SMAC and XGBoost your Theorem Prover

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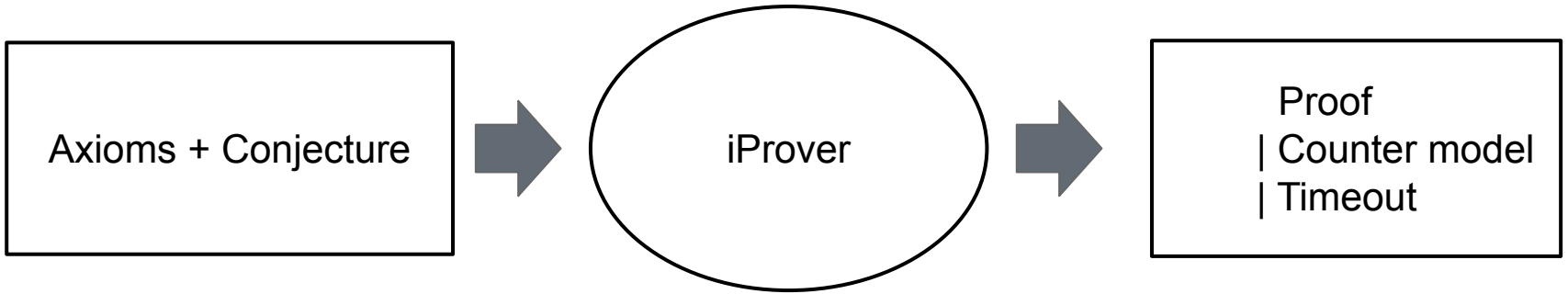
Theorem Proving in First-Order Logic



Heuristics – The Key to Success

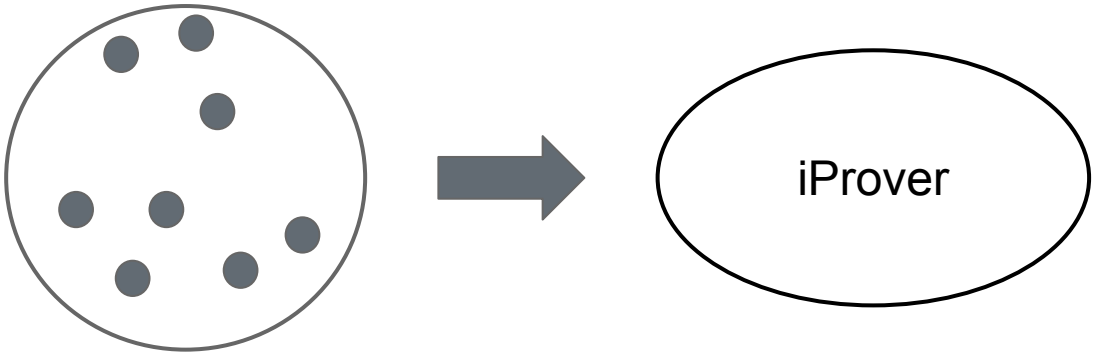
- Controls the proving process
- Crucial for performance

- No single optimal heuristic
- Manual exploration is infeasible

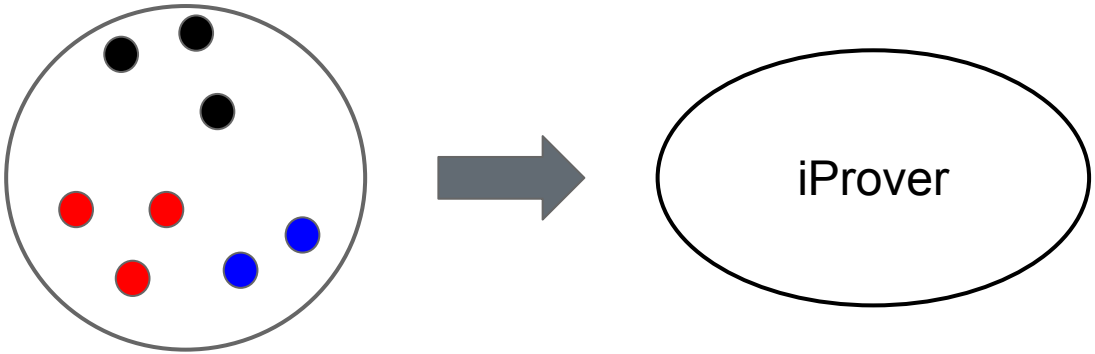
Heuristics – iProver ~100 Options

```
        ...
--instantiation_flag   true
--inst_lit_sel   [+prop;+sign;+ground;-num_var;-num_symb]
--inst_lit_sel_side  num_symb
--inst_solver_per_active  1400
--inst_passive_queues    [[-conj_dist;+conj_symb;-num_var];[+age;-num_symb]]
--inst_passive_queues_freq   [25;2]
        ...
--res_passive_queues  [[+conj_symb;-num_symb];[+age;-num_symb]]
--res_passive_queues_freq  [15;5]
--res_forward_subs  full
        ...
```

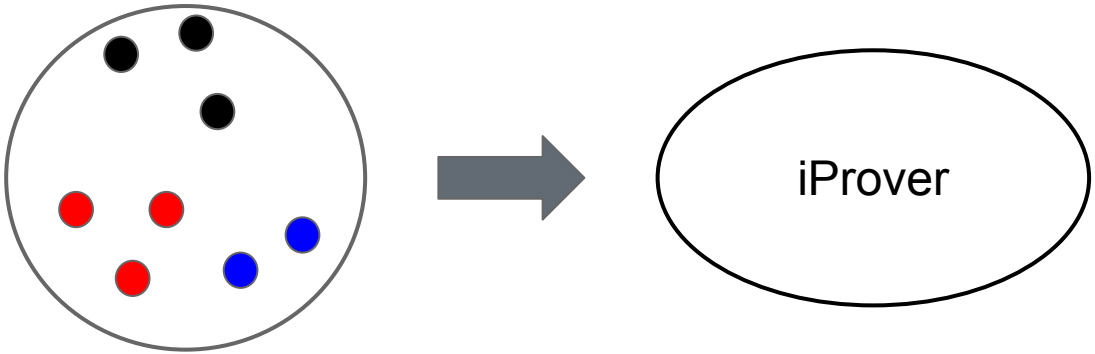
Proving Problems



Proving Problems

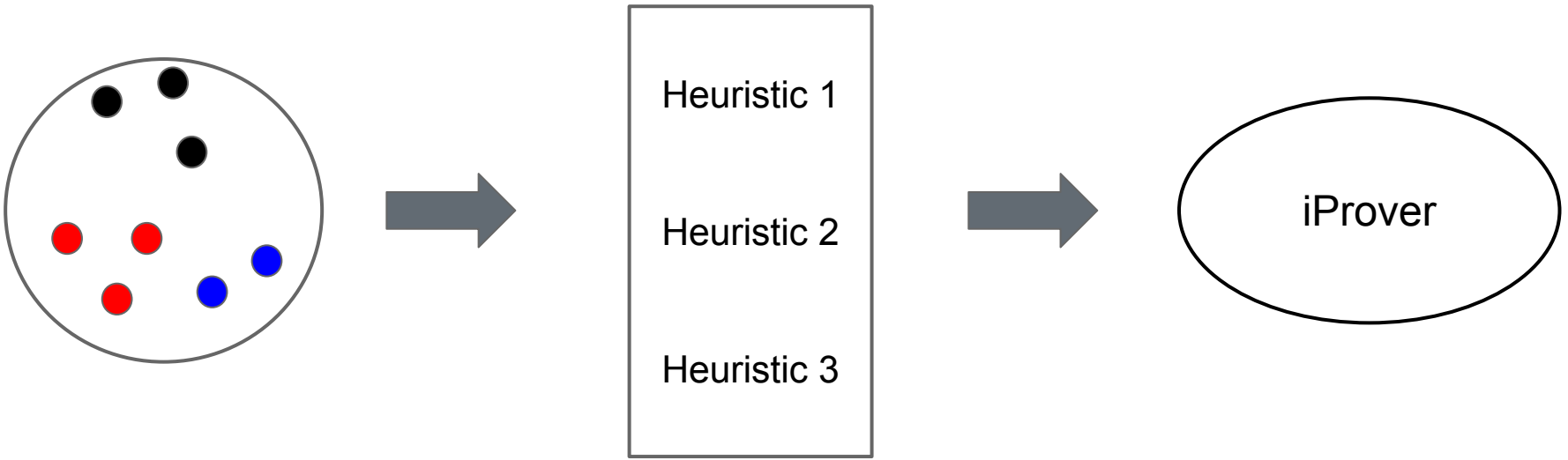


Proving Problems

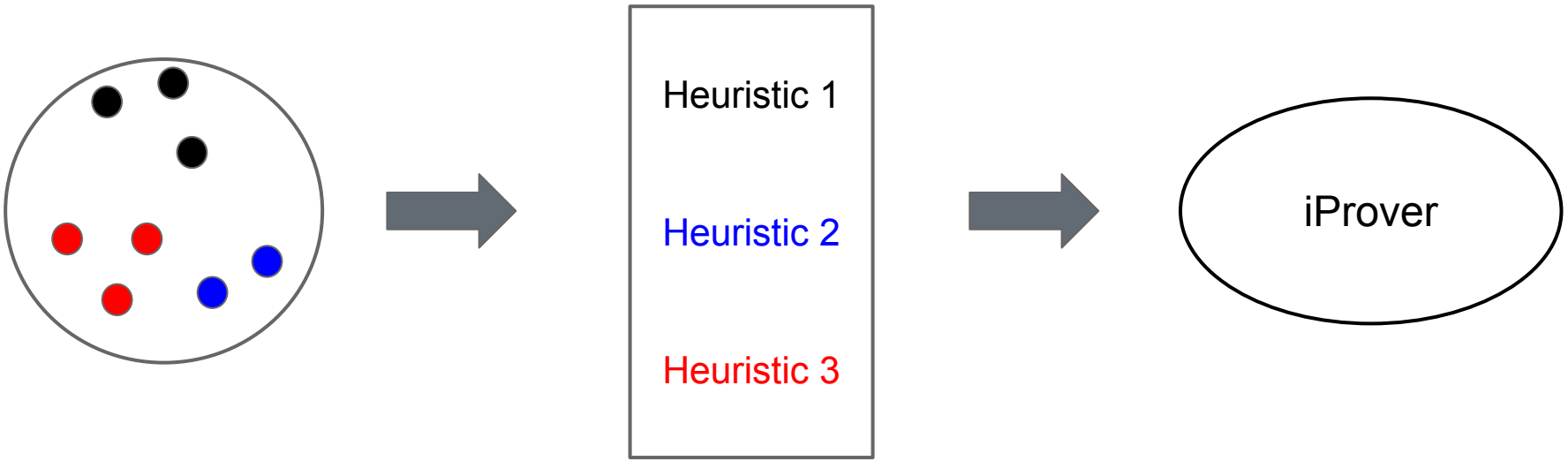


	Solved
Black	3 / 3
Blue	1 / 2
Red	0 / 3

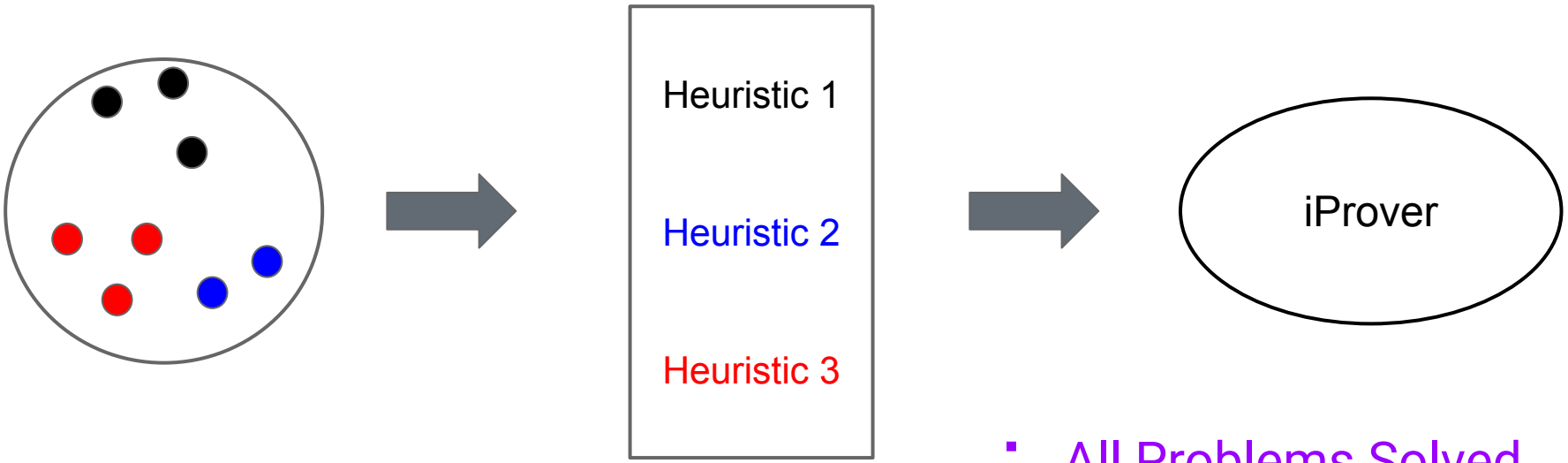
Proving Problems



Proving Problems



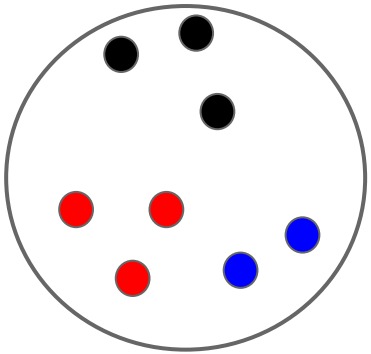
Proving Problems



∴ All Problems Solved

Proving Problems

How to group?



How to map?

What are the heuristics?

Heuristic 1

Heuristic 2

Heuristic 3

iProver

Heuristic Challenges

Phase 1

- Discover good heuristics

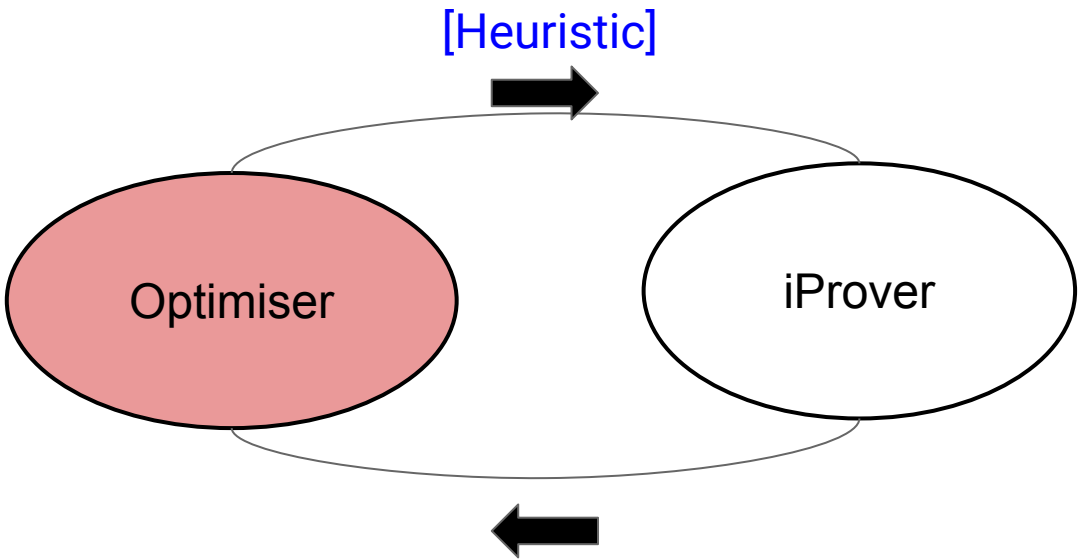
Phase 2

- Select the right heuristic

Phase 1

Learning and discovering efficient heuristics

Heuristic Learning – Optimisation

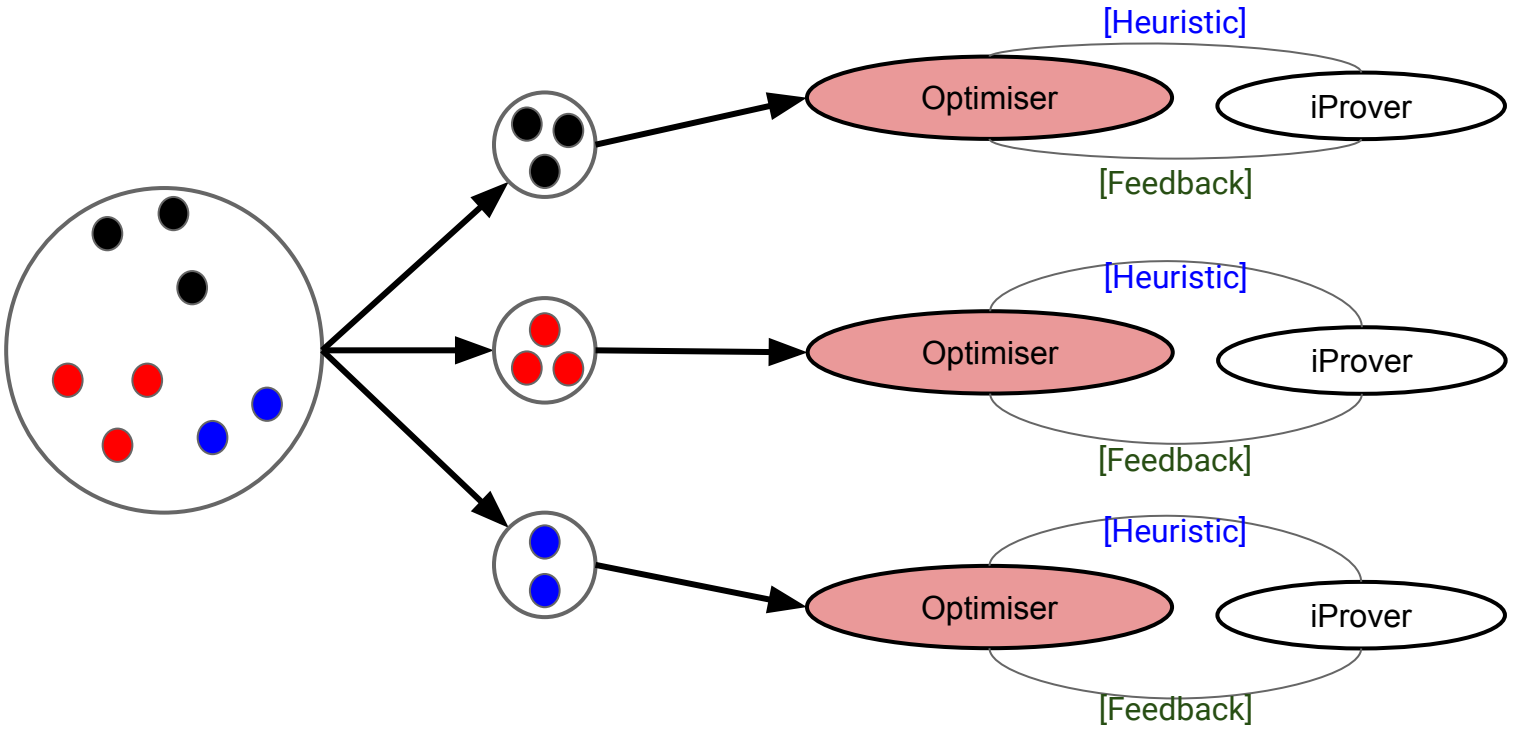


Heuristic Learning – SMAC

Sequential Model-Based Algorithm Configuration

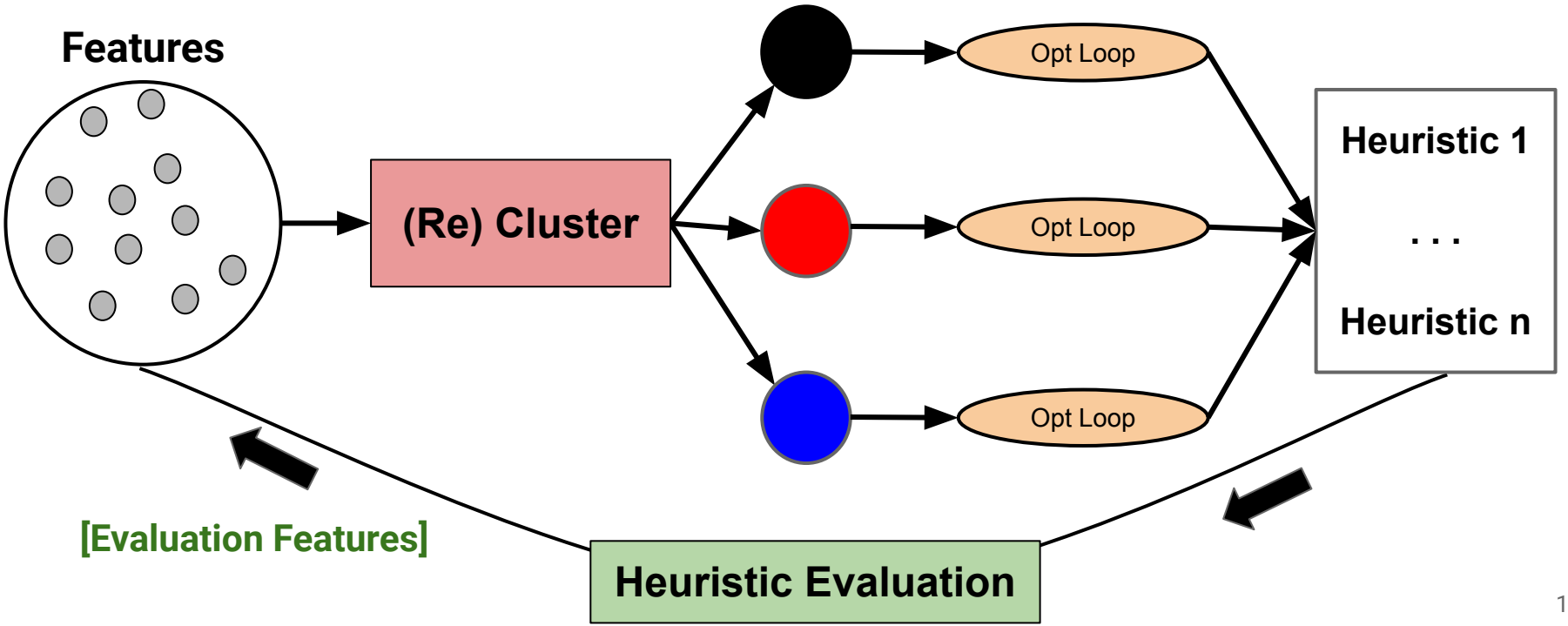
- Construct the heuristics
- Optimisation Parameters: ordinal, categorical, real
- Optimise with Random Forest
- Maximise number of solved problems

Heuristic Learning – Optimisation & Clustering

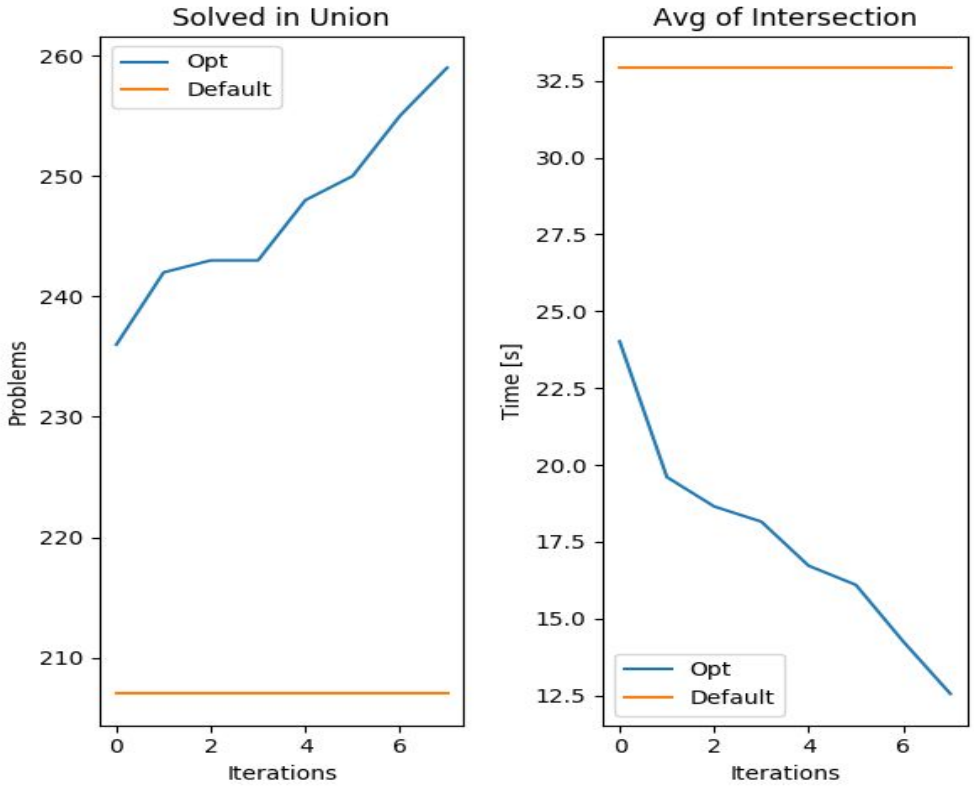


Heuristic Learning – Clustering Problems

Heuristic Learning - Overview



Heuristic Learning - Results

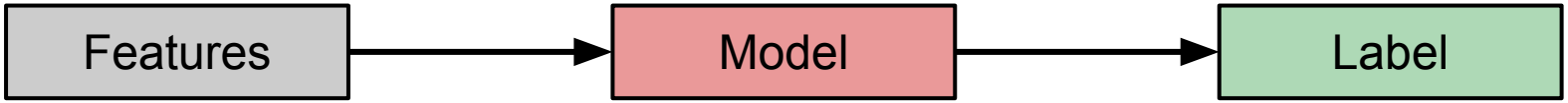


- 500 CASC FOF Problems
- Default solves 207
- Optimise ~2 days
- Optimise instantiation options

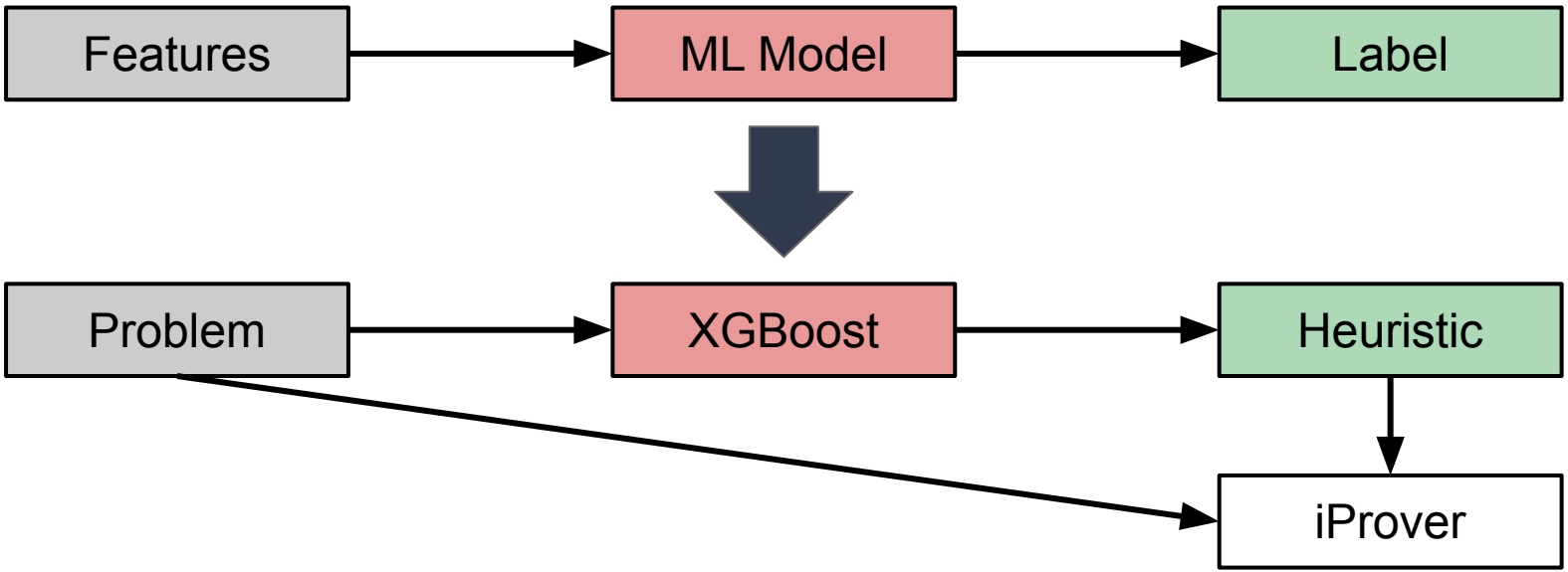
Phase 2

Selecting the best heuristic

Heuristic Mapping - Supervised Learning

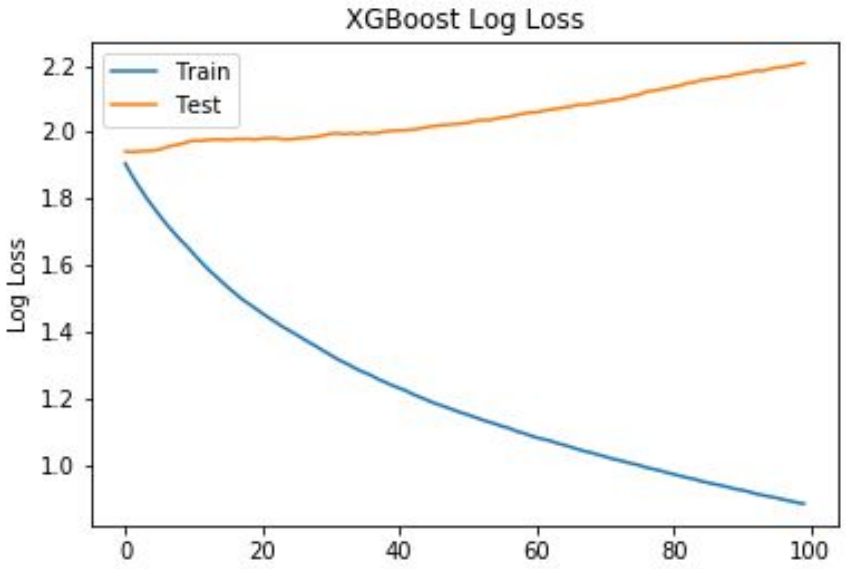


Heuristic Mapping - Overview



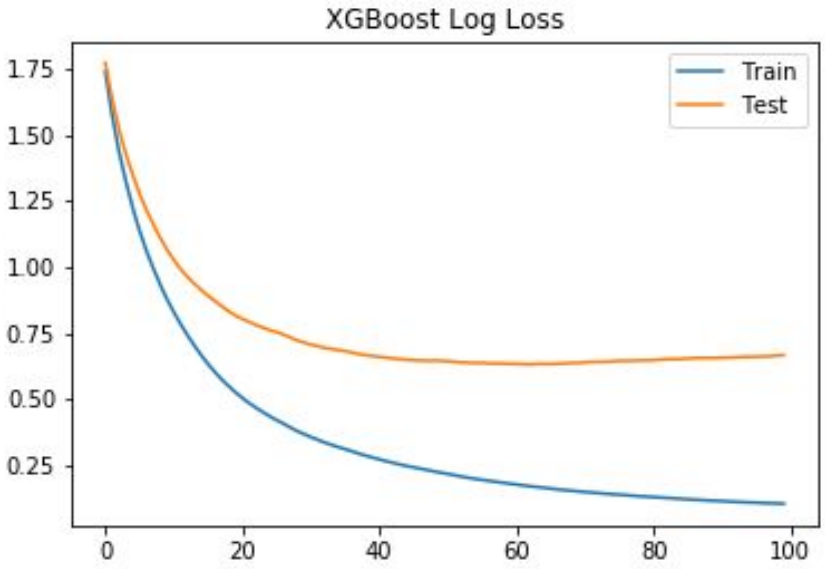
Heuristic Mapping: Labelling

Optimal Time Mapping



AVG Label Time: 27 s

Temporal Property Mapping



AVG Label Time: 42 s

Heuristic Mapping - Model Results

	10-Fold-Cross-Validation
Test Accuracy	86% ± 2%
Ratio of solved problems	88% ± 2%

Heuristic Mapping - Prover Results

	Default Heuristic	**Best Optimised Heuristic**	**Heuristic Mapping***
Solved:	207	217	**248**
AVG Time in intersection:	27.9	28.7	**26.0**

*Trained with 30-70 split

Conclusion

Heuristic evaluation to learn heuristics

- Solves 24% more problems
- Reduces solving times by 60%

Multi-class heuristic selection

- Specialised and diverse heuristics
- Solves nearly all solvable problems
- 16.3% speed improvement over default heuristic