IPC-23 Numeric Track

Chairs: Joan Espasa, Enrico Scala

Motivation and Objectives

- Competition over problems explicitly mentioning numeric state information
- Advancement on numeric planning facilitates planning into real-world applications
  - Modeling Resources
  - Modeling Spatial Configurations
  - Quantitative reasoning
  - More interesting objective functions

- Numeric reasoning is building block in more expressive formalisms (e.g., PDDL+, ANML, HDDL)
- This track stresses numeric reasoning putting other aspects aside

Some history

- No track on numeric planning **specifically** before
- Numeric planning was previously tested together with temporal actions
  - Domains mostly temporal with very little numeric reasoning
- We argue this hindered the complexity arising from the numeric structures, and the techniques targetting this setting

Numeric Planning Problems

- X: set of numeric state variables. F: set of Boolean state variables
- Formula defined recursively:
  - $\sum_{\{x \in X\}} \boldsymbol{w_x x} + \boldsymbol{c} \geq \boldsymbol{0}$ **is a formula**
  - Let $f \in F, f = \top$ or $f = \bot$ is a formula
  - If ϕ and ψ are formula so are $\phi \vee \psi$ and $\phi \wedge \psi$
- Numeric Planning Problems
  - A: set of labels denoting actions
  - I: set of assignments for Boolean and **Numeric** state variables
  - G: a formula
  - Pre: mapping from A to a formula
  - Eff: mapping from A to effects of the form $x := \xi$ with ξ **linear expression** over X
- Solution:
  - Sequence of actions applicable at init and goal reaching
  - Optimal solutions are those satisficing objective function at the final state
    - Ex. Minimize linear function over X

Simple and Linear Numeric Planning

- Simple Numeric Planning (**SNP**)
  - Restrict effects to be increase/decrease by a constant
- Linear Numeric Planning (**LNP**)
  - Restrict effects to be increase/decrease/assign of a linear function over numeric state variables

- **LNP** includes **SNP**

- **SNP** more studied and understood

Example of a Numeric Planning Problem

- A single agent in a discretised 3D Space
- Can move 6 directions:
  - up, down, left, right, forward, backwards
  - Increases and decreases x,y and z coordinates
- Objective is to visit a set of destinations and come back to destination
- Limited resource (battery)
- Can recharge at destination

```
(:action move-right
    :parameters ()
    :precondition (and
                      (>= (battery-level) 1)
                      (<= (x) (- (max_x) 1) )
                  )
    :effect (and (increase (x) 1)
                 (decrease (battery-level) 1)
                 )
)

(:action decrease_x
```

Domains

- Three sets of domains:
  1. Selection of domains from previous competitions (IPC-5)
     - **TPP**, **ZenoTravel**, Depots, Rover, **Settlers**
  2. Domains scattered in various papers (Coles et al. 2011, Frances et al. 2016, Scala et al. 2016, Leofante et al. 2021)
     - Block-Grouping, Counters, **Fo-Counters**, Sailing, **Fo-Sailing**, Farmland, Hydropower, Markettrader, Mprime, Pathwaysmetric, Sugar
  3. New domains
     - Drone, Expedition, Extended-Plant-Watering, Delivery
- **LNP (5 domains)**
- SNP (15 domains)
- Total of 20 domains, each with 20 instances

Subtracks

Same setting as classical planning track. All have 8GB memory limits and run on **Cirrus**, a HPC and data science service from the University of Edinburgh

- **Agile** (5 min): 1 if within one second, 1 - log(T)/log(300) if within 5 minute. 0 otherwise
- **Satisficing** (30 min): C*/C where C is the cost of the cheapest plan and C* is the cost of a reference plan
- **Optimal** (30 min): number of solved tasks

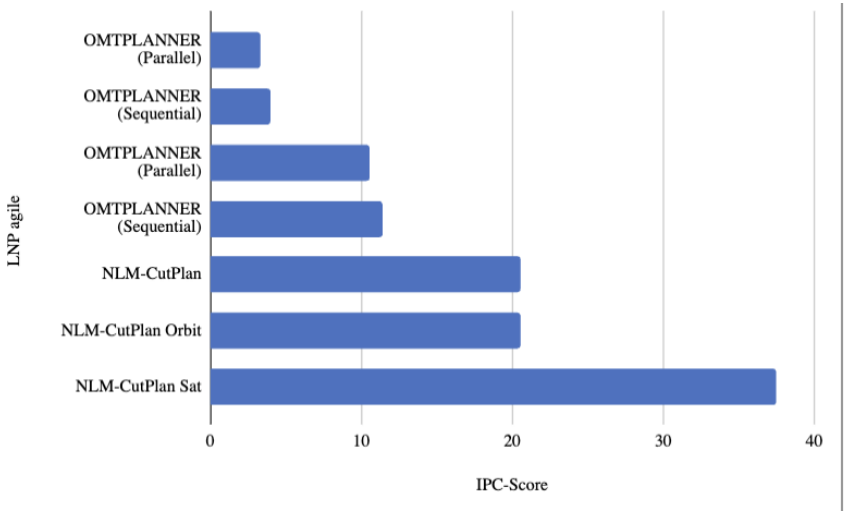
Participants

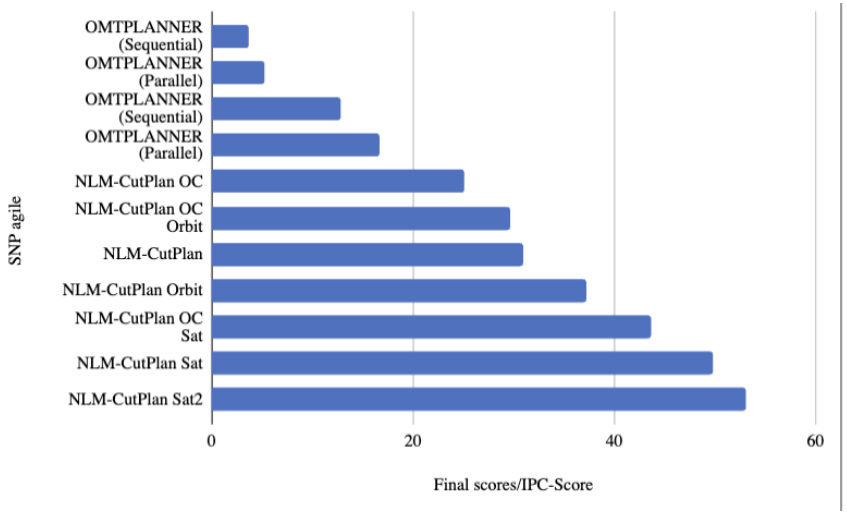
- Optimal
  - LNP Planners:
    - NLM-CutPlan
    - NLM-CutPlan Orbit
    - OMTPlan (Sequential)
    - OMTPlan (Parallel)
  - SNP Planners:
    - NLM-CutPlan OC
    - NLM-CutPlan OC Orbit
- Satisficing/Agile
  - LNP Planners:
    - NLM-CutPlan Sat
    - OMTPlan (Sequential)
    - OMTPlan (Parallel)
  - SNP Planners:
    - NLM-CutPlan OC Sat
    - NLM-CutPlan Sat2

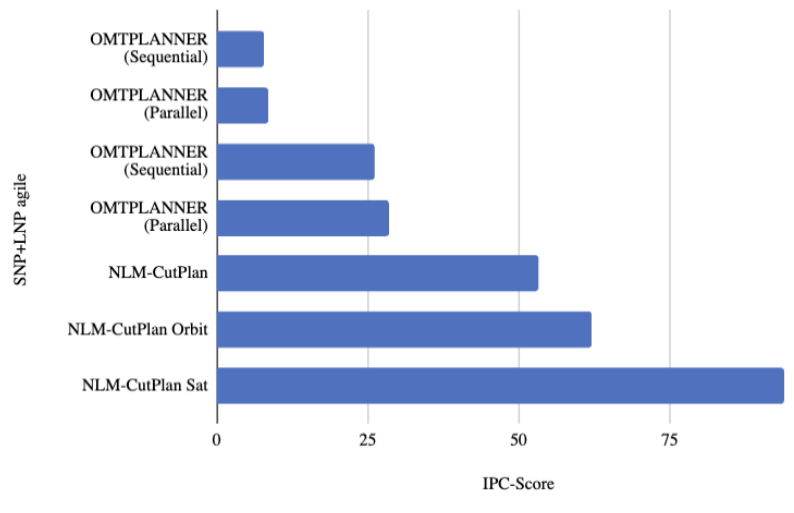
- TEAM 1: Ryo Kuroiwa, Alexander Shleyfman, J. Christopher Beck
  - NLM Planners
- TEAM 2: Francesco Leofante
  - OMT Planners
- Team 3: Retracted

Agile :: Results

- SNP: The winner is
  - NLM-CutPlan SAT2
- LNP: The winner is
  - NLM-CutPlan SAT
- LNP+SNP: The winner is
  - NLM-CutPlan SAT

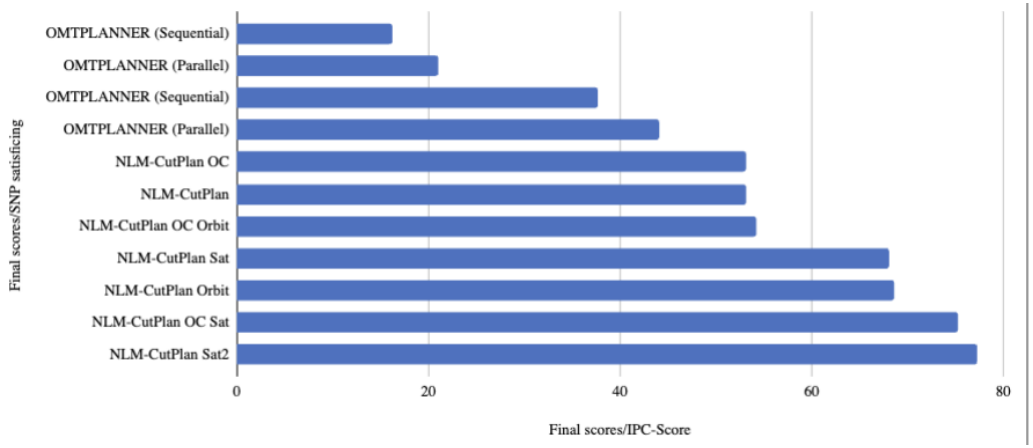


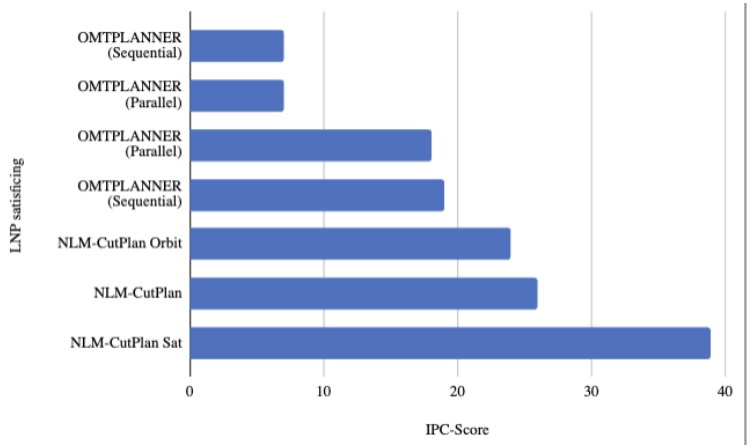


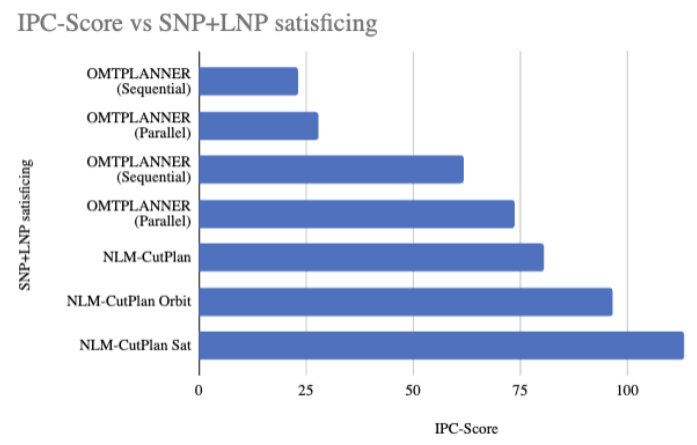


Satisficing :: Results

- SNP: The winner is
  - NLM-CutPlan SAT2
- LNP: The winner is
  - NLM-CutPlan SAT
- LNP+SNP: The winner is
  - NLM-CutPlan SAT

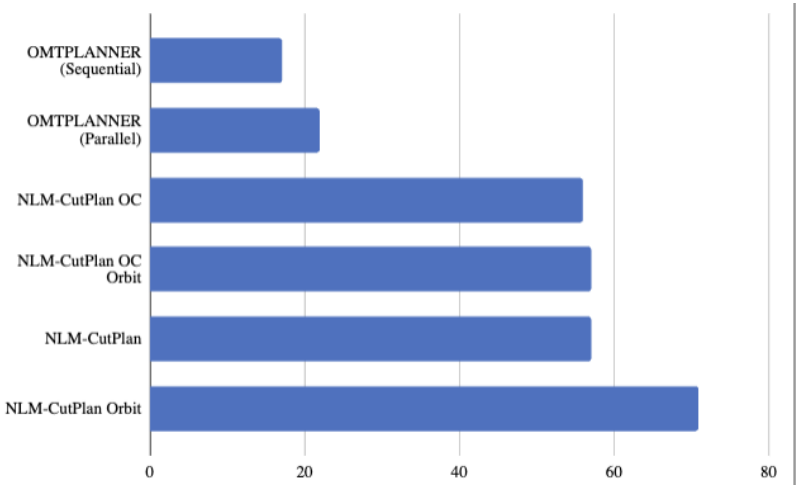


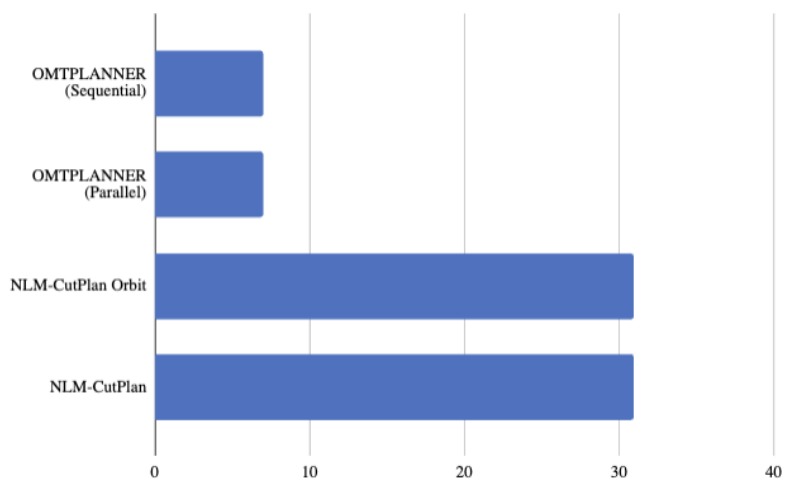


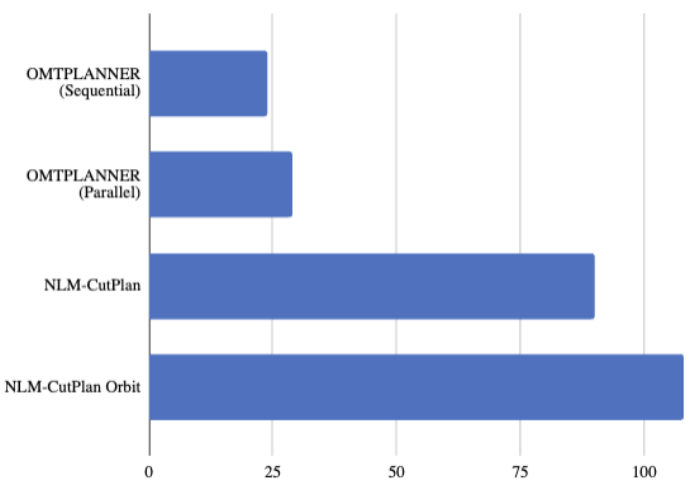


Optimal :: Results

- SNP: The winner is
  - NLM-CutPlan Orbit
- LNP: The winner is
  - NLM-CutPlan, NLM-CutPlan Orbit
- LNP+SNP: The winner is
  - NLM-CutPlan Orbit







Winner per Domain

(SNP + LNP) Satisficing

Satisficing	NLM-CutPlan Sat	OMTPlan (Parallel)
block-grouping	0	**2**
counters	11	**20**
delivery	**7**	2
drone	**15**	3
expedition	**4**	3
ext-plant-watering	**18**	0
farmland	**9**	0
fo_counters	**4**	3
fo-farmland	**9**	1
fo-sailing	**14**	1
hydropower	**4**	1
markettrader	0	0
mprime	10	**11**
pathwaysmetric	2	**3**
rover	3	**16**
sailing	**8**	0
settlers/settlersnumeric	**2**	0
sugar	5	**19**
tpp	2	**4**
zenotravel	9	**11**

Complementarity

- No Planner has total Dominance
- Data on VBS on the SNP+LNP Satisficing

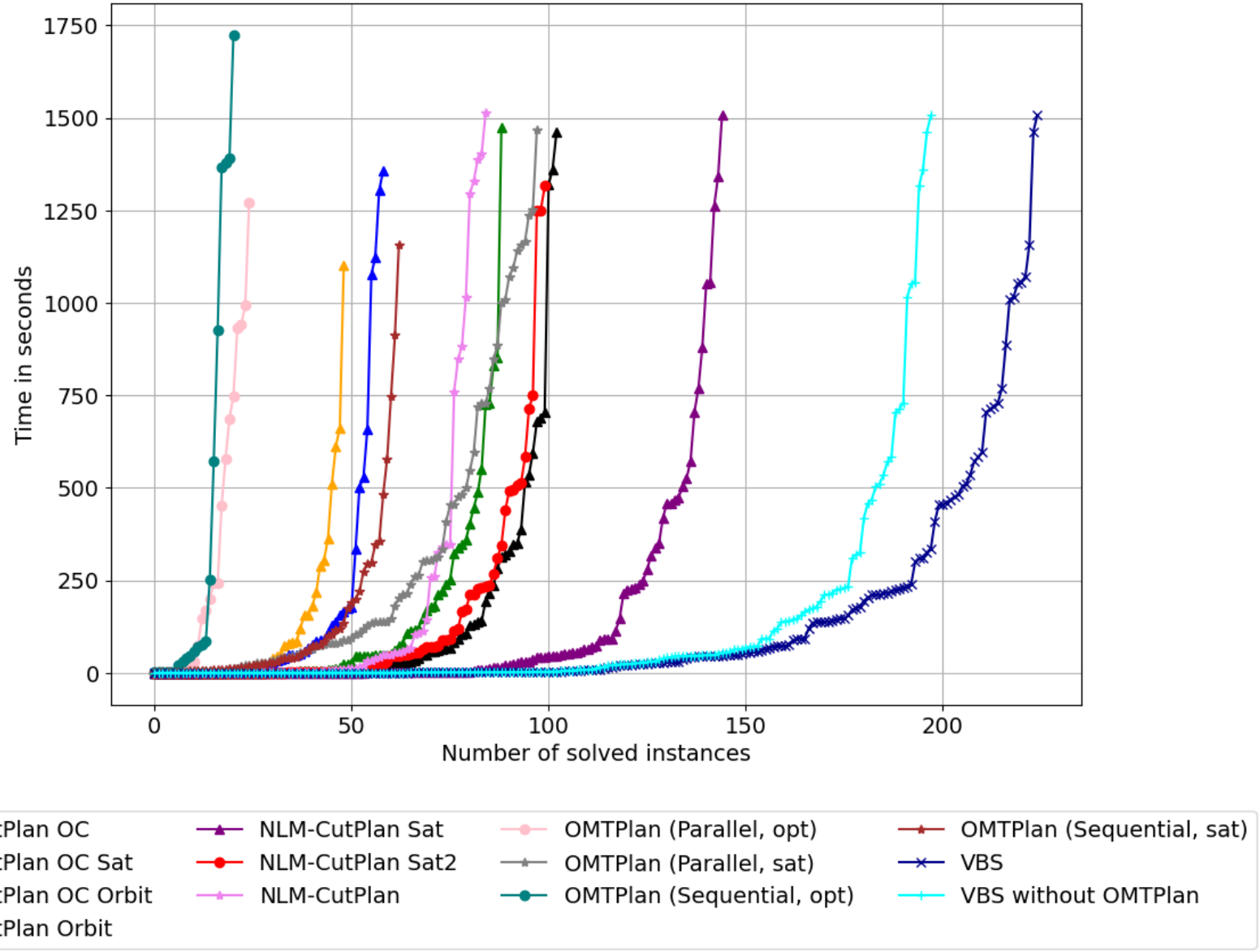
Planner	#Instances Best	Contribution
NLM-CutPlan	17	7.56%
NLM-CutPlan Orbit	27	12%
NLM-CutPlan OC	4	1.78%
NLM-CutPlan OC Orbit	3	1.33%
NLM-CutPlan Sat	80	35.56%
NLM-CutPlan OC Sat	11	4.89%
NLM-CutPlan Sat2	45	20%
OMTPlan (Sequential)	8	3.56%
OMTPlan (Parallel)	30	13.33%

Winner per Domain

(SNP + LNP) Optimal

Optimal	NLM-CutPlan Orbit	OMTPlan (Parallel)
block-grouping	0	**1**
counters	**4**	**4**
delivery	**5**	1
drone	**4**	2
expedition	**5**	1
ext-plant-watering	**0**	**0**
farmland	**13**	0
fo_counters	**3**	**3**
fo-farmland	**8**	1
fo-sailing	**6**	1
hydropower	**10**	1
markettrader	**0**	**0**
mprime	**14**	6
pathwaysmetric	**1**	**1**
rover	4	**6**
sailing	**7**	0
settlers/settlersnumeric	**1**	0
sugar	**8**	1
tpp	**2**	0
zenotravel	**7**	0

Survival Plot on the SNP+LNP Satisficing



Conclusion and What's Next

- Not a lot of participants but this is a good start
- First public repository with numeric domains
- Thanks to all participants and congrats to the winner!