Discrete Event Simulation and Dynamical Systems: A study of art

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***Abstract* — This work aims to study two simulation methods, based on techniques of Dynamical Systems and Discrete Event Systems. Each of these techniques has its advantages and disadvantages being that the designer is who should assess the best method to apply them in a given system. The bibliographical study was conducted to investigate the characteristics and the particular potential of each methodology, aiming to apply it in building simulation tools.**

Keywords — Methodologies, Dynamical Systems, Discrete Event, Simulation.

I. INTRODUCTION

Computer simulation is a powerful tool that can help the better understanding of the operating systems in general [2]. Through simulation, real systems can be studied in a dynamic and flexible manner, allowing changes of various aspects can be easily evaluated without a physical experimental setup. This flexibility allows adjust project parameters, aiming improve system performance as a whole and minimizing costs. Some of the disadvantages of the simulations are related to the freedom of the designer to model a system, can he model incoherent concepts compared with reality.

Aiming to design simulation tools for systems, each time more efficient and reliable, the use of techniques related to Discrete Event Systems (DES) and System Dynamics (SD) is studied. This study identifies the strengths and weaknesses of each simulation methodology, allowing a detailed comparison of both and identifying yours possibilities of applications and contributions.

In general, the simulation of Systems Dynamics SD and Discrete Event (DES) analyze the behavior of the system over time, in different perspectives, interpreting real systems [4].

SD is for system coupled, non-linear, with differential equations of first-order or integrals. Assumes a high degree of aggregation of the objects to be modeled, which are represented by their quantities, without regard to all individual properties. Such systems emphasize a continuous view, that is, looking beyond individual events, but the structure as a whole

The fundamental concepts of DES are entities, attributes, events, resources, queues and time. The time is an essential component of the method, because the treatment enables the use of the data for describing the time for each event, particularly if they change over time.

In this work is presented in section 2 DES methodology, in section 3 is treated the SD methodology, in section 4 are compared the two techniques, and in section 5 is modeled an example of each type of methodology adopted. Finally, in section 6 there is a conclusion of the proposed study.

II. DISCRETE EVENT SIMULATION (DES)

A system can be defined as a set of entities that interact to perform an operation [4].

The DES methodology as mentioned in the introduction model a system as it evolves over time, representing instant changes of its state variables in separate points in time corresponding to the vision of flow of entities. Thus the process of creating a DES model starts with a description of a process map or flow chart, which is time consuming to analyze the distribution of data to validate the model statistically.

His modeling consists of queues network and entities, activities and resources [6] through which the entities are updated with state changes occurring at discrete points of the time, through "events", where the integration of elements of technique is made through a calendar of events

One of the potential that DES has, is its ability to describe systems more complex, including stochastic elements, where they cannot easily be described by mathematical or analytical models [8].

One of the limitations of DES is regarding the system stability, which does not validate methodology [24]. The stability is referred to on the concept of bounded input-bounded-output (BIBO), that is, limited output by a limited input, being dependent on external and internal random processes, making it difficult the definition of modeling.

The main feature of the methodology are the events, where that the changes occur through them. The counting of the duration of these events is made from probability distributions. The construction of the model involves the identification and representation of resources, entities, logic and flow of these entities. The randomness of the processes involved in the model and the linear relationship between the most of variables modeled are characteristic of this technique.

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III. SYSTEM DYNAMICS (SD)

System Dynamics (SD) was proposed by [9], as an analytical modeling methodology with basic design centered on the theory of control of the feedback, being its main characteristic [6].

SD is defined as a set of elements which interact continuously over time to form a unified whole, providing an approach that has an integrative perspective of the system. It is dependent, principally, on the definition of the feedback loops, well suited for modeling of continuous processes, systems in which changes in behavior occur in a nonlinear fashion, so, in most of the cases difficult to quantify.

According [10], [11], SD is a methodology that improve the understanding of complex systems, through of capture and presentation of user causal diagrams, feedback loops and flow, and also a mechanism for interaction and delay between components of the system. The feedback structures come through a series of equations which are often non-linear. Although its randomness is not normally considered, or when considered, is simplified the delay structures, unlike of the loops and feedback, which also exist in DES approach, that are not explicitly featured in the model.

Can verify that the methodology combines two aspects: qualitative and quantitative, with the objective to enhance understanding of a problem and the relationships between the variables that are relevant [3], presenting a flexibility of combination of these two aspects. Aiming a better understanding of the system, general data and numerical extrapolations can be considered, allowing the insertion of less tangible variables in the model [12].

Briefly, for the SD, the construction of the feedback loops and the representation of dynamic delays are important parameters for the correct modeling of a system.

IV. COMPARISON BETWEEN DES AND SD

The methodologies SD and DES are compared based in investigations already done by researchers of area. They are considered technical differences related to the way how to make the representation and interpretation of systems [3], [4], [12], [13].

Generally, SD is most used in the analysis of the complete process of the system, thus more suitable for modeling of continuous processes, high degree of aggregation of variables and explicit causal relationships between variables for the dynamic behavior of the system.

While DES is more focused on partial processes and can model both continuous processes and discrete, however, it is more suitable for modeling discrete processes.

According [14], was identified that the SD models represent closed and non-linear processes, while DES models represent open linear process.

The applicability of SD is defined by its feedback structures that treats of the determination of the causal relationships between variables of the model, thus, explicit through of a series of nonlinear equations [15].

Was argued about the great potential of DES in representing systems of high degree of complexity of details, considering the refinement of data and analysis of the variables over time [1], [4], [12].

Was also stated that DES is more appropriate to model systems in which the system will change significantly when a specific variable reaches a certain threshold level [16], like as a production line or call center. Seen that SD is better when the system reacts of fashion gradual, as in an industrial hydraulic system, by controlling the maximum pressure limit of a valve.

was alleged that if the system is large, the best choice must be SD, due to the complexity of the DES model increase exponentially with the system size [3], [17].

V. MODELING

For the representation of the use of techniques defined, was used the MATLAB® software, where numerical calculations can be used interactively. Your data structure is based on arrays, and can have real and complex elements, having a vast set of functions of generic character as well as several libraries of functions that expand its capabilities in specific applications.

The used libraries are the Communications System ™ that is designed to design, simulate and analyze systems, model systems can dynamic communications, DSP™ System that provides the ability to design and simulate signal processing systems, and that Simulink® is a block diagram environment for the simulation of multiple domains, supporting system-level design for modeling and simulation of dynamic systems.

And another library is SimEvents, with a discrete event simulation engine and components to develop system models oriented to specific events.

The model presented incorporates both simulation methodologies for modeling flow discrete event (blue) and dynamics for continuous flow (red). For this modeling was used Simulink simulation environment of Matlab software, in its version 8.3 64-bit (2014a)

The model consists of a sine wave model – CW – with your view in discrete event flow domain and continuous flow domain.

Its most basic form as a function of time (t) is as follows:

$$y(t) = A\sin(2\pi ft + \varphi) = A\sin(\omega t + \varphi)$$

At where:

A = the amplitude, the peak deviation of the zero-function.

f = common frequency, the number of fluctuations (cycles) that occur every second time.

$\omega = 2\pi f$, angular frequency, rate of change of the function argument in units of radians per second.

φ = Phase, specifies in radians, which in its oscillation cycle is t = 0.

When φ is nonzero, the waveform appears to be shifted in time by the amount φ/seconds. A negative value represents a delay, and a positive value represents a breakthrough.

CW (Continuous Wave) is the simplest form of modulation. The output of the transmitter is switched on and off, typically to form the characters of the Morse code, making a simple analogy.

In telecommunications, continuous wave or continuous waveform (CW) is an electromagnetic wave that has constant amplitude and frequency. The information is carried in the rhythm and space with which the signal is sent.

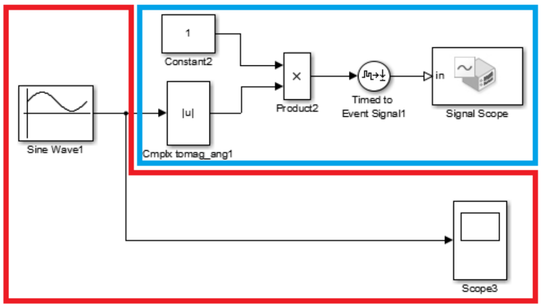

Figure 01

In continuous modeling according to SD, the model uses the frequency of the sine wave on 2*pi*1x10^{8} Hz, with amplitude 1x10^{-8} and bias 1x10^{-8}, and simulated time equal to 1x10^{-8}.

As for modeling discrete event according to DES, it is occurred performing the calculation of the product of the magnitude of the sinusoidal signal with a value of constant 1, to then, this result be converted into events.

In this way, both the sine wave in the discrete flow domain (Figure 02) as the continuous flow domain (Figure 03) is displayed according to the methodologies in study.

In Figure 02, it is the discrete modeling, where it is possible to see that 51 events form created with the specifications and features of the CW, and in Figure 03 to continuous modeling.

In this way, becomes clearer the occurrence of events at discrete points of time according as discrete flow CW flows over the simulated time, and similarly the continuous flow of the same behaving according to the technique SD.

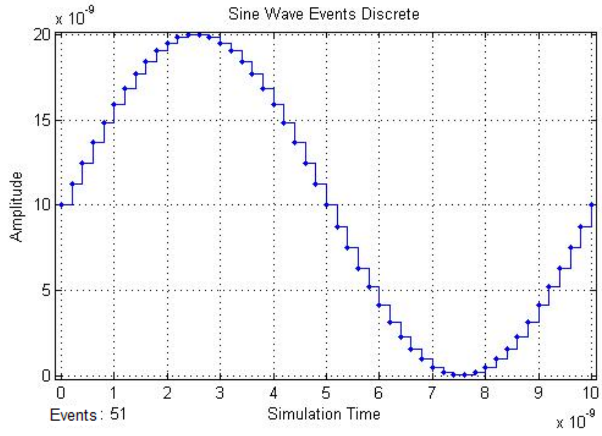

Figure 02

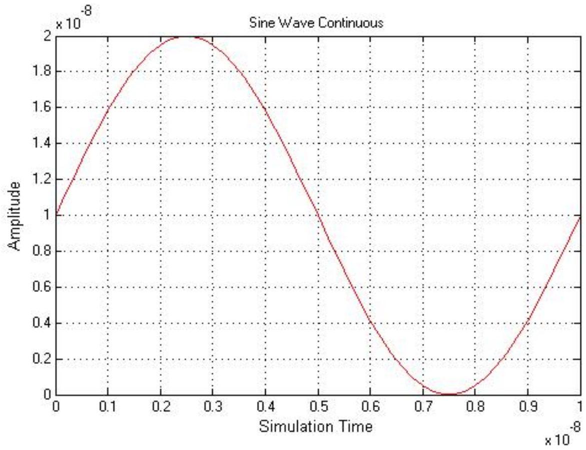

Figure 03

VI. CONCLUSIONS

The methods SD or DES were created to model different problems in systems in general. With the objective of choose the most appropriate method, the key issue should be related to the type of model that best represents the system under study, and for what purpose will be used.

DES is a technique with properties to model a physical system that has changes at precise points in the simulated time, so both the nature of the state change and the time at which the change occurs require detailed description. The technique describes the behavior of a system as a series of well defined and ordered events, working well in virtually any process where there is variability and limited resources.

SD is a simulation technique that uses equational models, often of physical systems, that do not accurately depict time and pre-defined states. His modeling does not require the explicit representation of the relations of state and time.

In contrast, there are specific systems that must be modeled with SD or DES.

From its characteristics, the techniques studied become appropriate and suitable for different types of systems and different types of problems, as can also be understood on the basis of their capabilities and limitations, such as the applicability of SD for larger systems and DES for systems lower

May also be considered the fact that the complexity involved in the SD model increase linearly with system size, while that the complexity of the model DES increases exponentially [7].

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