The **Diffusion Simulation** component executes the Diffusion Abstract model. It can be implemented using a number of simulators (in our case, any DEVS simulator such as CD++, DEVSJava, CDBoost, etc.). Once all the components of the Diffusion Abstract model are implemented, the top model can be implemented by processing the information in the Network and Agent-Based models.

The **Result analysis** component represents the process of analyzing the simulation results provided by the Diffusion simulation component. The analysis process can be carried using different statistical analysis and data visualization tools such as R, PowerBI or any tool available for big data analysis.

3 CONCLUSIONS

We presented an architecture to simulate diffusion processes in multiplex networks. The main advantages of the proposed architecture are as follows. Different scenarios and network configurations can be run just updating the model parameters. Moreover, there is no restriction on the diffusion behavior of the agents or if different agents have very different behavior. We improve reusability (since the behavior of the agents and objects are separated, we can reuse these models for the study of other problems). Using four models to update the properties of the components, allows us to simulate diffusion processes where the topology or characteristics of the network change over time. We can update the network topology and the behavior of both the nodes and the links at runtime without modifying the simulation model.

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