ROBUSTNESS COMPUTATION OF DYNAMIC CONTROLLABILITY IN PROBABILISTIC TEMPORAL NETWORKS WITH ORDINARY DISTRIBUTIONS. M. Saint-Guillain[1], T. S. Vaquero[2], J. Agrawal[2], S. Chien[2], [1]Université Catholique de Louvain (Place de l'Université 1, 1348 Louvain-la-Neuve, Belgium), [2]Jet Propulsion Laboratory, California Institute of Technology (4800 Oak Grove Drive Pasadena, CA 91109 USA).

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Introduction: Temporal networks formalize the arrangement and inter-dependencies of tasks, or activities, that compose an operational project. In a simple temporal network (STN), activities are modeled as a finite set of time events. In practice, some activity durations, considered as contingent, remain unknown beforehand. In the case some stochastic knowledge on the uncertain durations exists, then one can model it as(estimated) probability distributions, leading to the extending concept of probabilistic STN, or PSTN. Solving a STN then amounts at finding an assignment of time values to events that fulfils all the constraints between events. Whenever such a schedule exists, a network is said to be controllable. When the operational assumptions enable it, the schedule may be dynamically constructed, the time values being assigned as durations are observed. Yet, even under dynamic decision, due to unfortunate durations a network may reveal uncontrollable. How likely is a PSTN to lead to a successful execution?

Provided some stochastic knowledge on contingent activity durations, the degree of dynamic controllability (DDC) of a PSTN can be quantified, as the success probability of a given task network. The current literature proposes DDC computation methods for PSTNs that involve *unimodal distributions only* (uniform or normal), or exploit Monte Carlo simulation, which admits ordinary distributions. On both cases, the computed DDC values are *approximations* only, without guarantee on the true robustness of the network.

Contributions: We propose the first efficient DDC (*aka.* robustness) computation method capable of dealing with PSTNs with *any possible ordinary probability distributions* (*i.e.* non-parametric, non-symmetric, multimodal, or even hand-made). Our method computes *a valid lower bound on the exact* DDC of a PSTN. Under a specific dispatching protocol, it computes the *exact* execution success probability. Furthermore, it enables to compute a lower bound on each task's own success probability within that network, which can be mapped to activity temporal brittleness. On the application side, we propose a new method for identifying structural bottlenecks in temporal brittleness analysis, applied to the real case study of the Mars 2020 rover's task networks.

Illustrative example of rover operations: An hypothetical example of Mars rovers PSTN is depicted in Fig. 1. Each rover has three activities in sequence: drive towards a science site, experiment, and relay results to an orbiter. A special time point $t_0 = 0$ represents the beginning of the operations. Time events are linked by temporal constraints, either controllable or contingent. In our example, the rovers work independently during their driving and science activities. They do not coordinate until the communication time window, which strictly happens between time 600 to 700. Communication tasks cannot overlap, and *Rover1* is chosen to relay first. However, duration of driving and experimental activities are highly uncertain. In practice, distributions can be estimated from historical observations. Even an inaccurate stochastic knowledge, e.g. obtained accurate observations, leads to valuable results in practice (as illustrated in [2] for Mars-inspired operations). In Fig. 1, distribution $X_{1,2}$ describes the stochastic duration of driving activity (t_1,t_2), encoded in the PSTN as a contingent constraint.

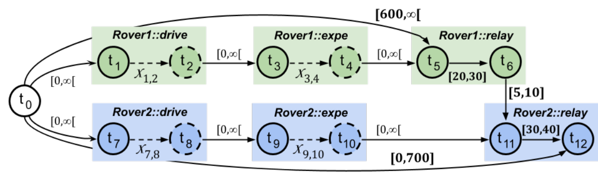

Figure 1: A simplified hypothetical sol on Mars for two planetary rovers, encoded as a PSTN. Bold: controllable. Dashed: contingent.

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References: [1] M. Saint-Guillain, T. S. Vaquero, J. Agrawal, S. Chien (2020), IJCAI, 4168-4175. [2] M. Saint-Guillain (2019), ICAPS, 368-376.