Tutorial: Colored Petri Nets based Modeling and Simulation in Healthcare

Duration: Half-day
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Healthcare is one of the fastest growing sectors that can benefit from broad adoption of modeling and simulation approaches. Healthcare spending in the US is expected to grow at a faster than ever pace over the next decade. With this growth come some challenges. Specifically, modern healthcare systems are increasingly under pressure to improve patient safety, operations, security, and delivery of care against heightened expectations and constrained resources. Unlike, say manufacturing, where adoption of traditional discrete event simulation approaches have yielded good returns in terms of understanding cost and benefits, healthcare simulation needs are much more complex.

From a systems point of view, healthcare is a cyber, physical, biological, social, economic system of systems with many complex interactions and decision points. The workings of this system not only include activities at individual cellular level but also the interactions that are central to national healthcare information network. Thus, if we were to hope for a wider adoption and institutionalization of modeling and simulation healthcare, we need a flexible framework that can be used both at micro as well as macro level with ease and does not need to be segregated into agent-based vs. discrete event vs. system dynamics etc. Towards this end, we propose adoption of Colored Petri Nets (CPNs) based modeling and simulation for healthcare.

Colored Petri Nets is a graphical modeling language suitable for modeling systems that are inherently distributed, concurrent, with resource constraints exhibiting both synchronous and asynchronous communications. One attraction of CPNs is that the basic vocabulary is small which renders them very flexible in terms of application domains for modeling. CPNs can be used with ease not only to model patient workflow, business processes, and network communications but also signaling pathways at the cellular level, human agent behaviors, and socio-economic systems. From a practical applications point of view, CPNs support a mechanism of modules that allows one to construct models of large systems in a hierarchical manner. The hierarchy and module concept of CPNs allow different levels of abstraction that are inherent in most system of systems such as healthcare. The graphical representation makes it easy to see the basic structure of a complex CPN model, i.e., understand how the individual subsystems interact with each other. CPN models are built using CPN Tools, which is a graphical software tool for creating, editing, simulating, and analyzing models. It has a graphical editor that allows the user to create and layout the different system components and their interconnections and behaviors at different levels of details.

This tutorial will introduce the audience to basics of CPNs as well as CPN Tools by using a *Health and Wellness Neighborhood* as a target for modeling and simulation. We define a Health and Wellness Neighborhood to consist of individual homes as well as elderly care facilities. Each unit of this neighborhood may contain a multitude of monitoring devices. These devices may communicate via wired or wireless (including cellular) networks. As has been noted by the Department of Health and Human Services (HHS), the ability for clinicians to monitor patients

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based on information, including activities of daily living measurements, captured remotely could be a key enabler for the management and control of chronic health problems and to maintain wellness for aging populations. For disease management and aging populations, Patient Care Devices (or PCDs) have become common personal health tools. Most modern PCDs are wireless, to promote patient ambulation. Wireless devices have complex interactions and potential interdependencies, however. Unfortunately, wireless PCDs currently are often tested in isolation from other devices or electronic medical record systems, and without regard to the user's living environment or device or algorithm-specific concerns. Using modeling and simulation one can get definitive answers to patient safety issues such as: How many patients can be supported in a single building, What is a prediction for the number alarms based on a specific population and their devices, What is the maximum number of devices or patients that can be supported in a neighborhood, etc.

We will illustrate the key ideas by means of numerous examples and live demonstrations that emphasize practical applications of CPNs and CPN Tools. It requires no prior familiarity with CPNs, system design and analysis, modeling, simulation, or any particular computer language. Its emphasis is on the practical, hands-on use of CPN Tools to build and execute CPN models.

Presenter Biography:

Vijay Gehlot is a faculty in the department of Computing Sciences at Villanova University. He is also has an appointment as a research faculty with Villanova's Center of Excellence in Enterprise Technology (CEET). He received his PhD in Computer and Information Science from the University of Pennsylvania. His published work has addressed both theoretical and practical aspects of Petri Nets. His current research focus is applications of Colored Petri Nets (CPNs) in modeling and analysis of systems.

Elliot B. Sloane is an adjunct faculty of Computing Sciences at Villanova University and a research faculty with Villanova's Center of Excellence in Enterprise Technology (CEET). He is also the Co-Founder and Executive Director of the Center for Healthcare Information Research and Policy (CHIRP). He received his PhD in Information Science and Technology from Drexel University. His research interests include improving patient care using Health Informatics and advanced Health Technology Management solutions. His published work includes applications of CPN modeling and simulation in healthcare domain.

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