Reduced Time-Expansion Graphs and Goal Decomposition for Solving Cooperative Path Finding Sub-Optimally

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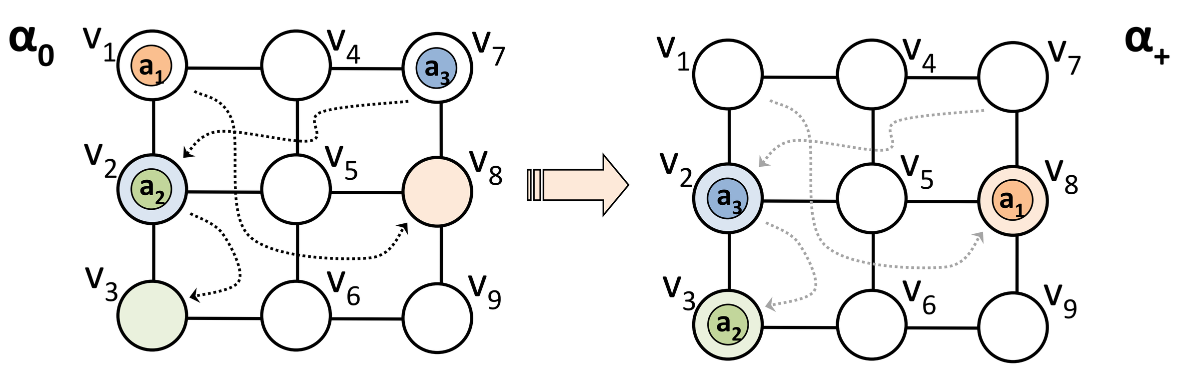
Cooperative Path-Finding

- a task to **relocate agents** to their goals in a non-colliding way
- agents move over undirected graph
  - an agent can move to unoccupied vertex

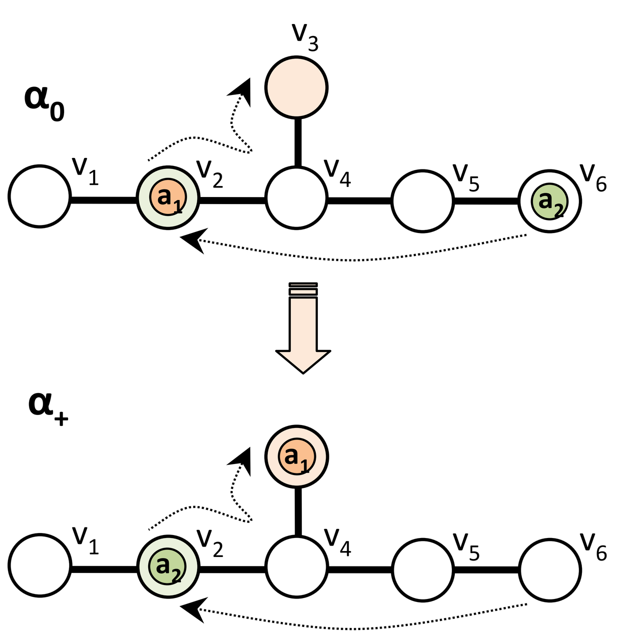
CPF Σ=(G, {a_1,a_2,a_3}, α_0, α_+)



	α_0	α_1	α_2	α_3	$\alpha_4 = \alpha_+$
a_1	v_1	v_1	v_2	v_5	v_8
a_2	v_2	v_3	v_3	v_3	v_3
a_3	v_7	v_4	v_4	v_1	v_2

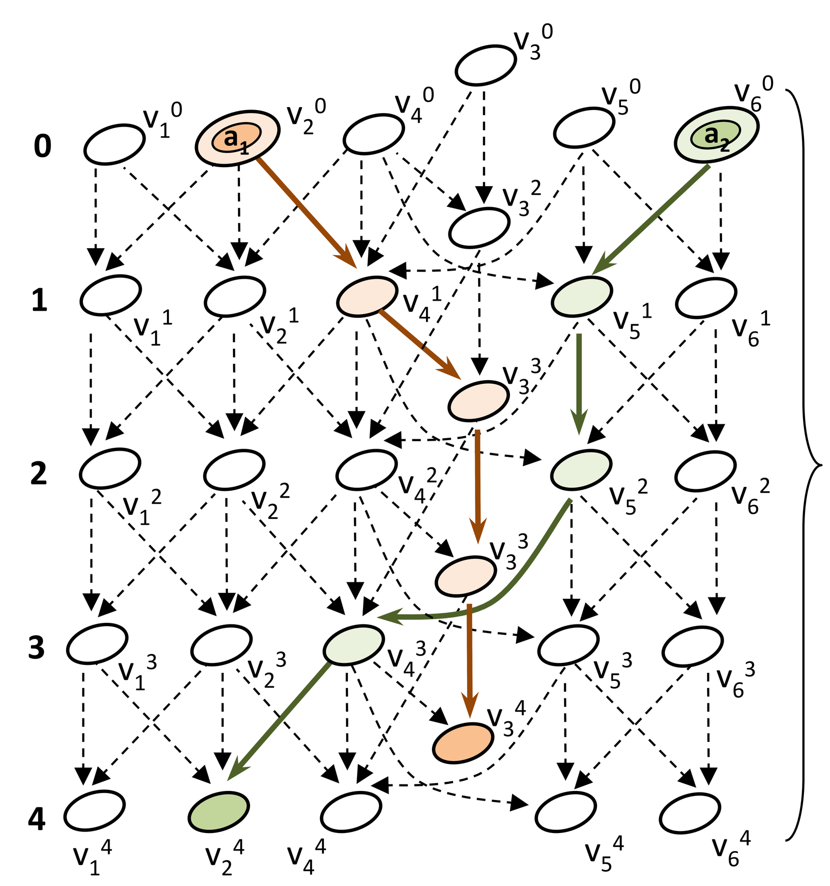
Standard Time Expansion

CPF Σ=(G=(V,E), {a_1,a_2}, α_0, α_+)



	α_0	α_1	α_2	α_3	$\alpha_4 = \alpha_+$
a_1	v_2	v_4	v_3	v_3	v_3
a_2	v_6	v_5	v_5	v_4	v_2

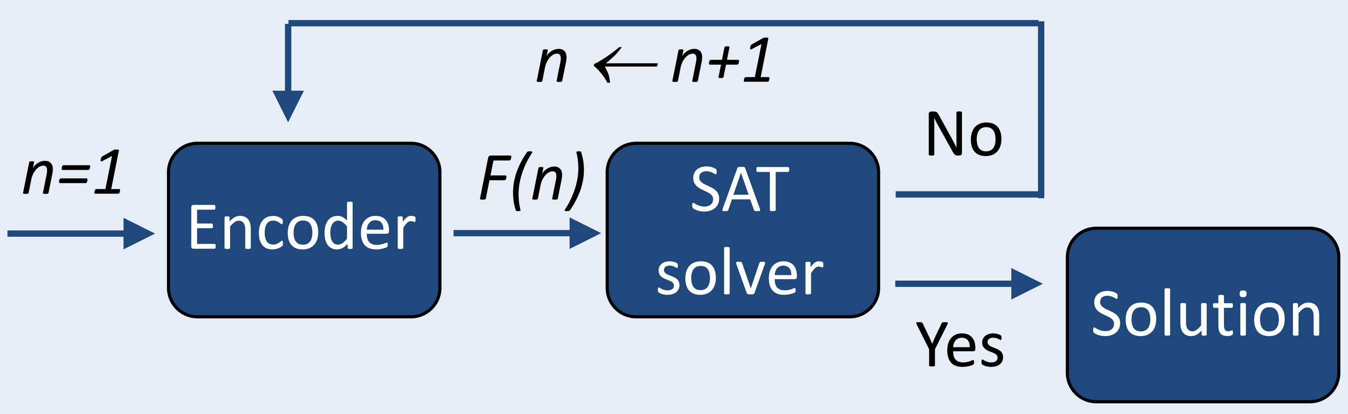
Exp$_T$ (G, 4)



- the number of copies of the graph corresponds to the **makespan** in time expansion graph Exp$_T$
- the set of **sources** and **targets** for non-trivial moves must be **disjoint** for each consecutive layers

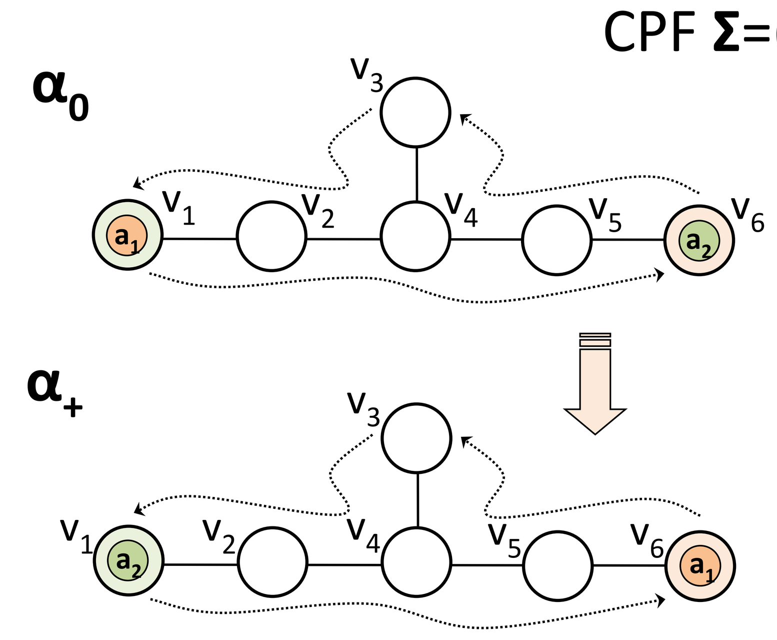
Reducing CPF to SAT

- **expand** the graph modeling the environment over time
  - number of expansions *n* is specified
- **encode** relocation of agents through expanded graphs as a propositional formula *F(n)*
  - ask **SAT solver** whether *F(n)* is solvable

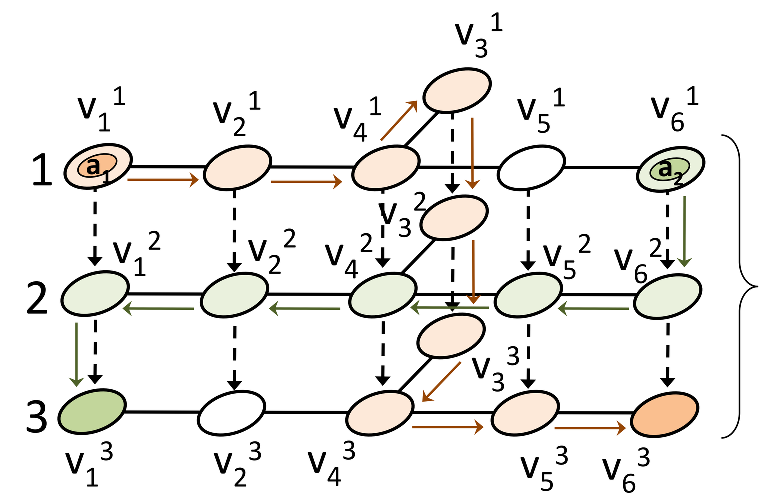


Reduced Time Expansion

CPF Σ=(G=(V,E), {a_1,a_2}, α_0, α_+)



	a_1	a_2
α_0	v_1	v_6
α_1	v_2	v_6
α_2	v_4	v_6
α_3	v_3	v_6
α_4	v_3	v_5
α_5	v_3	v_4
α_6	v_3	v_2
α_7	v_3	v_1
α_8	v_4	v_1
α_9	v_5	v_1
$\alpha_{10} = \alpha_+$	v_6	v_1



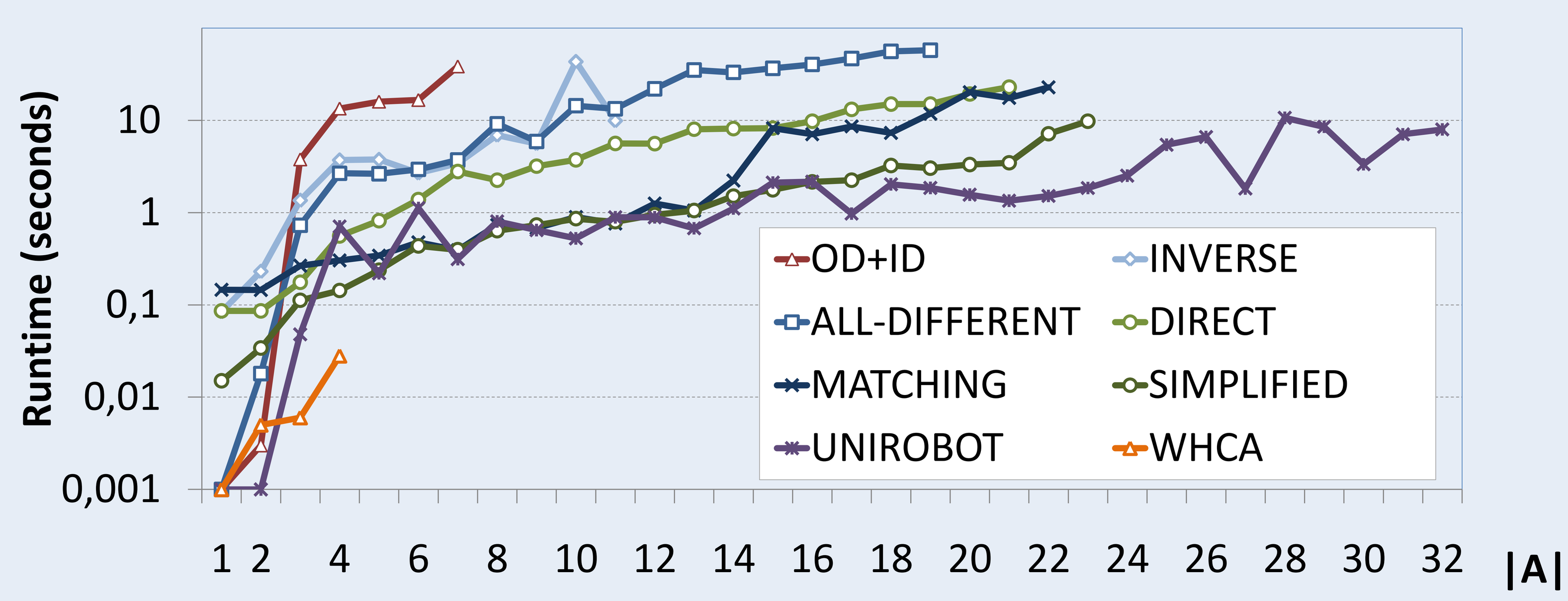
- **solution of CPF** corresponds to **vertex disjoint paths** in reduced time expansion graph rExp$_T$
- no extra constraint except disjointness
  - easy modeling as propositional satisfiability
- produces makespan **sub-optimal solution**

Goal Decomposition

- place agents to their goals **one by one** (UniROBOT)
  - build a separate CPF for each agent placement
- initial arrangements and goals **differ little** for single agent placement
  - small number of layers in rExp$_T$ to reach solvability
  - small SAT instances to solve

Experiments

Average runtime | Grid 8×8 | 20% obstacles



Makespan

|A|	1	4	8	12	16	20	24	28	32
optimal	5.3	8.4	11.0	11.7	12.4	12.3	-	-	-
WHCA*	5.6	9.3	-	-	-	-	-	-	-
UniROBOT	9.3	15.8	33.0	49.3	83.4	96.1	131.4	154.1	201.7

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