# The More the Merrier?! Evaluating the Effect of Landmark Extraction Algorithms on Landmark-Based Goal Recognition

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February 8, 2020

# Summary

- **Motivation**
- **Goal Recognition and Landmark-Based Goal Recognition**
- **Experimentation Methodology**
  - Heuristics and Algorithms;
  - Dataset;
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  - Missing, Noisy and Full Observations
- **Conclusions**

# Motivation

- **Explore** different landmark extraction algorithms with landmark-based heuristics for goal recognition;
- **Evaluate** wether more landmarks lead to a more precise recognition;
- **Inform** future fine-tuning of algorithms to enhance recognition precision;

# Goal Recognition and Landmark-Based Goal Recognition

- **Goal Recognition**: recognize agent's goal based on it's interactions with the environment;
- **Landmarks**: necessary facts or actions that must be present in any solution plan;
- **Landmark-Based Goal Recognition**: goal recognition techniques that leverage on landmarks.

# Experimentation Methodology

- **Heuristics and Algorithms**
- **Dataset**
- **Evaluation Metrics**

# Experimentation Methodology: Heuristics and Algorithms

- 2 landmark-based heuristics for goal recognition[1]:
  - Goal Completion Heuristic ($h_{gc}$);
  - Landmark Uniqueness Heuristic ($h_{uniq}$).
- 5 landmark extraction algorithms:
  - *Exhaust*;
  - $h^{m}$[2];
  - *RHW*[3];
  - *Zhu & Givan*[4];
  - *Hoffamnn et al.*[5]
- 2 threshold values: 0% and 10%.

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[1] *Pereira et al., Landmark-Based Heurristics for Goal Recognition. AAAI, 2017.*

[2] *Keyder et al., Sound and complete landmarks for and/or graphs. ECAI, 2010.*

[3] *Richter et al., Landmarks revisited. AAAI 2008.*

[4] *Zhu L. e Givan R., Landmark extraction via planning graph propagation, 2003.*

[5] *Hoffmann et al., Ordered landmarks in planning. JAIR, 2004.*

# Experimentation Methodology: Dataset

- Dataset with goal and plan recognition problems[6];
- Problems from 15 classical planning domains;
- 6313 problems with missing and full observations with 5 observability levels (10%, 30%, 50%, 70% and 100%);
- 2850 problems with missing, noisy and full observations with 4 observability levels (25%, 50%, 75% and 100%).

[6] *Pereira F. R. e Meneguzzi F., Goal and plan recognition datasets using classical planning domains. 2017.*

# Experimentation Methodology: Evaluation Metrics

- Percentage of extracted landmarks;
- Accuracy (%);
- Spread in $\mathcal{G}$;
- Accuracy/Spread in $\mathcal{G}$ ratio;
- Recognition time (s).

- **Missing and Full Observations**
- **Missing, Noisy and Full Observations**

# Results: Missing and Full Observations

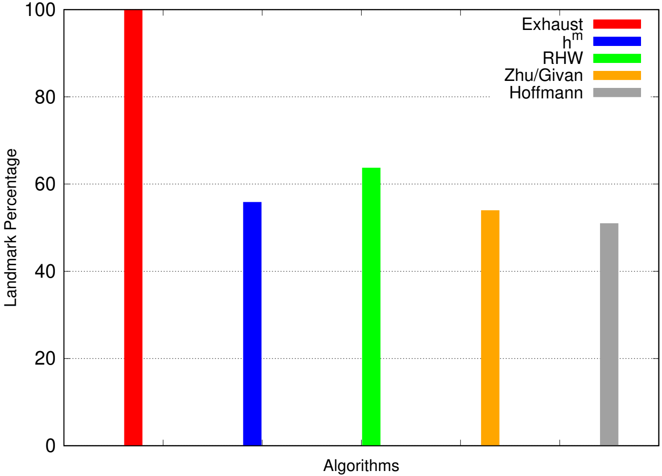


Figure: Percentage of extracted landmarks.

# Results: Missing and Full Observations

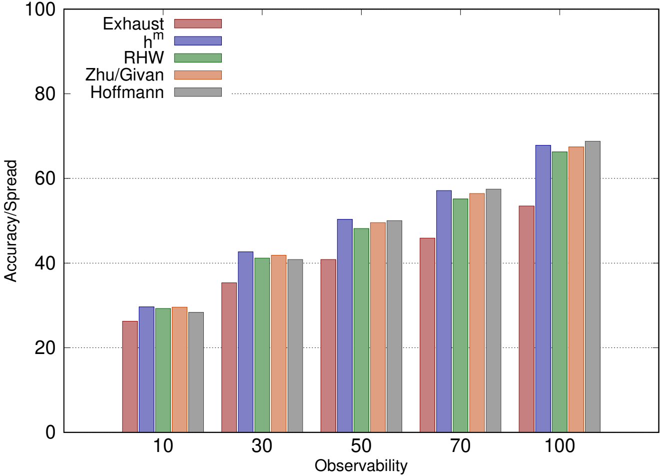


Figure: Accuracy/Spread in $\mathcal{G}$ ratio for $h_{gc}$.

# Results: Missing and Full Observations

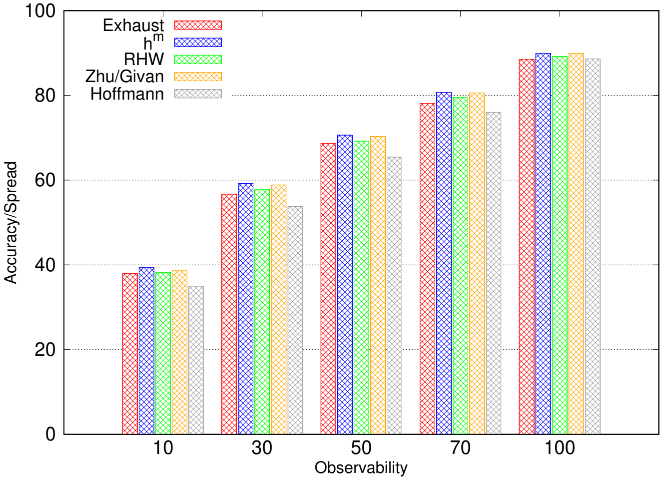


Figure: Accuracy/Spread in $\mathcal{G}$ ratio for $h_{uniq}$.

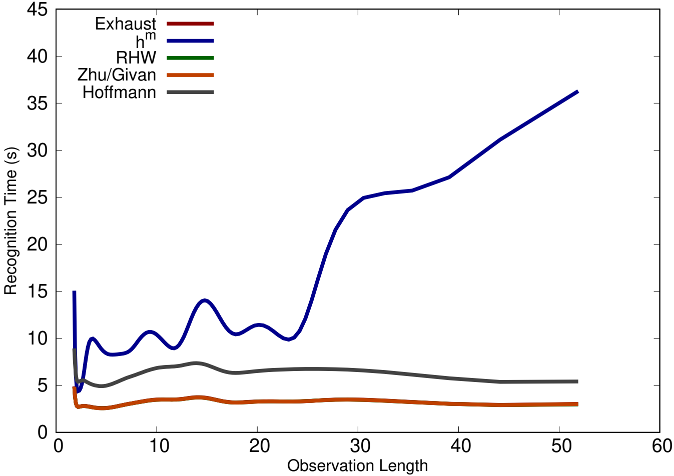


Figure: Recognition time for $h_{gc}$.

# Results: Missing and Full Observations

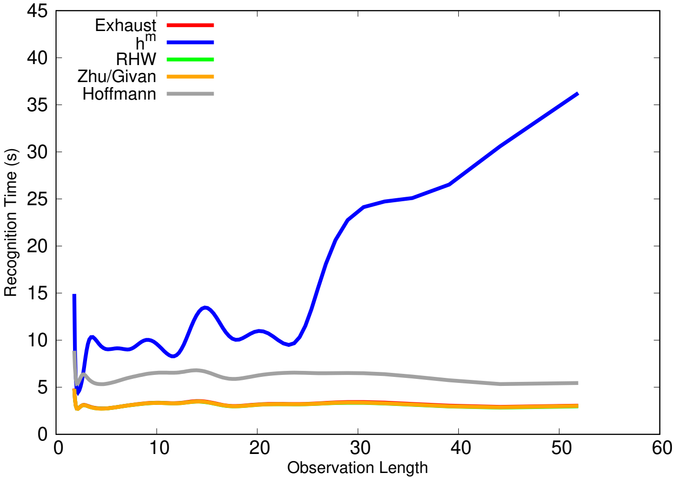


Figure: Recognition time for $h_{uniq}$.

# Results: Missing, Noisy and Full Observations

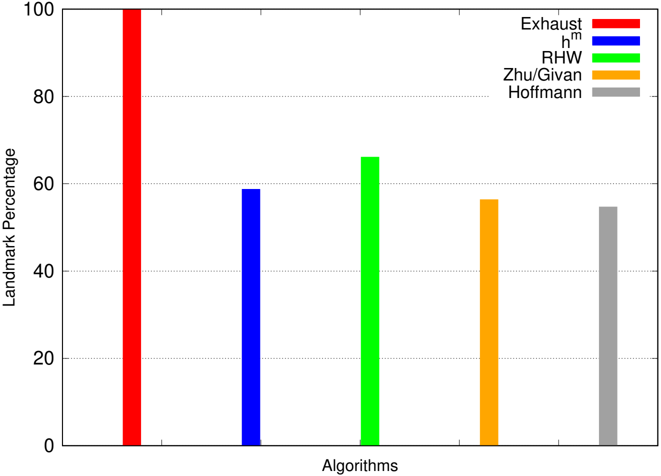


Figure: Percentage of extracted landmarks.

# Results: Missing, Noisy and Full Observations

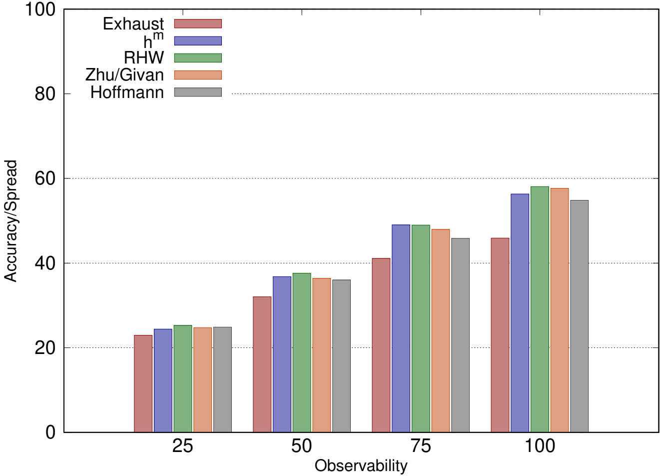


Figure: Accuracy/Spread in $\mathcal{G}$ ratio for $h_{gc}$.

# Results: Missing, Noisy and Full Observations

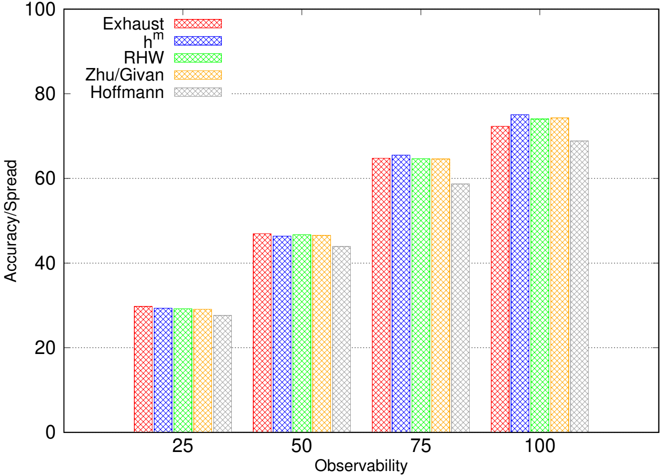


Figure: Accuracy/Spread in $\mathcal{G}$ ratio for $h_{uniq}$.

# Results: Missing, Noisy and Full Observations

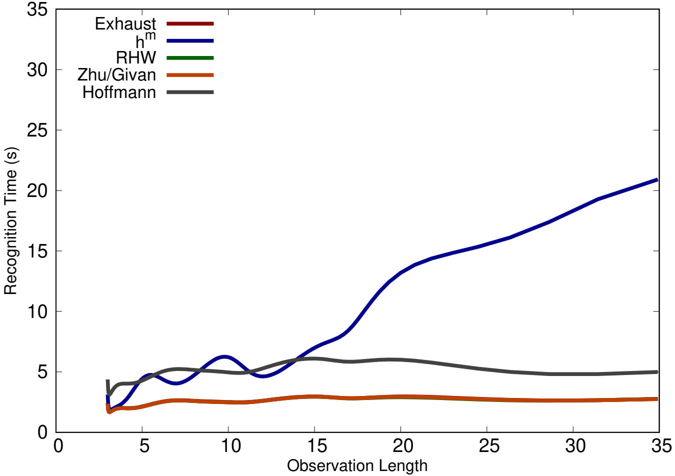


Figure: Recognition time for $h_{gc}$.

# Results: Missing, Noisy and Full Observations

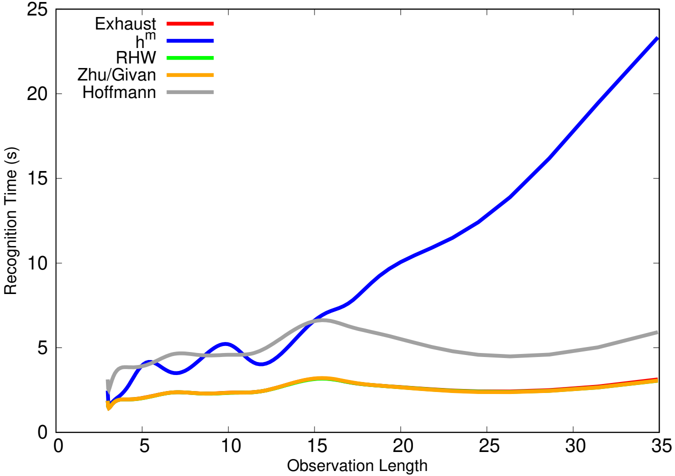


Figure: Recognition time for $h_{uniq}$.

# Conclusions

- Quantity is not more important than quality;
- Algorithms with higher extraction capability obtained better performance with $h_{uniq}$;
- Quantity matters more when dealing with noisy observations.

Thank You!

Questions?