Applying STAMP with Petri Nets

Analyzing the safety of a socio-technical system using Colored Petri Nets and STAMP

by T.W. Wijburg
& R.J. de Boer

Hogeschool van Amsterdam
Amsterdam University of Applied Sciences

What makes CPN suitable for the application of STAMP to a socio-technical system?

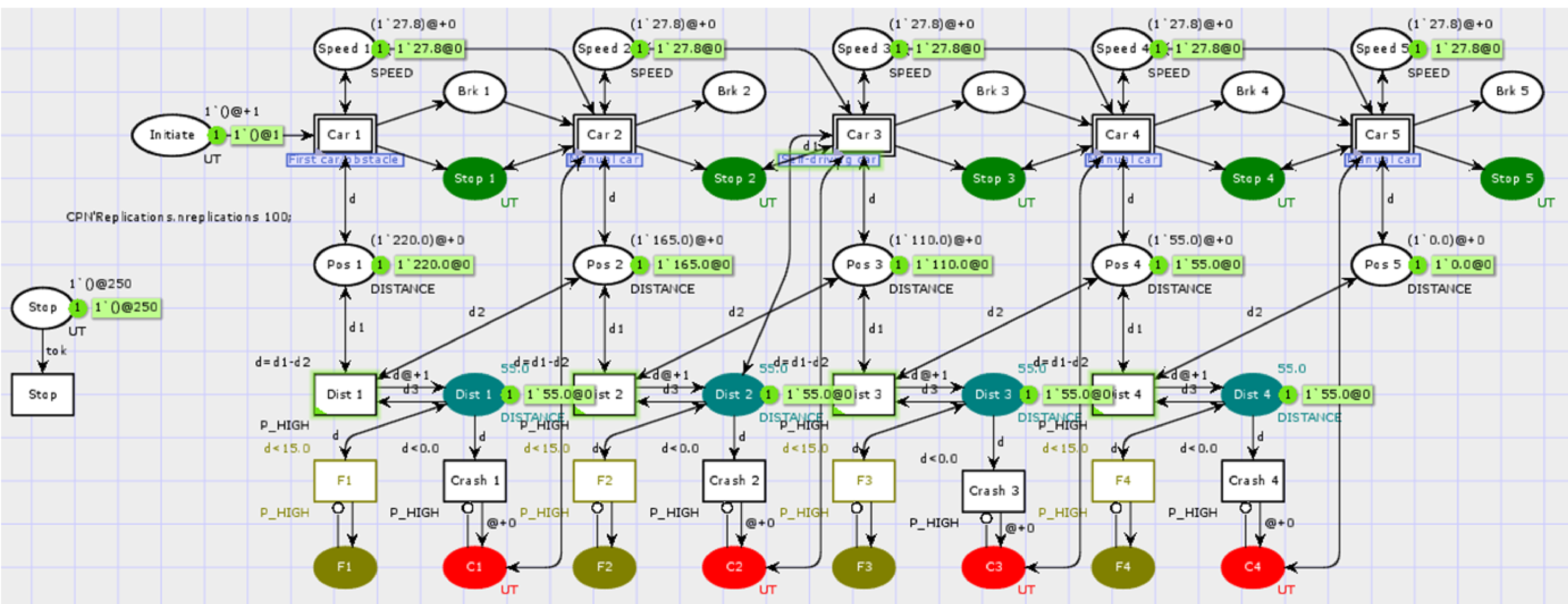
Colored Petri Nets (CPN) and the CPN Tools software offer a number of features that are very relevant and valuable for STAMP:

- Ability to model complex systems with various components and subcomponents
- Dynamic evolution over time that is dependent on deterministic and/or probabilistic interactions
- Separate step and time counters, meaning that multiple actions can occur in a certain sequence within one timeframe
- Unforeseen sequences of interactions can lead to different and unexpected outcomes if the simulation is repeated multiple times

To determine whether the theory holds up in practical applications, an experiment was performed using a CPN model of convoy consisting of manually driven and self-driving cars.

Why cars?

The topic of self-driving cars and their integration with traditional vehicles is a very current and relevant one. More importantly, scenarios such as the one that was modelled are great examples of situations in which STAMP is a valuable (and arguably even essential) tool.



This diagram corresponds to an overview of the system (the convoy) as modelled in CPN Tools. The full model consists of the superpage—as shown above—and one subpage per vehicle. The superpage allows for the interconnection of the various cars and houses the modules that calculate the distance between the cars, as well as the crash and 15m detection loops. The rest of the calculations occur within subpages, which contain the physics model, the driver or sensor loop and the braking behavior algorithm for each vehicle.

Another use for CPN: elevator congestion

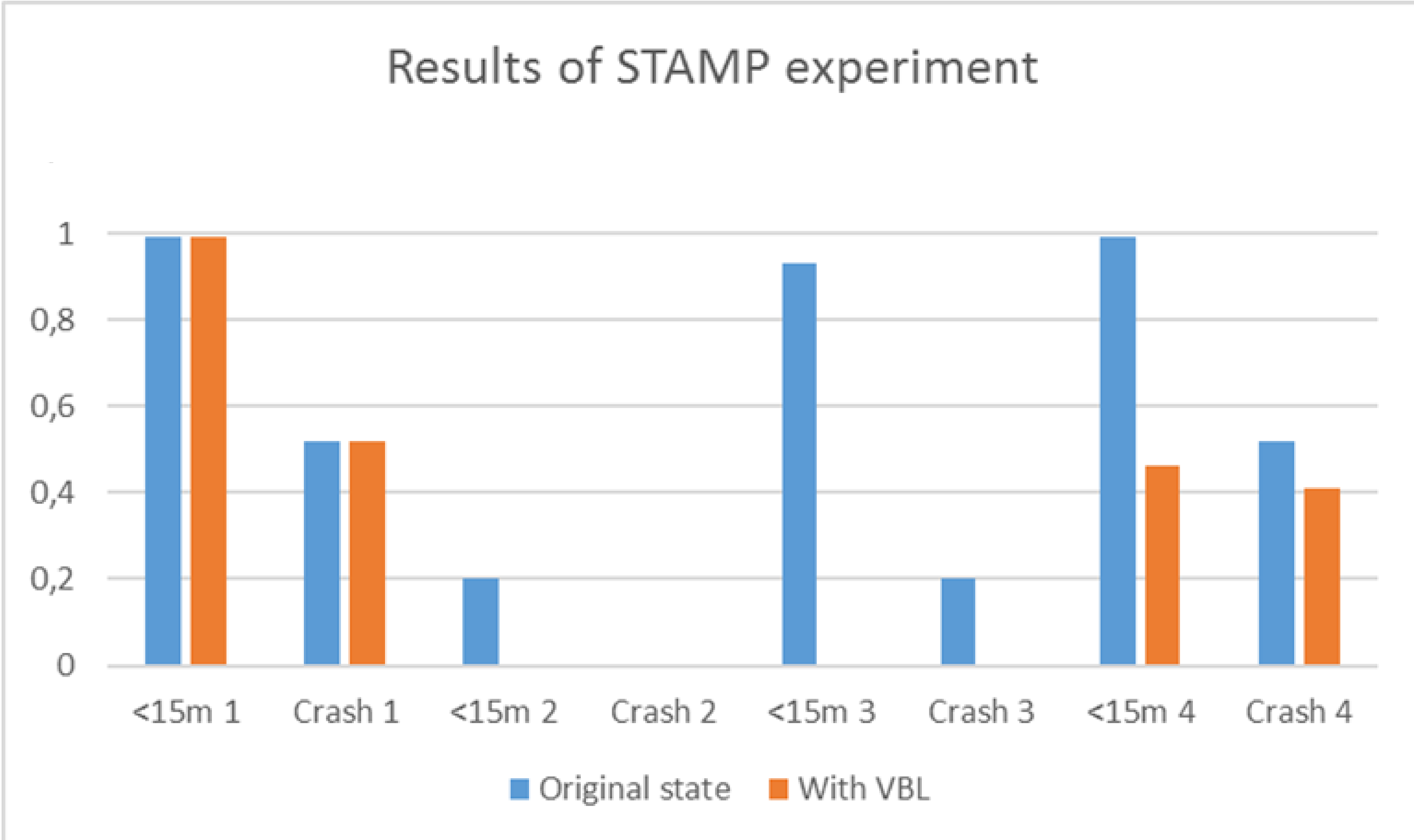
While familiarizing himself with CPN Tools, the student also performed another experiment: if the Leeuwenburg building's elevator system is modified to prevent people from taking rides to the first three floors, could this help solve the congestion problem during rush hours?

As with the cars, the question could be answered positively, demonstrating the value of CPN modelling in other situations as well.

The experiment

In this experiment, five cars drive along a straight road at 100km/h with two seconds of separation between them, when the foremost car slams on the brakes; the effect on the rest of the convoy is measured (i.e. which cars crash, and which cars get within 15 meters of each other). Then, the cars are equipped with **Virtual Braking Lights (VBLs)**, fictional devices that let the drivers/sensors detect what is happening two positions ahead of them; again, the effects of a sudden braking action are recorded.

It should be noted that in both cases, a hundred simulation runs are performed and their results compiled. In the graph below, 1.0 corresponds to an event that occurred on each of the hundred runs, while 0.0 corresponds to an event that never occurred.



The experiment demonstrates the effectiveness of CPN when using STAMP to analyze this type of situation. Not only can the graph above be used to clearly observe the impact of the modification on the system, the results can be used to make a number of interesting observations and conclusions. For instance, it was found that programming the self-diving cars to have a relatively mild and progressive reaction to the VBLs and braking lights has a substantial positive impact on the overall safety of the system.

Challenges and disadvantages

It was found that Petri Nets can be difficult to create and interpret. A thorough understanding of the SML programing language is required to use some of the advanced functionalities. In particular, extracting numerical data like the distance between the cars was found to be impossible without resorting to manual coding, so a workaround had to be used (the 15m markers).

References:

Leveson, N. G. (2011). Engineering a Safer World. Cambridge, MA: The MIT Press.

The CPN Group. (2016, 4 1). Retrieved from CPN Tools: http://cpntools.org/

van der Aalst, W., & Stahl, C. (2011). Modeling Business Processes - A Petri Net-Oriented Approach. Cambridge, MA: The MIT Press.