No One SATPlan Encoding To Rule Them All

1. What is Planning?
- World state: instantiation of multivalued state variables
- Actions:
  - require certain values of state variables to be used
  - change values of state variables by their effects
- Objective:
  - Given a set of actions
  - Given an initial state (start) and goal conditions
  - Find a plan (sequence of actions to get from start to goal)

2. Example: delivering 2 packages to Las Vegas

3. Finding Plans with Satisfiability Solvers
- If the formula $F_k$ is satisfiable then a plan of size $k$ exists
- Solve $F_k$... until a satisfiable formula $F_k$ is reached
- Use the solution of $F_k$ to construct a plan

4. Encoding Planning as SAT
- The key aspect for the performance
- Many encoding schemes in the last decades
- Various encodings work well for different problem kinds
- The aim is to be the best for all

   BUT is this the best approach?
   - We assemble a set of encodings
   - Select the best encoding for a given problem
   - Inspired by sequential portfolios
   - The set of encodings should be diverse
   - The selecting algorithm should be fast and smart (choose well)

5. Four Kinds of SATPlan Encodings
- Based on restrictions on actions in a single step:
  - Forall-Step – most strict
  - Exists-Step
  - Relaxed Exists-Step
  - Relaxed Relaxed Exists-Step

   $(R^2$ Exists-Step) – least strict

   To be diverse we choose a Forall-Step encoding ($R^2$ Exists-Step) – least strict

6. Guessing action ordering for $R^2$ Exists-Step
- We need to guess the order of actions in a resulting plan.
- We compared a few heuristics, the best are:
  - TSort – topological sorting of action interactions
  - Input – the order of actions in the problem definition

7. Encoding Selection Rule
- A transition = change of a state variable
- The set of transitions is defined by the actions
- The heuristic rule used in our approach

   $T = \#transitions / \#stateVariables$

   $IF \ T > 10 THEN$
   use the Reinforced encoding
   $ELSE IF$ makespan is even
   use $R^2$ Exists-Step with TSort ordering
   $ELSE$
   use $R^2$ Exists-Step with Input ordering

8. Experiments
- Compared:
  - Selective encoding and its components ($R^2$ Exists and $R^2$ Exists
  - State-of-the-art encodings of Rintanen and their optimal combination ($R^*$)
  - Benchmark problems: IPC 2011, each domain contains 20 problems
  - Sat Solver: Lingeling (version ats)
  - PC: Intel i7 920 cpu @2.67 Ghz and 6 GB of memory

9. Conclusion
- Combining diverse encodings works very well
- Just combining the best encodings (of Rintanen) is not the best approach
- Action ordering has huge impact on $R^2$ Exists encoding
- The presented method is very simple yet experimental results are great
- Future Work: More diverse set of encodings, smarter selection heuristics