Multi-agent Temporal Planning under Uncertainty: current challenges of temporal consistency checking problems

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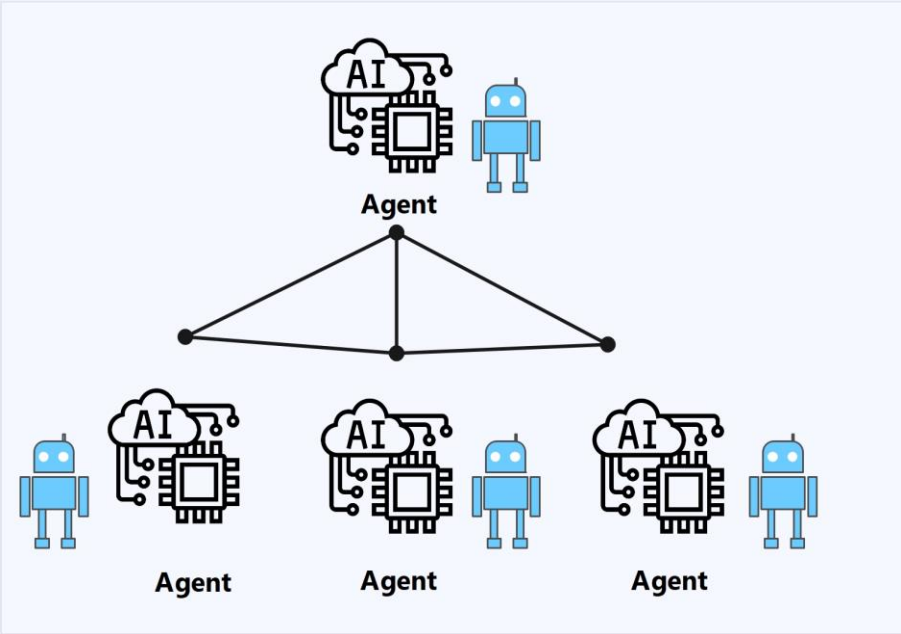
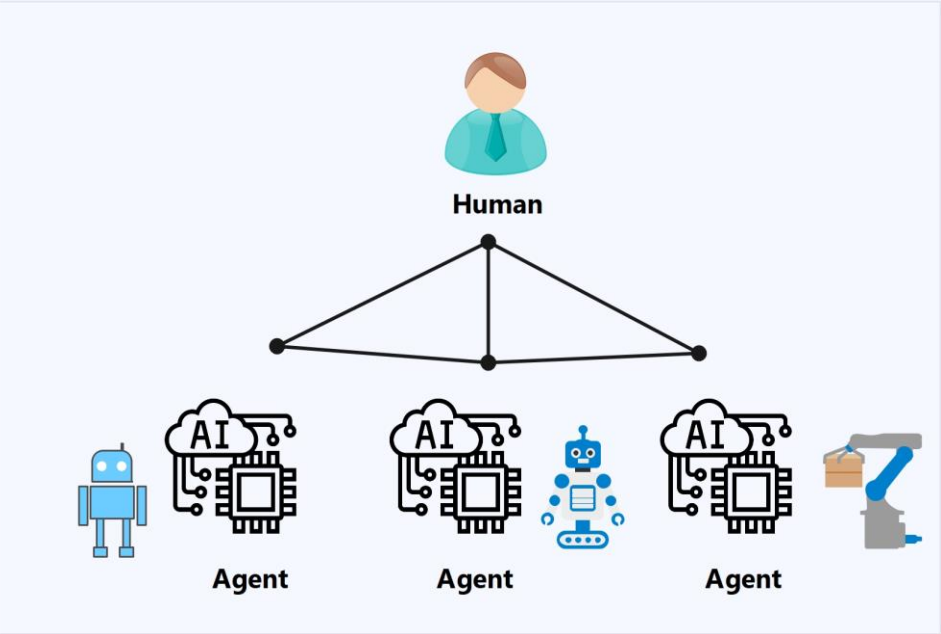
Context

Context

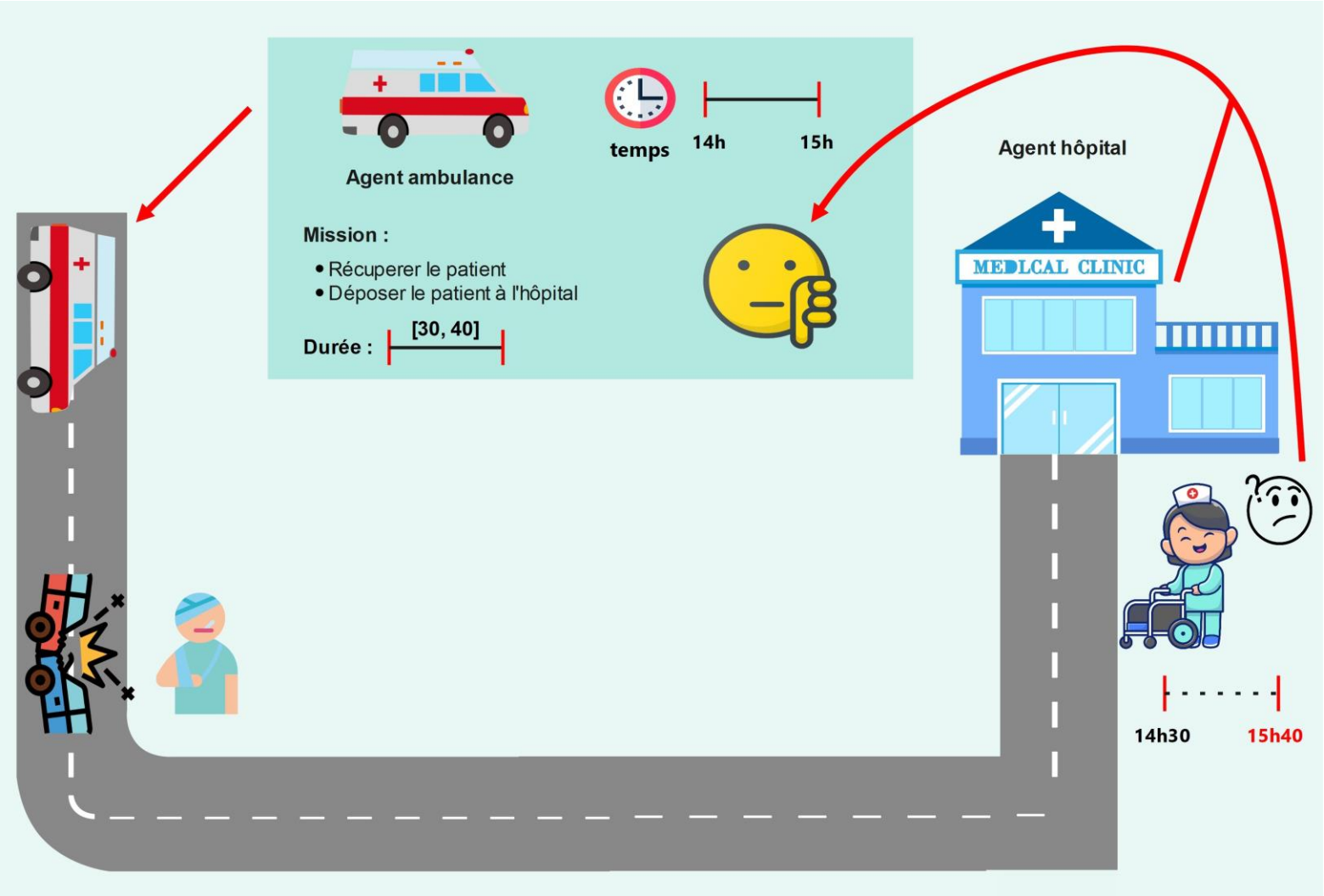


homogeneous

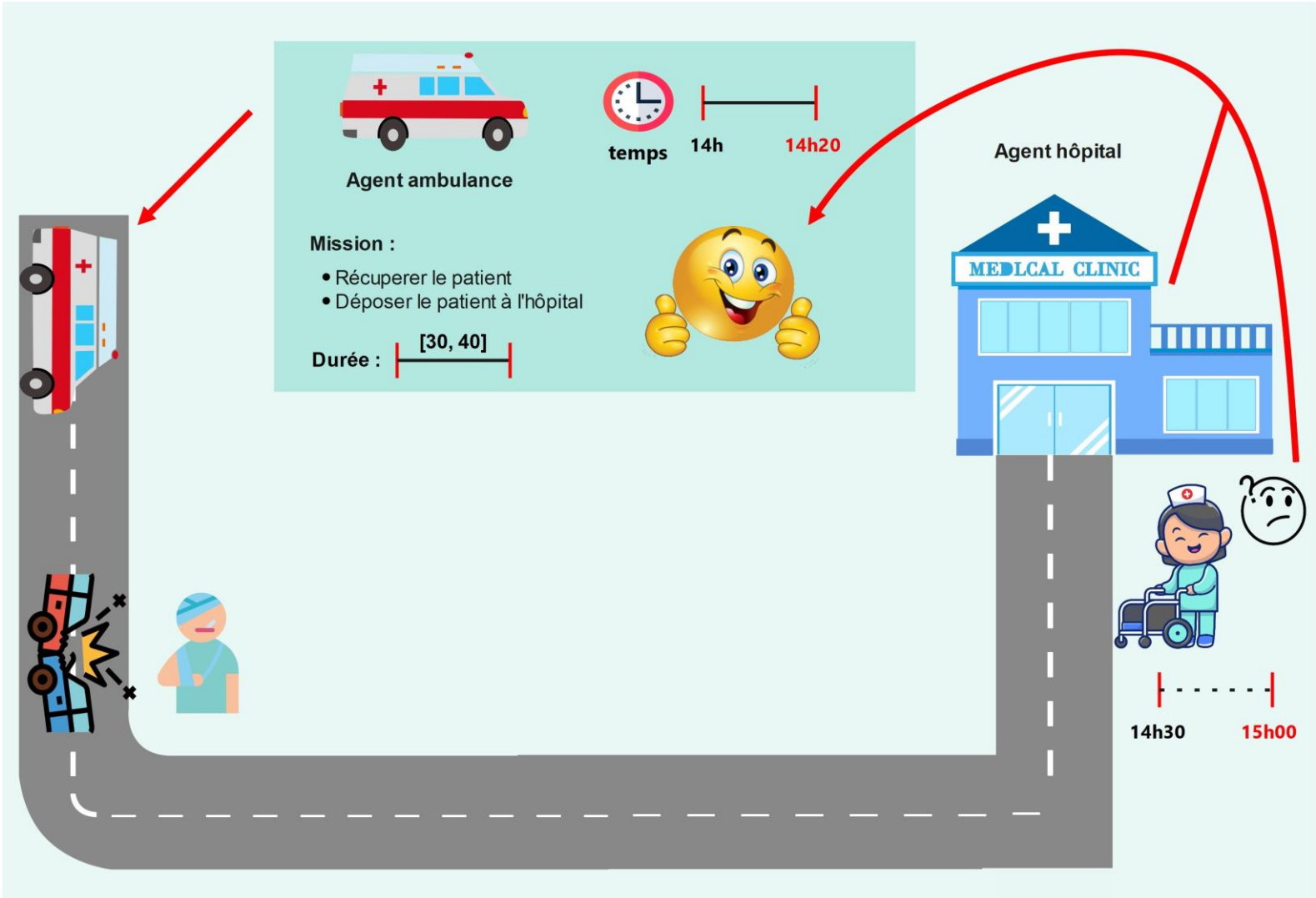


heterogeneous

Context


Agent ambulance
temps
14h
15h
Mission :
• Récuperer le patient
• Déposer le patient à l'hôpital
Durée :
[30, 40]
Agent hôpital
MEDLCAL CLINIC
14h30
15h40

Context


Agent ambulance
temps
14h
14h20
Mission :
• Récuperer le patient
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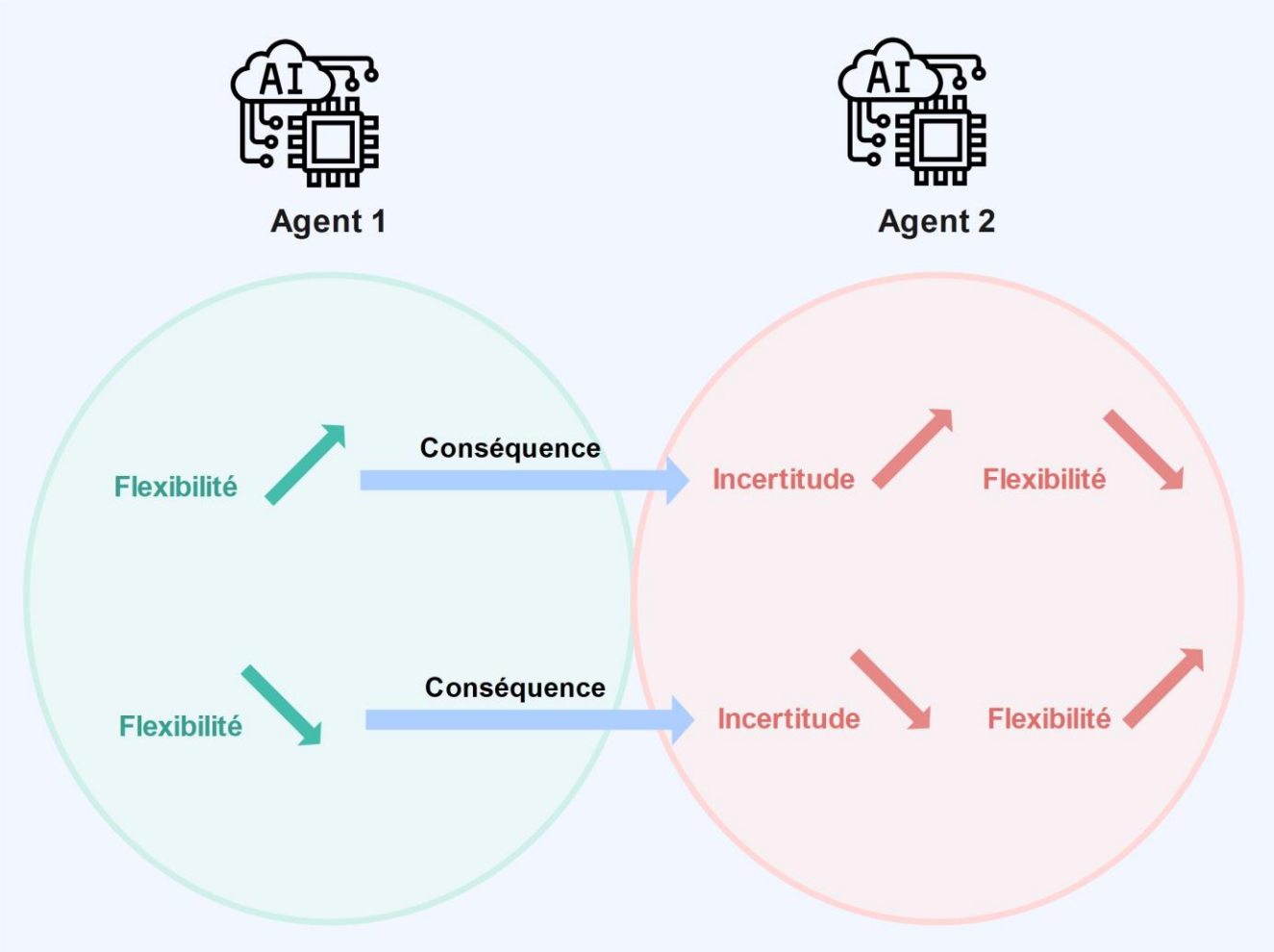
Durée :
[30, 40]
Agent hôpital
MEDLCAL CLINIC
14h30
15h00

Context

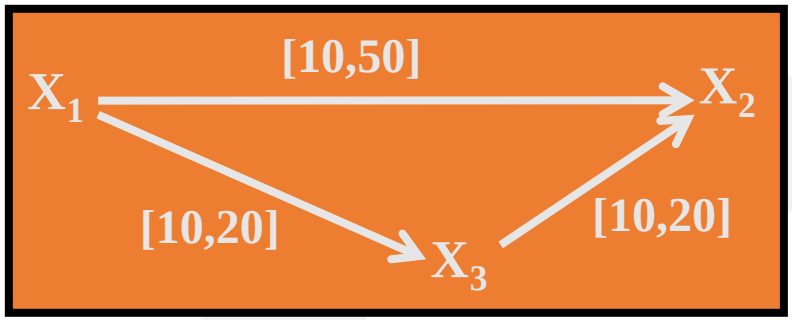

AI
Agent 1
AI
Agent 2
Flexibilité
Conséquence
Incertitude
Flexibilité
Flexibilité
Conséquence
Incertitude
Flexibilité

Background

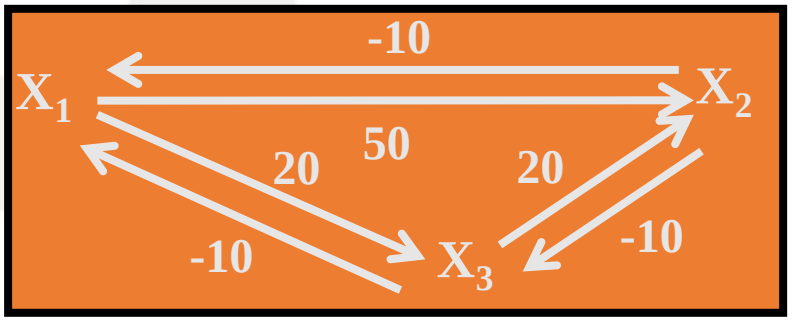
Background

STN (Simple Temporal Network with Uncertainty) **is consistent** if there exist an assignment of the time-point that satisfies all the constraints

STN = (V, E)



Distance graph



Polynomial propagation type algorithm in $O(n^3)$:

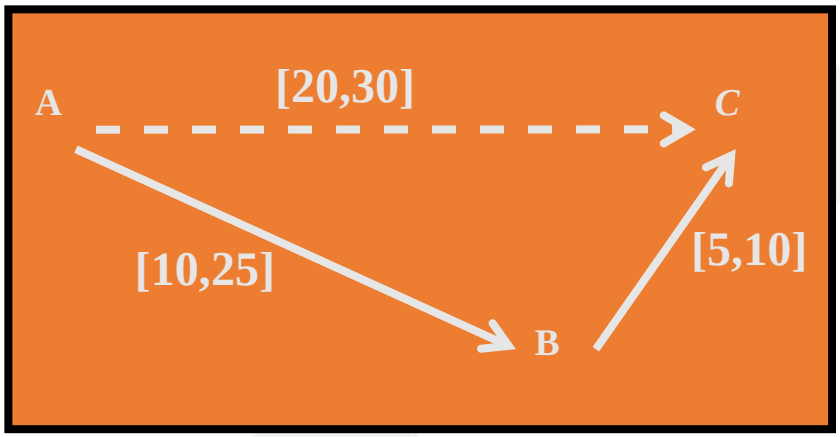
- Path consistency
- Floyd-Warshall

Negative cycle = inconsistency

Background

Simple Temporal Network with Uncertainty(STNU)
[Vidal et al., 1999, Journal of Experimental & Theoretical Artificial Intelligence]

- nodes = Time-points; Arcs = duration : **controllable** et **uncontrollable**



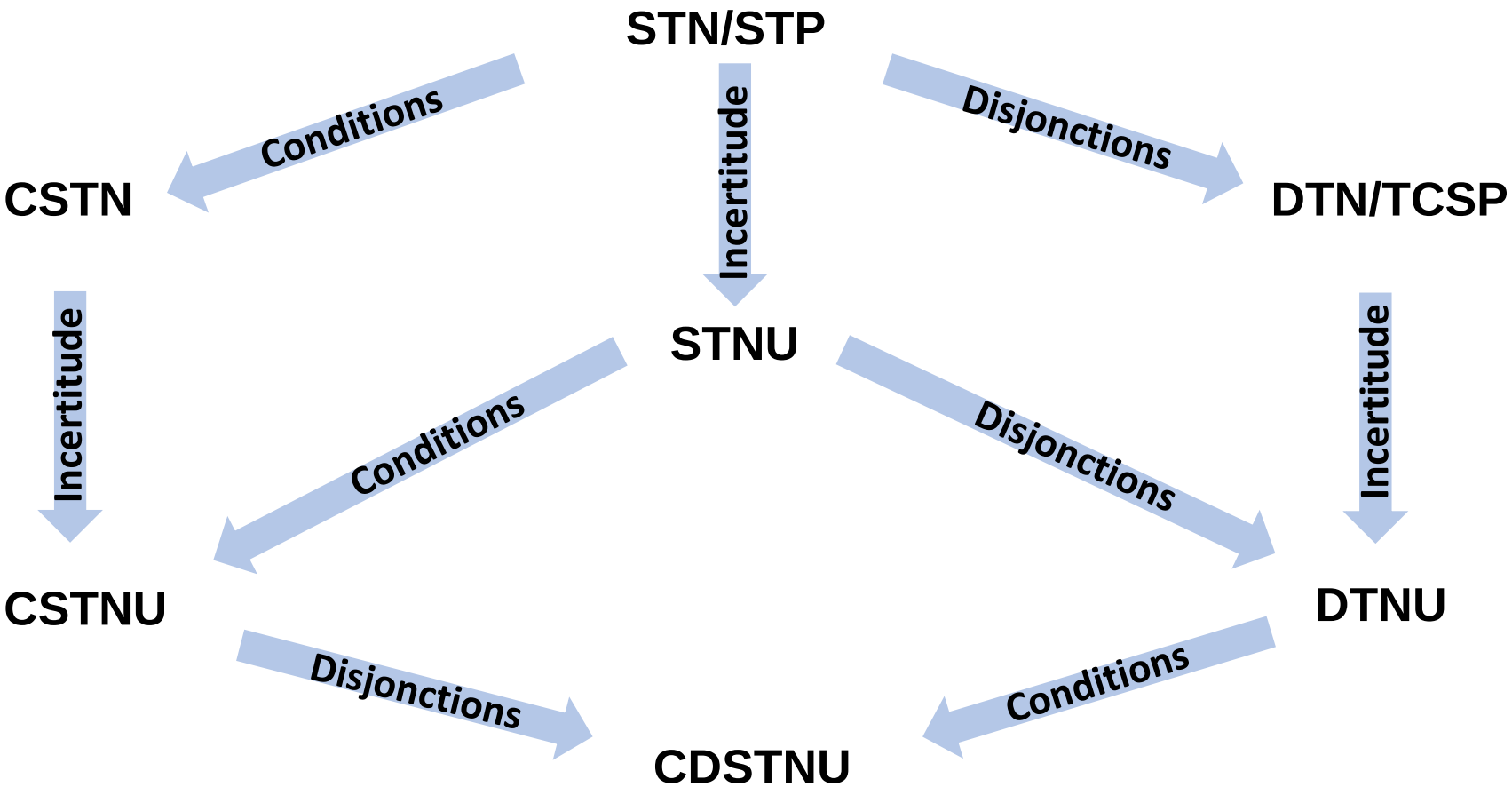
STNU = (V, E, C)

3 levels of controllability :

- Strong Controllability (SC) : Polynomiale
- Dynamic Controllability (DC) : Polynomiale
- Weak Controllability(WC) : coNP-complet ?

SC ⇒ DC ⇒ WC

Background


STN/STP
Conditions
Incertitude
Disjonctions
CSTN
DTN/TCSP
Incertitude
STNU
Incertitude
Conditions
Disjonctions
CSTNU
DTNU
Disjonctions
Conditions
CDSTNU

Background

Weak Controllability (WC): An STNU is weakly controllable if before execution there exist at least one successful strategy whatever the duration of the contingents

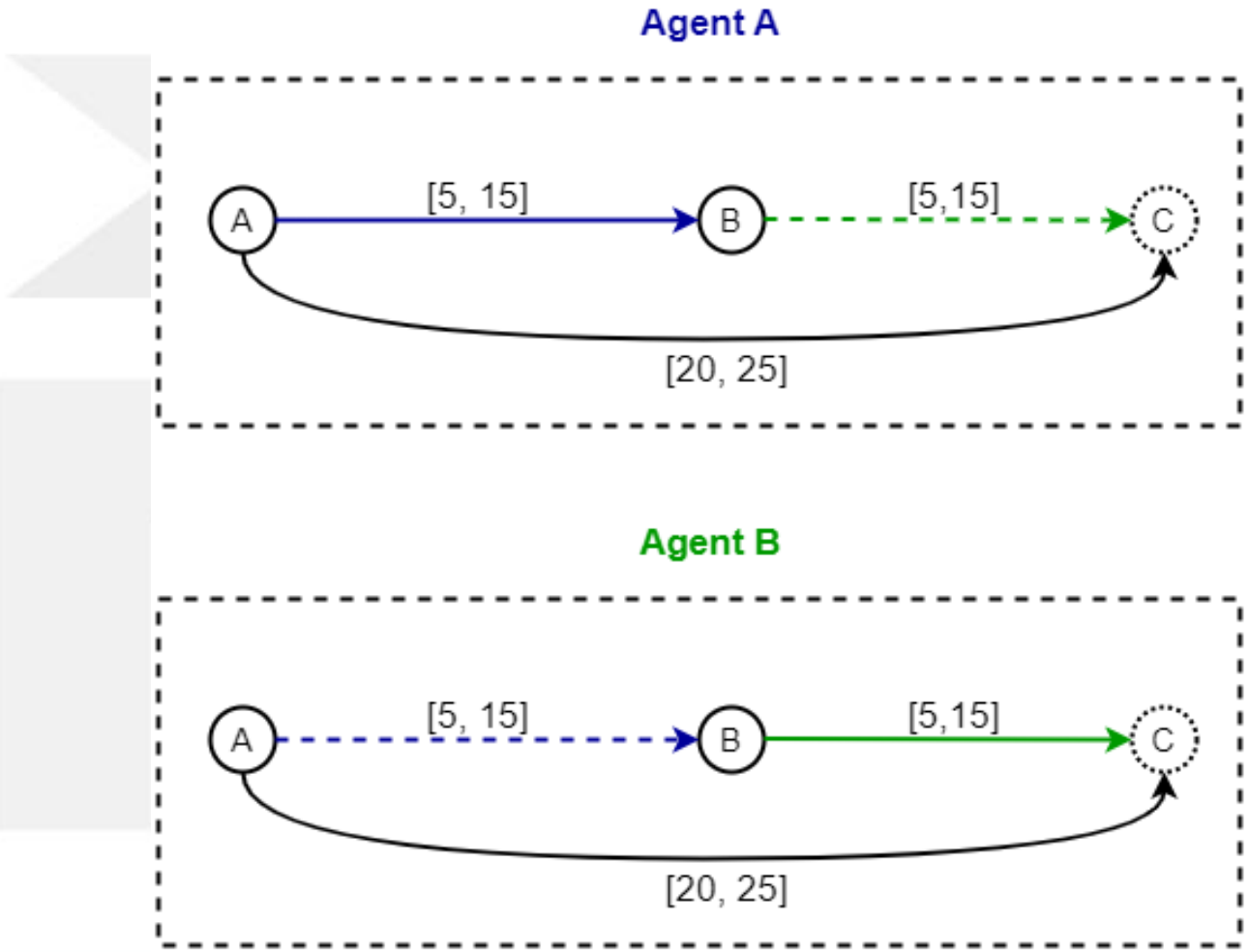
Dynamic Controllability (DC): An STNU is dynamically controllable if whatever the past decision took during execution, there exist at least one successful strategy for the remaining contingents duration

Strong Controllability (SC): An STNU is strongly controllable if before execution there exist a single fixed strategy that guarantees success regardless of the contingents duration

Strong Controllability $\Longrightarrow$ **Dynamic Controllability** $\Longrightarrow$ **Weak Controllability**

Current works & Challenges

Challenges & Current work



Challenges & Current work

Observations → **Needs**

Repair of Temporal Network with uncertainty → algorithm that **check & repair**

Challenges & Current work

Definition

Repair: find a reduction of the contingent of a non-X-Controllable STNU such that it becomes X-Controllable.

X = (V, E, C) ⟶ **X' = (V, E, C')**

Optimal Repair: find a minimal reduction of the contingent of a non-X-Controllable STNU such that it becomes X-Controllable.

$$\underset{\mathcal{X}' \in \mathcal{R}_{\mathcal{X}}}{\operatorname{argmin}} \left(\sum_{i \overset{[l,u]}{\dashrightarrow} j \in \mathcal{C}} ((l' - l) + (u - u')) \right)$$

Challenges & Current work

check & repair

Fairness: find an optimal repair of a non-X-Controllable STNU such that it maximize the number of contingent that are equally reduced

Fairness 1: equally reduce the flexibility by its percentage:

$$\frac{(l' - l) + (u - u')}{u - l}$$

Fairness 2: equally reduce the size (time-unit):

$$(l' - l) + (u - u')$$

Challenges & Current work

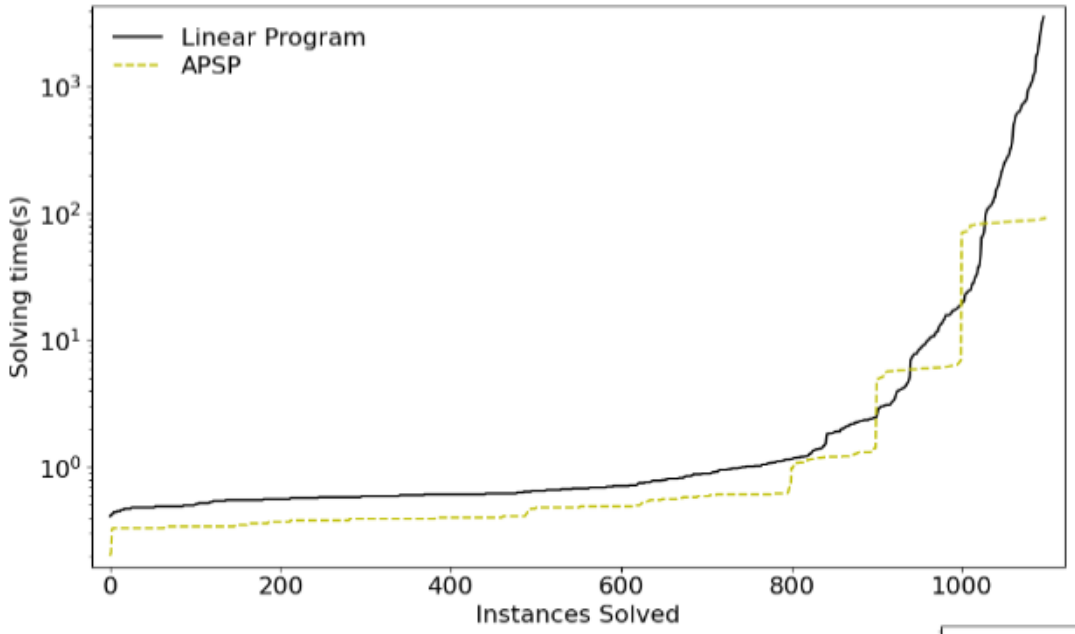
Work

Submission CPAIOR :

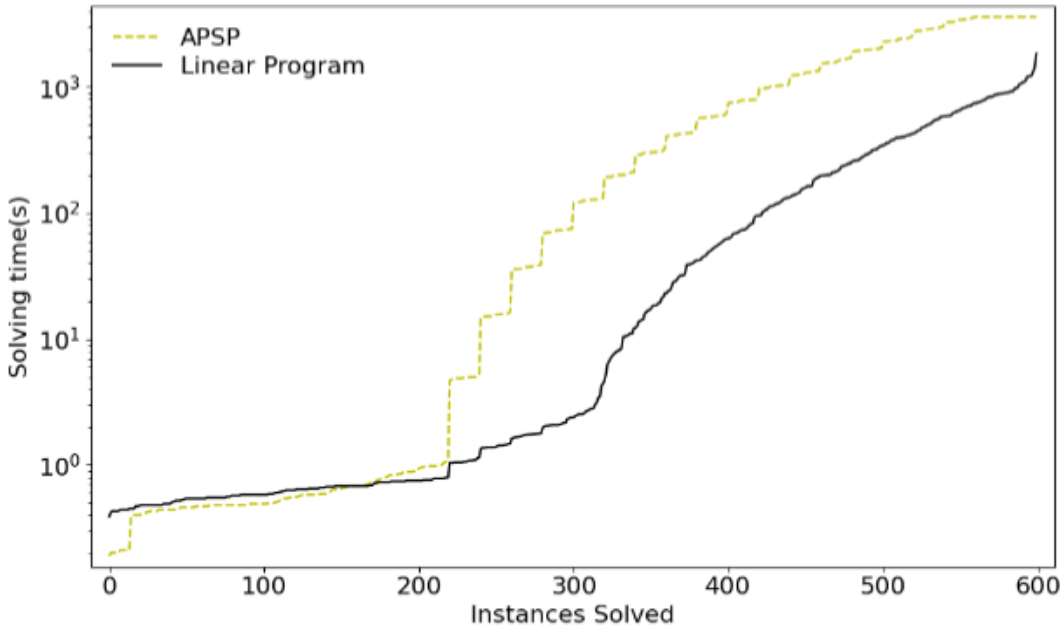
- SMT approach for DTNU repair for WC & SC
- LP approach for STNU repair in WC & SC

Submission ICAPS :

- LP approach for STNU repair for WC & DC by extending the repair problem to negative cycles
- A new LP approach for SC repair for STNU:
  - Use the tractability of the paper [Vidal et al., 1999]
  - Can check, repair, and give an execution strategy in better time complexity than the Floyd-Warshall algorithm in realistic graph



Maximum size = 2000
30% of contingent
30% divergent node
3 childs per divergent node



Challenges & Current work

Observations → **Needs**

Repair of Temporal Network with uncertainty → algorithm that **check & repair**

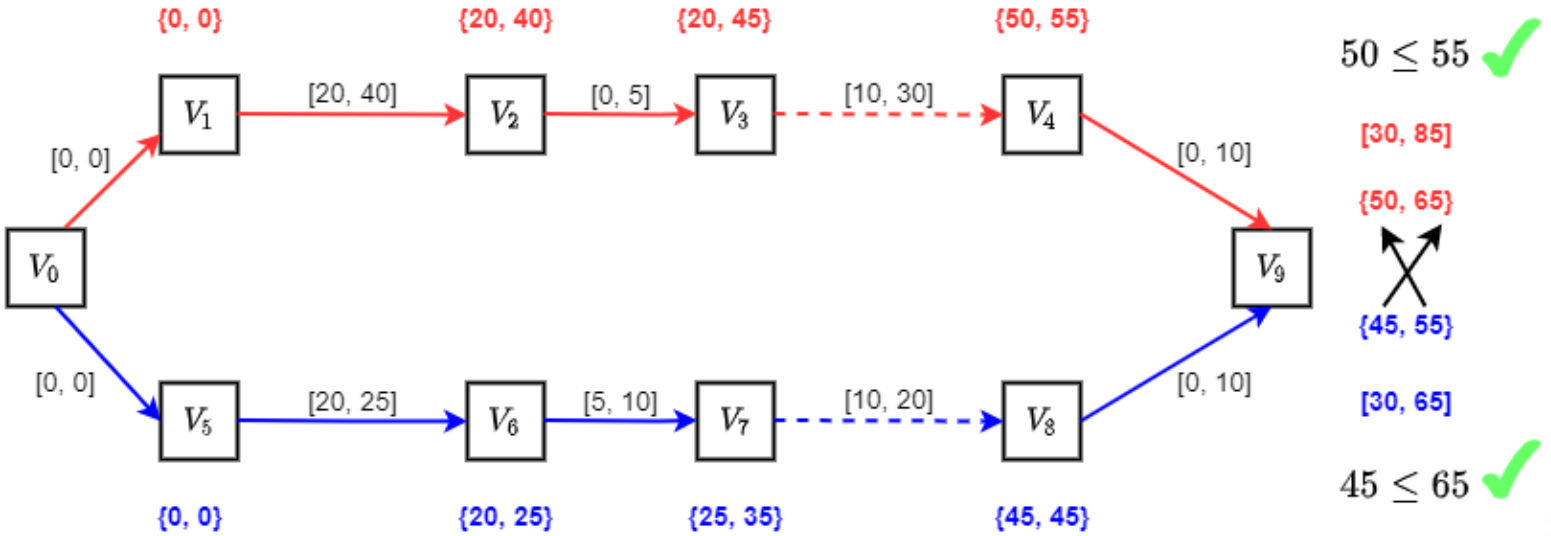
WC is **clearly relevant** (MAS) → more efficient & informed algorithms for checking WC

Challenges & Current work

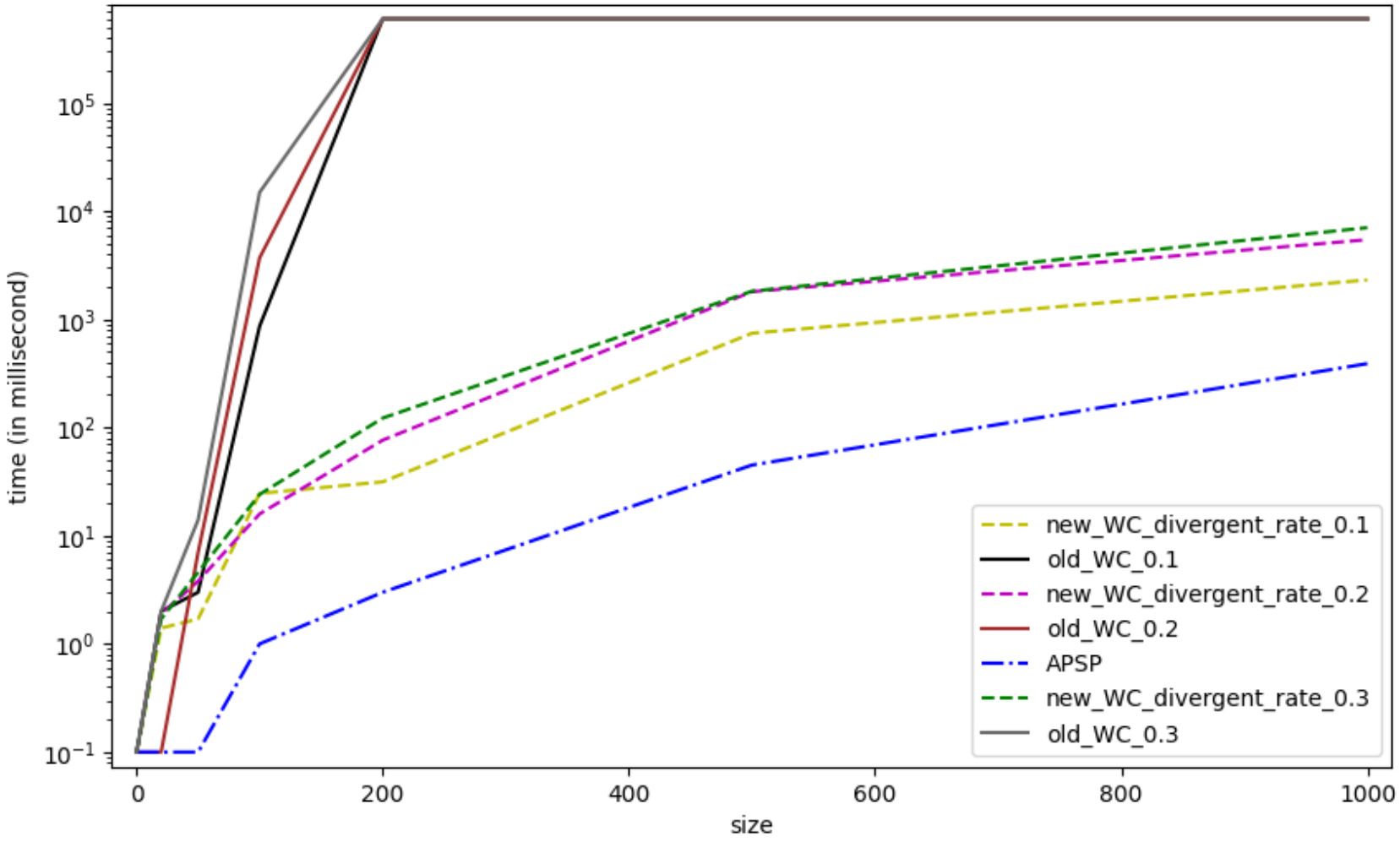
WC

Submission CPAIOR :

- propagation algorithm more practical than existing algorithms for realistic STNU
- Complexity still exponential but related to the density of the graph
- Can return the cycle that are not consistent
- Incremental but not a perfect one
- Can be parallelized



10% of contingent
3 childs per divergent node



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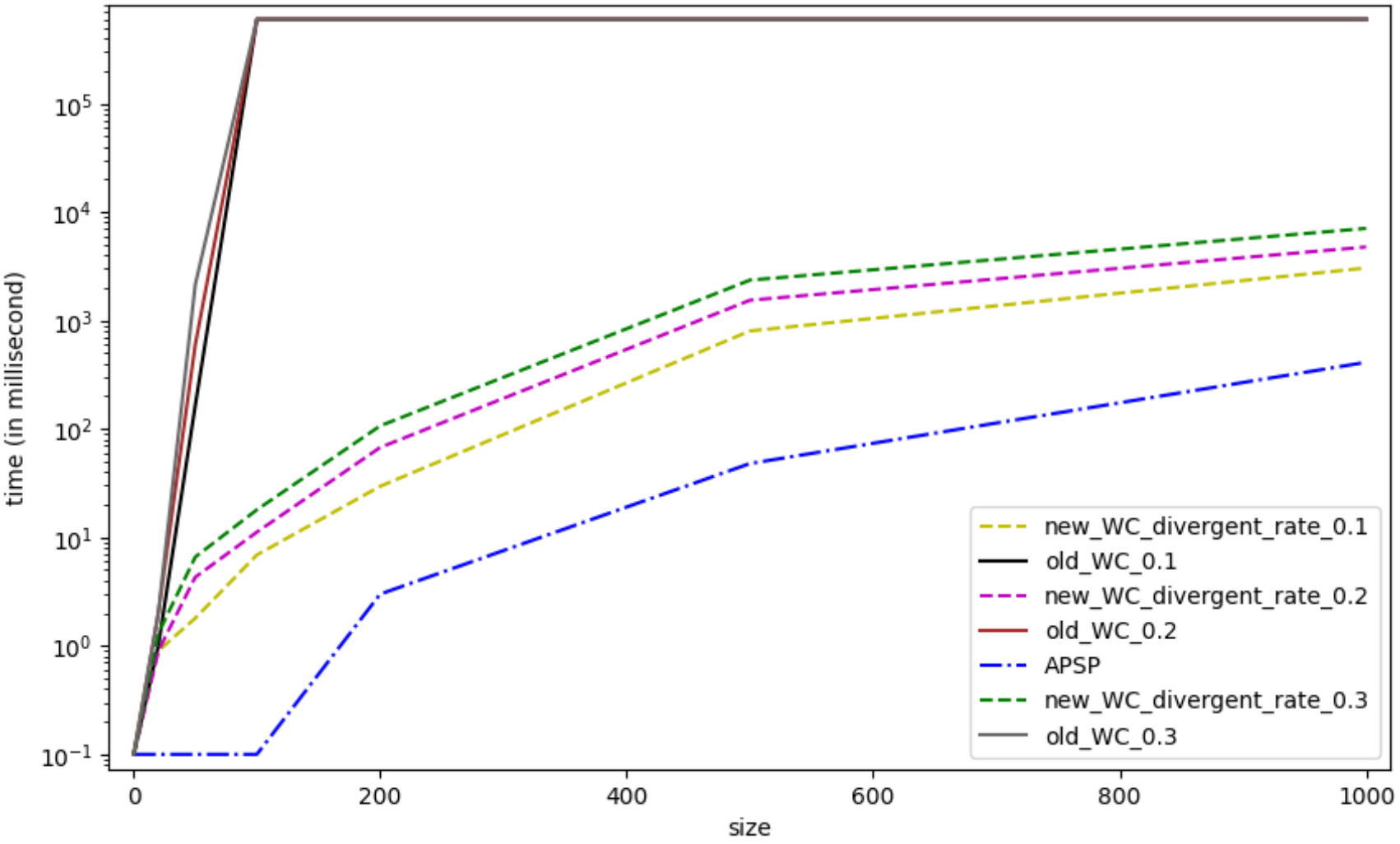

30% of contingent
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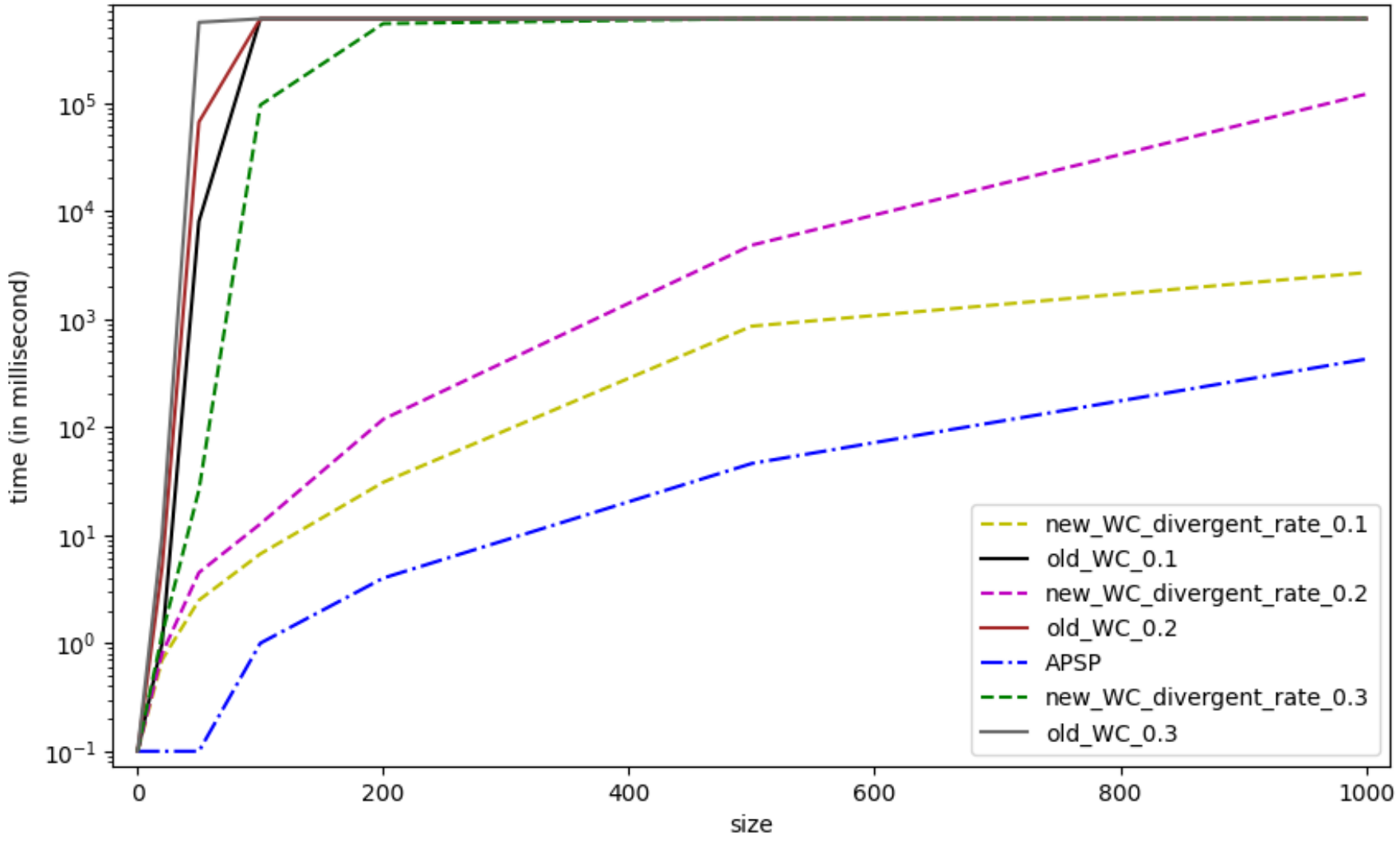

Challenges & Current work

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A **new global model** that represents Inter-independant STNUs, with

- a set of contracts = shared activities/events which duration/time is controlled by an agent and observed by others
- in each STNU, we add a reference to such a contract and the type (contingent/controllable)

Challenges & Current work

Contracting STNU

Definition 8. *(cSTNU) A Contracting STNU (cSTNU) is an STNU where links representing contracts are labeled. A cSTNU is a tuple* $\mathcal{S} = \langle V, R, W, E, C, O \rangle$ *such that:*

- *V is a set of time points, partitioned into controllable* (V_c) *and uncontrollable* V_u
- *R and W are sets of contracts, such that* $R \cap W = \emptyset$
- *E is a set of requirement links of the form* $v_i \xrightarrow{[l,u]} v_j$;
- *C is a set of labeled contingent links of the form* $v_i \overset{p}{\dashrightarrow} v_j$ *where* $p \in R$.
- *O is a set of owned contract links of the form either* $v_i \xrightarrow{p} v_j$ *or* $v_i \overset{p}{\dashrightarrow} v_j$, *one for each contract* $p \in W$.

In addition, we require that $\forall v_j \in V_u$, *there exists a unique labeled contingent link of the form* $v_i \overset{p}{\dashrightarrow} v_j$ *in* $C \cup O$.

Challenges & Current work

Multiple Interdependent Simple Temporal Network under Uncertainty

Definition 9. *(MISTNU) A MISTNU is a tuple* $\mathcal{G} = \langle A, \Sigma, B \rangle$ *such that:*

- *A is a set of agents* $\{a_1, a_2, \ldots, a_n\}$;
- Σ *is a set of cSTNUs* $\mathcal{S}_a = \langle V_a, R_a, W_a, E_a, C_a, O_a \rangle$, *one for every* $a \in A$, *such that*
  - $\forall a \in A$, $v_z \in V_a$, *where* v_z *is the reference time point;*
  - *for every pair of agents* $a, b \in A$, $W_a \cap W_b = \varnothing$
- *B is a map from contracts to bounds* $B : \bigcup_{a \in A}(R_a \cup W_a) \rightarrow \mathbb{R}^2$. *For the sake of this paper, we write* l *and* u *for* $\langle l_p, u_p \rangle = B(p)$.

Challenges & Current work

Controllability

Local Controllability = each cSTNU transformed into an STNU is X-Controllable (X = W/D/C)

Global Controllability = the MISTNU is X-Controllable

- Equivalence ? Semantics ? Link with execution strategy
- Controllabilty depends on agent's policy
- etc

Repair

MISTNU Repair: find an optimal reduction of the contracts (B) or a fair reduction such that Local/Global Controllability is satisfied

Aim:

- Models ECAI 2024
- Centralized solution with SMT to discuss ?
- Decentralized solution with negotiation: preliminary Time & complete approach AAMAS

Challenges & Current work

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WC is **clearly relevant** (MAS) → more efficient & informed algorithms for checking WC

A **new model** that represents independant STNU & who controls & who observe/read contingents

Heterogeneous agent with **different** temporal models → Interoperability

Challenges & Current work

Interoperability

Ontology:

- Formalize Temporal notions

Aim:

- Ontology to FOIS
- Decentralized system with Ontology to AAMAS

Perspectives

Perspectives

Enough for the next decade

MISTNU model has a **4th type of Controllability**

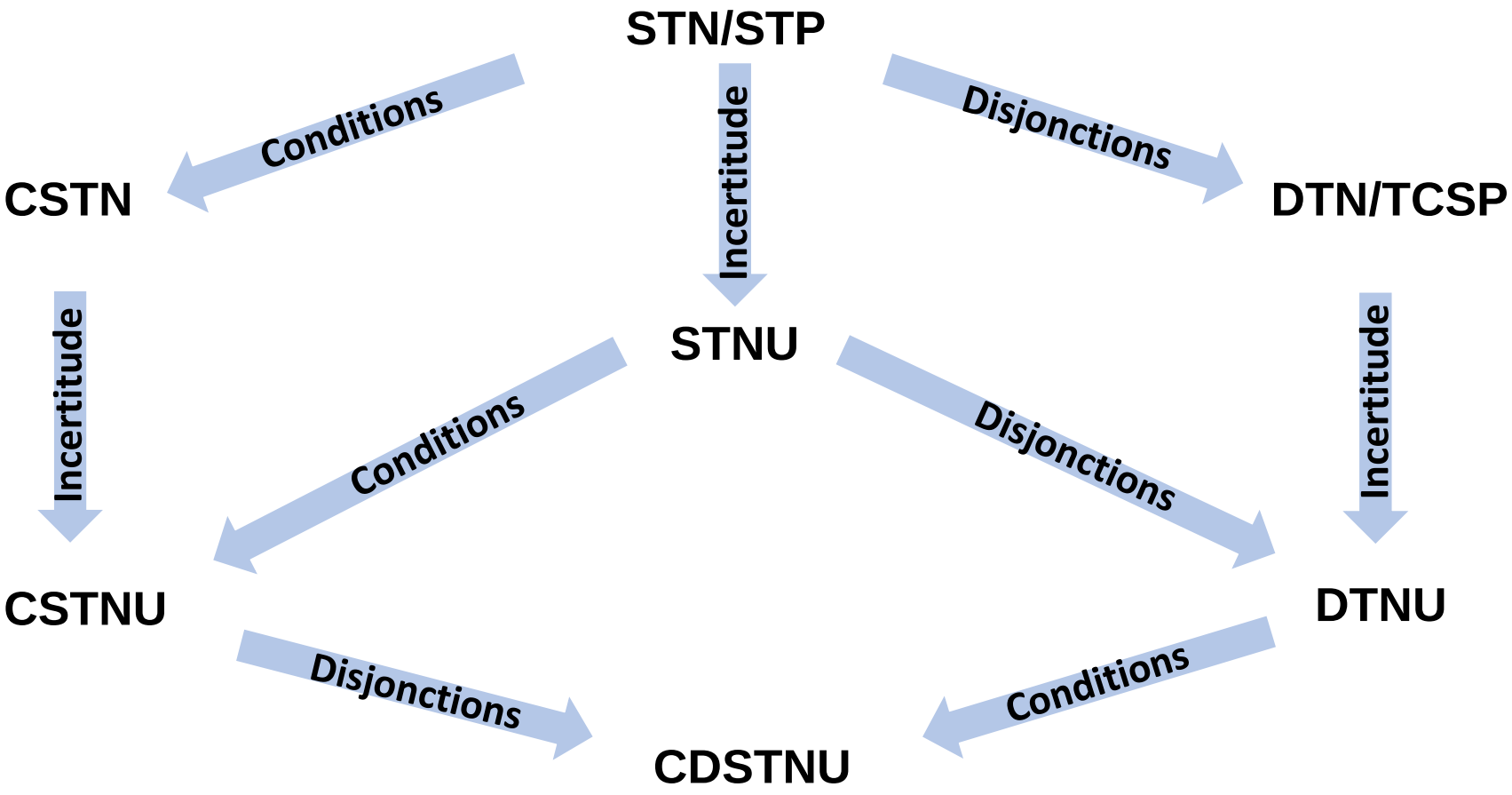
A **mixed controllability checking algorithm** is possible by extending B in the MISTNU model

Consider **different controllability** for each agent

Consider **cooperative & non-cooperative** agents

The **bigger view:** extend all of this to other TNU

Background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Thank you !