Reachability Heuristics for Handling State Uncertainty

Daniel Bryce, Will Cushing
Subbarao Kambhampati

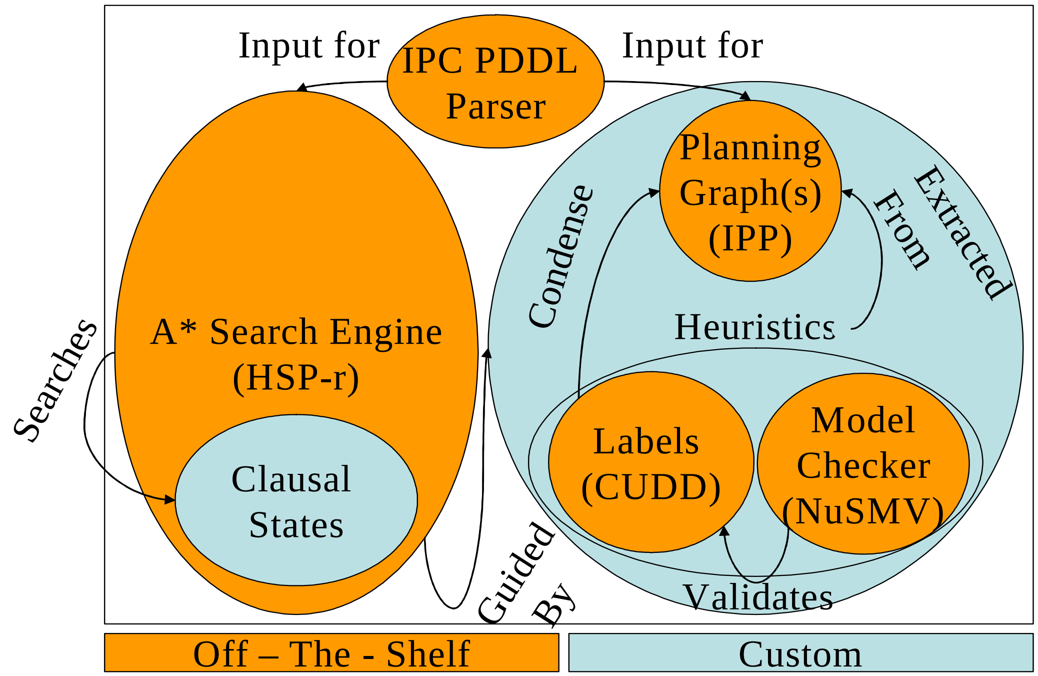
Joint with David E. Smith, NASA

ARIZONA STATE UNIVERSITY

[ICAPS 2004; AAAI 2005; UAI 2005]

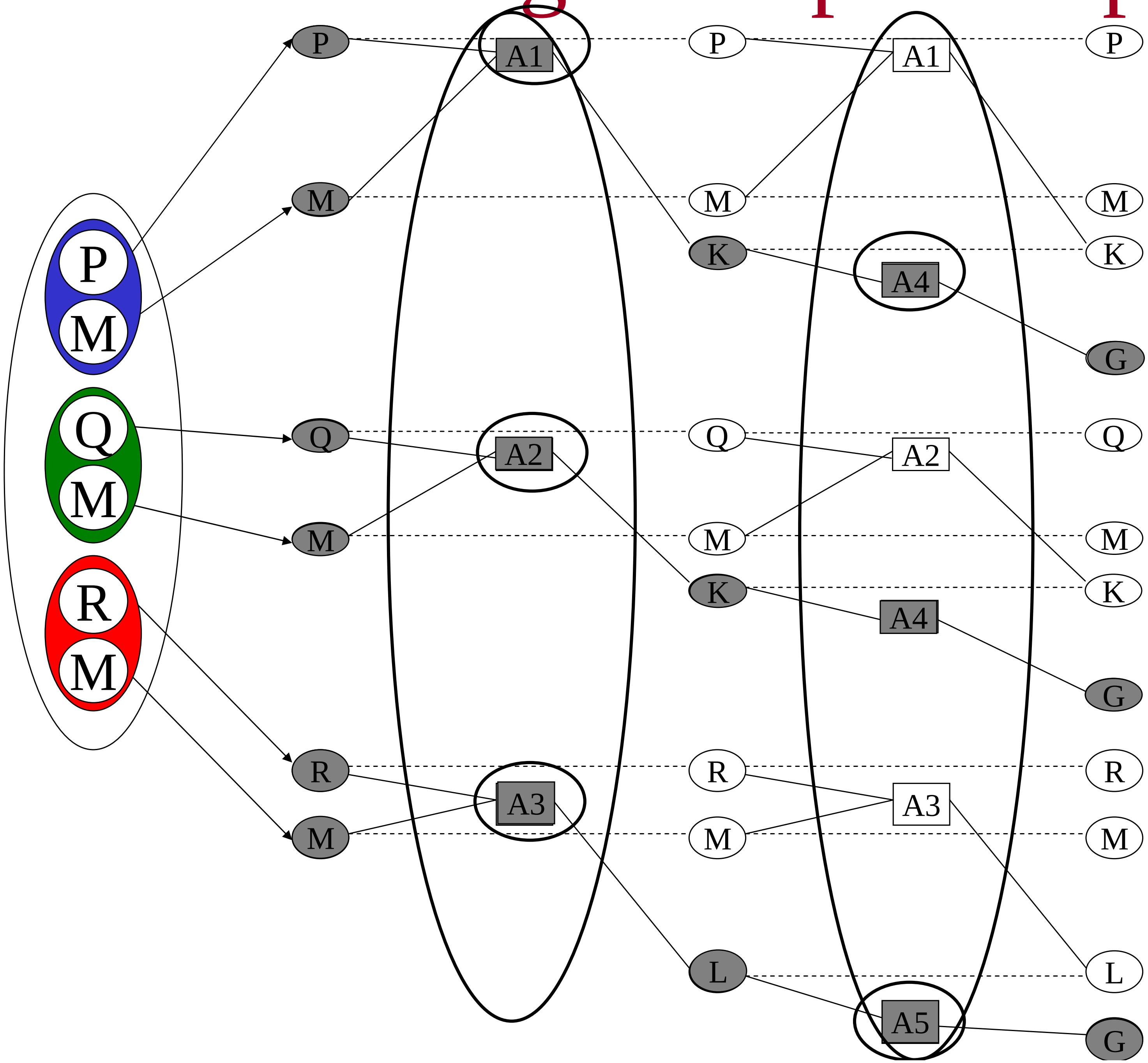
Belief Space Search

- Partially known initial state
- Actions with non-deterministic effects
- Need to search in Belief Space
  - Belief States are sets of world states (2^S)
    - Represented as formulas over fluents (implemented as BDDs)



Acute need for effective search control

Using Multiple Graphs

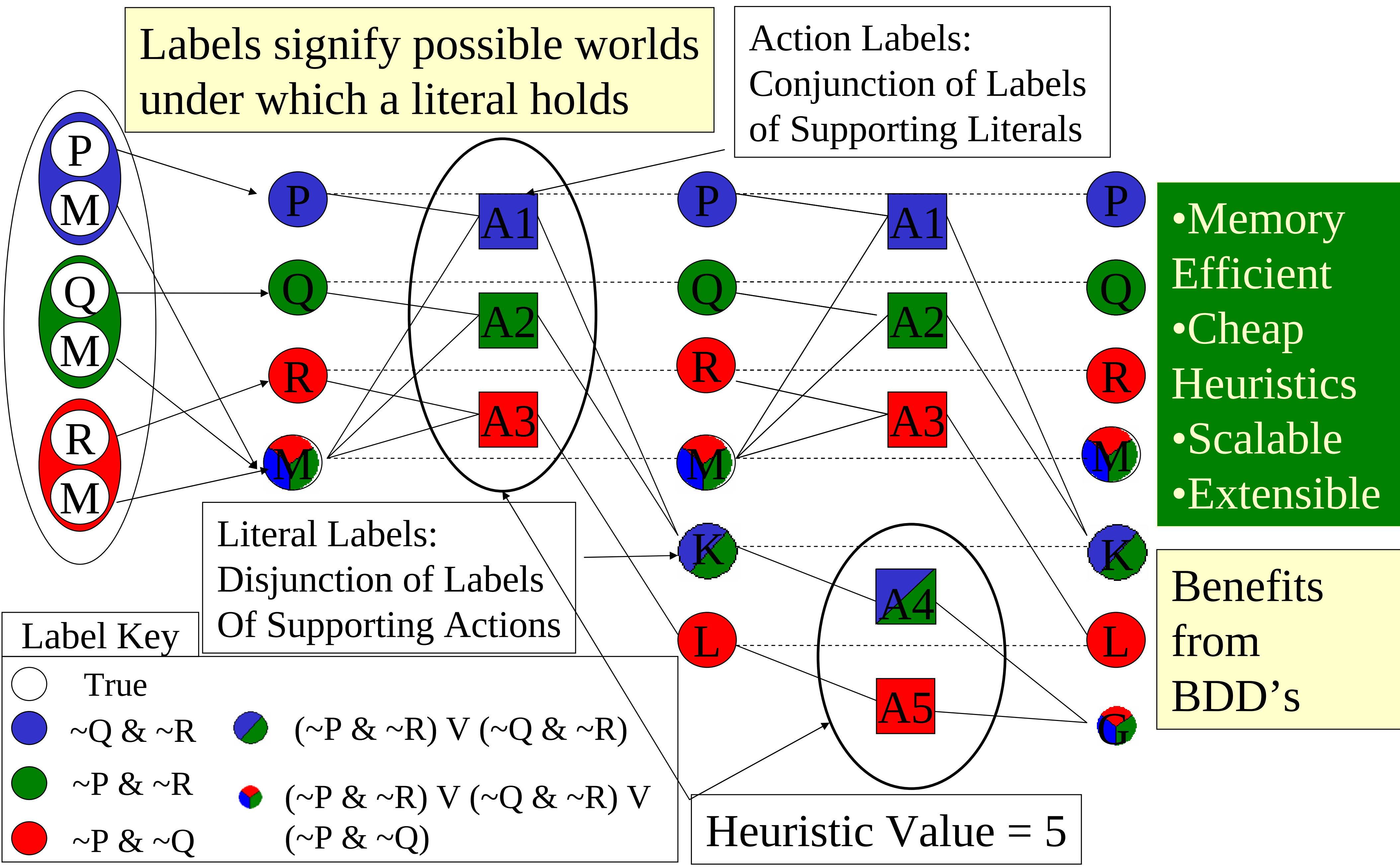


- Same-world Mutexes

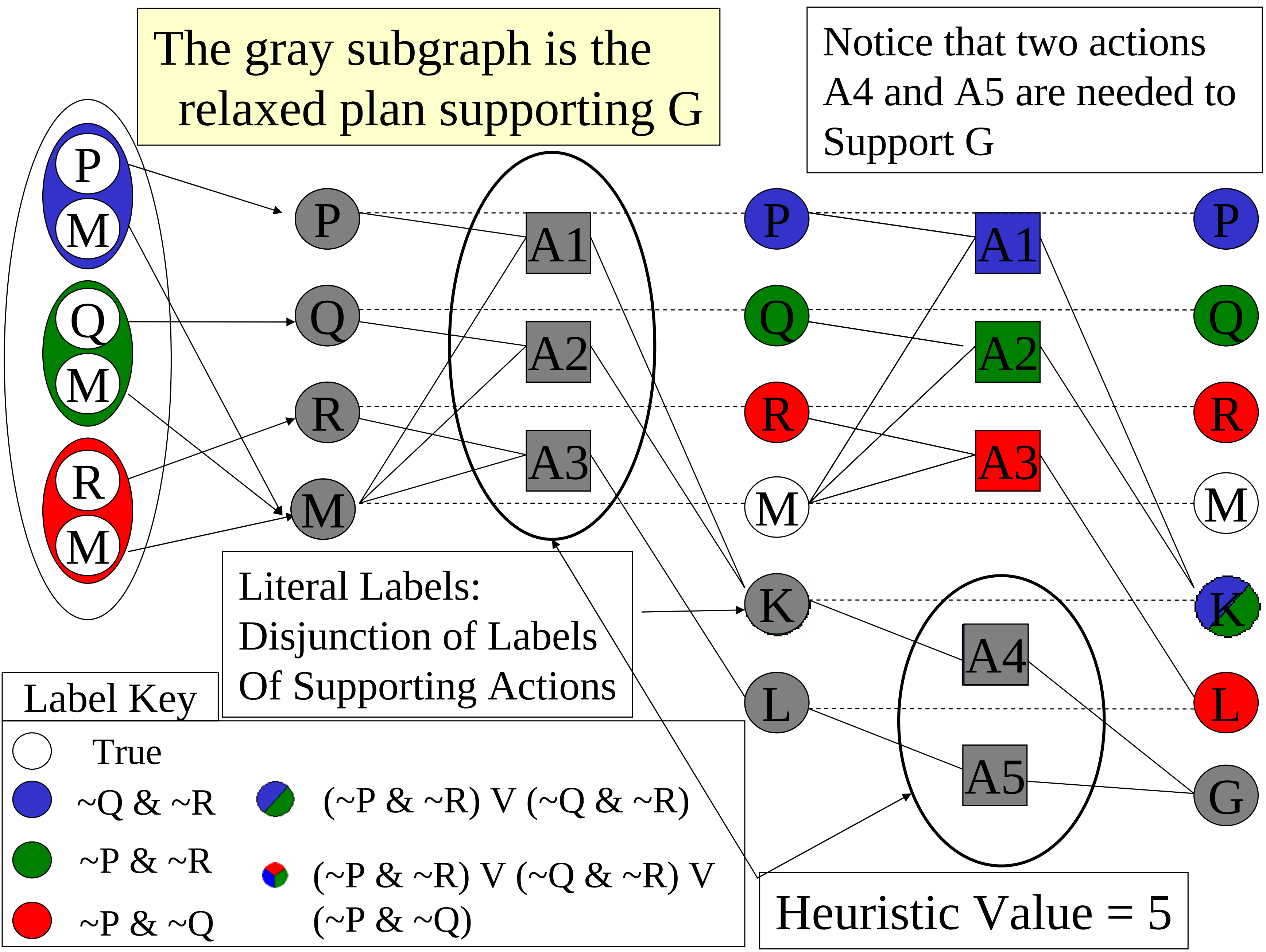
- Memory Intensive
- Heuristic Computation Can be costly

Unioning these graphs a priori would give much savings …

Using a Single, Labeled Graph



Relaxed Plan on Labeled Graph



State Agnostic Graphs

- Labelled graphs handle "state uncertainty" using labels on the PG elements
- But the same idea can be use to handle "search uncertainty"
  - We can compute a labelled graph that gives us reachability information from any set of states—including the set of *all reachable states*
    - Such state agnostic graphs do "all pairs shortest path" analysis (as against single source shortest path analysis done by normal PG).

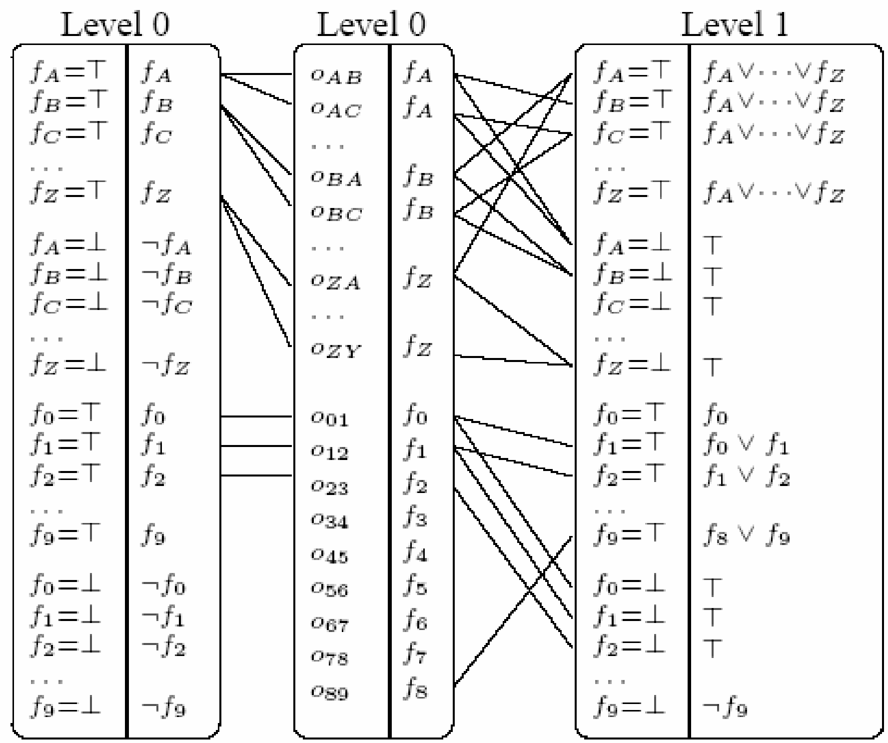


Figure 2: A SAG built for all states

Empirical Evaluation

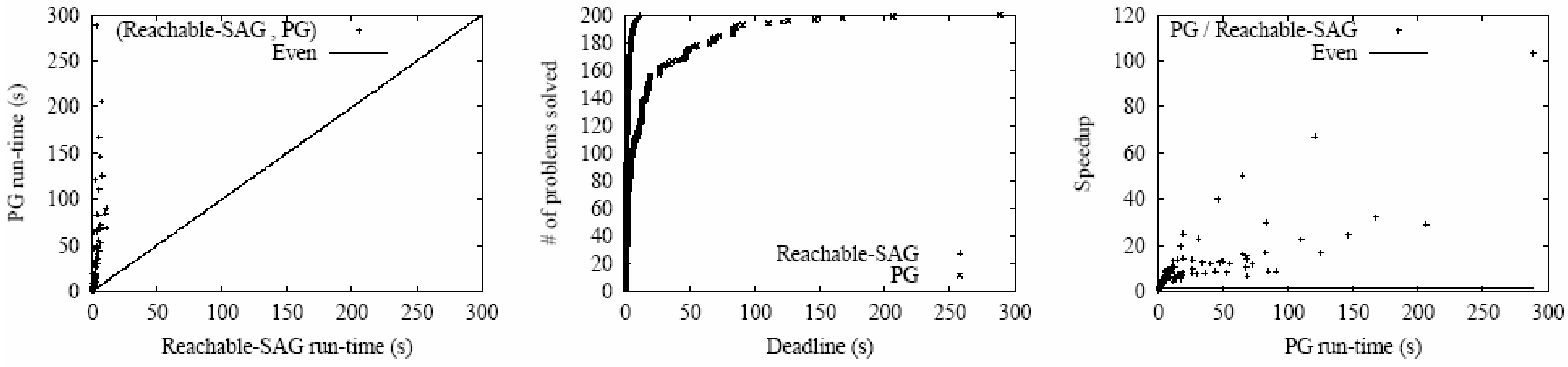


Figure 3: Reachable-SAG (using $SLUG$) vs. PG (using PG_{LUG}), Belief-Space Problems

Conformant

Conditional

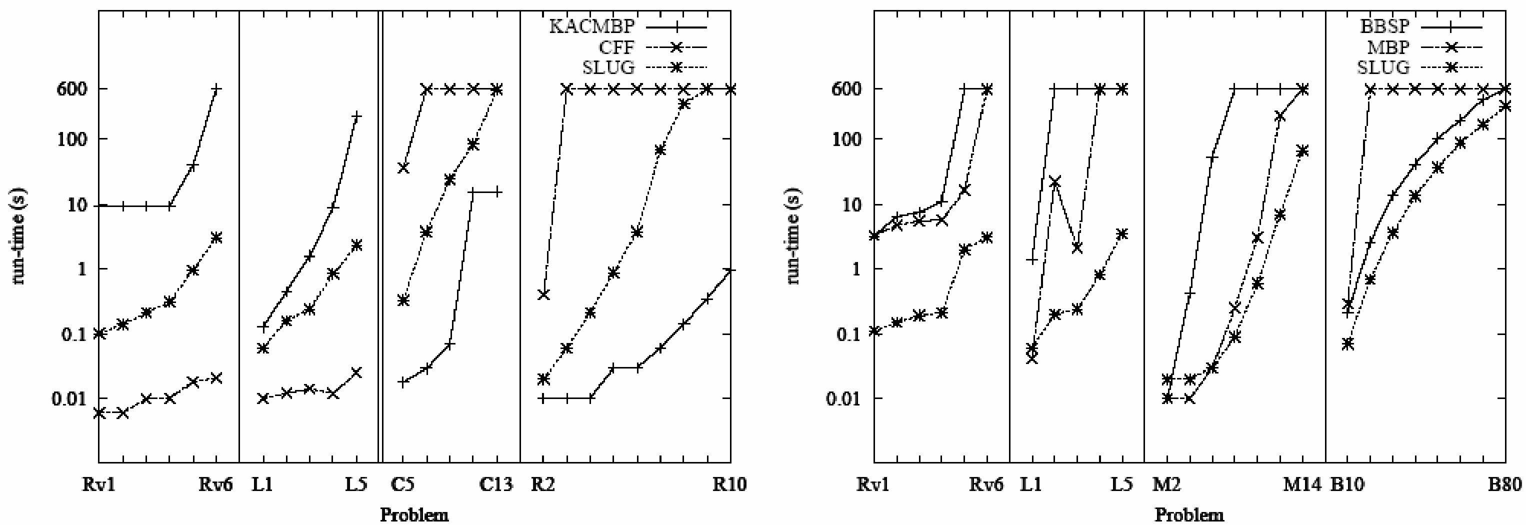


Figure 5: Comparison of planners on conformant (left) and conditional (right) domains. Four domains appear in each plot. The conformant domains are Rovers(Rv1-Rv6), Logistics(L1-L5), Cube Center(C5-C13), and Ring(R2-R10). The conditional domains are Rovers(Rv1-Rv6), Logistics(L1-L5), Medical(M2-M14), and BTCS(B10-B80).

- PG Variations
  - Serial
  - Parallel
  - Temporal
  - Labelled
  - State Agnostic

- Propagation Methods
  - Level
  - Mutex
  - Cost
  - Label

Versatility of PG Heuristics

- Planning Problems
  - Classical
  - Resource/Temporal
  - Conformant/Conditional
  - Partial Satisfaction

- Planners
  - Regression
  - Progression
  - Partial Order
  - Graphplan-style