

Inferential Approach to Mining Surprising Patterns in Hypergraphs

Nil Geisweiller, Ben Goertzel

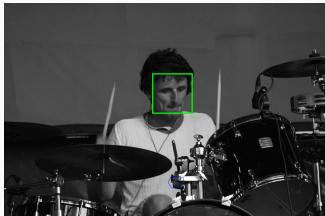
AGI-19, Shenzhen



SingularityNET



Reframing **learning** as reasoning



\Rightarrow

$\mathcal{T} \vdash \mathcal{F}$

Reframing mining surprising patterns as reasoning

1. Learning frequent patterns
2. Assessing their surprisingness

Learning how to reason efficiently

Inference Control Meta-learning

Unified Rule Engine

- Evolves Inference Trees

$$\frac{A \quad \frac{A \rightarrow C \quad C \rightarrow B}{A \rightarrow B} \text{ (MP)}}{B} \text{ (DED)}$$

Inference Control Meta-learning

Unified Rule Engine

- Evolves **Inference Trees**
- **Control Rules** to select premises and rules

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Inference Control Meta-learning

Unified Rule Engine

- Evolves **Inference Trees**
- **Control Rules** to select premises and rules

$$\frac{A \quad \frac{A \rightarrow C \quad C \rightarrow B}{A \rightarrow B} \text{ (MP)}}{B} \text{ (DED)} \quad \Rightarrow \quad \begin{array}{c} ? \\ \frac{\text{DED}}{\text{MP}} \end{array}$$

Mining Frequent Patterns

Brute force algorithm:

- \mathcal{D} : *database*
- S : *minimum support*
- \mathcal{C} : *pattern pool*
- P, Q : *patterns*

1. Select P from \mathcal{C}
2. Select *specialization* Q of P such that $S \leq \text{support}(Q, \mathcal{D})$
3. Add Q to \mathcal{C}
4. Repeat

Mining Frequent Patterns as Reasoning

$$\frac{S \leq \text{support}(Q, \mathcal{D}) \quad \text{spec}(Q, P)}{S \leq \text{support}(P, \mathcal{D})} \text{ (AP)}$$

Mining Frequent Patterns as Reasoning

$$\frac{S \leq \text{support}(Q, \mathcal{D}) \quad \text{spec}(Q, P)}{S \leq \text{support}(P, \mathcal{D})} \text{ (AP = A Priori Property)}$$

Mining Frequent Patterns as Reasoning

$$\frac{S \leq \text{support}(Q, \mathcal{D}) \quad \text{spec}(Q, P)}{S \leq \text{support}(P, \mathcal{D})} \text{ (AP = A Priory Property)}$$

$$\frac{S \leq \text{support}(P, \mathcal{D}) \quad \text{spec}(P, \text{Top})}{S \leq \text{support}(\text{Top}, \mathcal{D})} \text{ (AP)}$$

Mining Frequent Patterns as Reasoning

$$\frac{S \leq \text{support}(Q, \mathcal{D}) \quad \text{spec}(Q, P)}{S \leq \text{support}(P, \mathcal{D})} \text{ (AP = A Priory Property)}$$

$$\frac{S \leq \text{support}(P, \mathcal{D}) \quad \text{spec}(P, \text{Top})}{S \leq \text{support}(\text{Top}, \mathcal{D})} \text{ (AP)}$$

\Downarrow

$$\frac{S \leq \text{support}(Q, \mathcal{D}) \quad \text{spec}(Q, P)}{S \leq \text{support}(P, \mathcal{D})} \text{ (AP)} \quad \frac{\text{spec}(P, \text{Top})}{S \leq \text{support}(\text{Top}, \mathcal{D})} \text{ (AP)}$$

Mining Frequent Patterns as Reasoning

$$\frac{S \leq \text{support}(Q, \mathcal{D}) \quad \text{spec}(Q, P)}{S \leq \text{support}(P, \mathcal{D})} \text{ (AP = A Priory Property)}$$

$$\frac{S \leq \text{support}(P, \mathcal{D}) \quad \text{spec}(P, \text{Top})}{S \leq \text{support}(\text{Top}, \mathcal{D})} \text{ (AP)}$$

⇓

$$\frac{\frac{S \leq \text{support}(Q, \mathcal{D}) \quad \text{spec}(Q, P)}{S \leq \text{support}(P, \mathcal{D})} \text{ (AP)} \quad \text{spec}(P, \text{Top}) \text{ (AP)}}{S \leq \text{support}(\text{Top}, \mathcal{D})} \text{ (AP)}$$

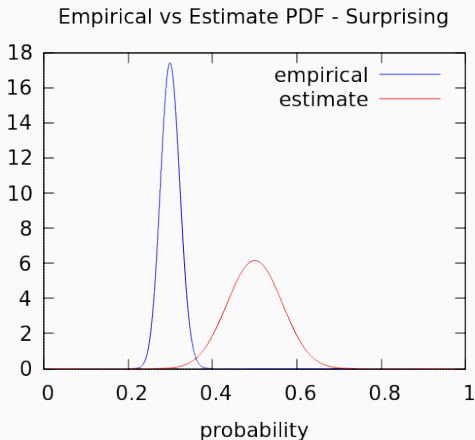
⇓

$$\frac{\frac{\frac{S \leq \text{support}(R, \mathcal{D}) \quad \text{spec}(R, Q)}{S \leq \text{support}(Q, \mathcal{D})} \text{ (AP)} \quad \text{spec}(Q, P) \text{ (AP)}}{S \leq \text{support}(P, \mathcal{D})} \text{ (AP)} \quad \text{spec}(P, \text{Top}) \text{ (AP)}}{S \leq \text{support}(\text{Top}, \mathcal{D})} \text{ (AP)}$$

Mining Surprising Patterns

Definition

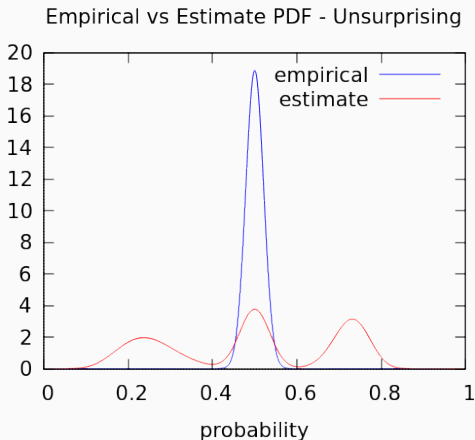
surprise: **contrary to expectation**



Mining Surprising Patterns

Definition

surprise: **contrary to expectation**



Mining Surprising Patterns as Reasoning

$$\frac{S \leq \text{support}(P, \mathcal{D}) \quad \frac{\frac{P \quad \mathcal{D}}{\text{emp}(P, \mathcal{D})} \text{ (DE)} \quad \frac{?}{\text{est}(P, \mathcal{D})} \text{ (JSD)}}{\text{jsd}(P, \mathcal{D})}}{\text{surprising}(P, \mathcal{D}, \text{jsd}(P, \mathcal{D}))} \text{ (S)}$$

Mining Surprising Patterns as Reasoning

$$\frac{S \leq \text{support}(P, \mathcal{D}) \quad \frac{\frac{P \quad \mathcal{D}}{\text{emp}(P, \mathcal{D})} \text{ (DE)} \quad \frac{\frac{P \quad \mathcal{D}}{\text{est}(P, \mathcal{D})} \text{ (IS)}}{\text{jsd}(P, \mathcal{D})} \text{ (JSD)}}{\text{surprising}(P, \mathcal{D}, \text{jsd}(P, \mathcal{D}))} \text{ (S)}$$

Mining Surprising Patterns as Reasoning

$$\frac{S \leq \text{support}(P, \mathcal{D}) \quad \frac{\frac{P \quad \mathcal{D}}{\text{emp}(P, \mathcal{D})} \text{ (DE)} \quad \frac{\frac{\vdots \quad \vdots}{\text{est}(P, \mathcal{D})} \text{ (JSD)}}{\text{jsd}(P, \mathcal{D})}}{\text{surprising}(P, \mathcal{D}, \text{jsd}(P, \mathcal{D}))} \text{ (S)}$$

Mining Surprising Patterns as Reasoning

$$\begin{array}{c}
 \frac{S \leq \text{support}(P, \mathcal{D})}{\text{surprising}(P, \mathcal{D}, \text{jsd}(P, \mathcal{D}))} \text{ (S)} \\
 \frac{\frac{P \quad \mathcal{D}}{\text{emp}(P, \mathcal{D})} \text{ (DE)} \quad \frac{\frac{\text{emp}(Q, \mathcal{D})}{\vdots} \quad \frac{\vdots}{\text{est}(P, \mathcal{D})} \text{ (JSD)}}{\text{jsd}(P, \mathcal{D})}}{\text{surprising}(P, \mathcal{D}, \text{jsd}(P, \mathcal{D}))}
 \end{array}$$

Mining Surprising Patterns as Reasoning

$$\begin{array}{c}
 \frac{S \leq \text{support}(P, \mathcal{D})}{\text{surprising}(P, \mathcal{D}, \text{jsd}(P, \mathcal{D}))} \text{ (S)} \\
 \frac{\frac{P \quad \mathcal{D}}{\text{emp}(P, \mathcal{D})} \text{ (DE)} \quad \frac{\frac{\text{emp}(Q, \mathcal{D})}{\vdots} \quad \frac{\vdots}{\text{est}(P, \mathcal{D})} \text{ (JSD)}}{\text{jsd}(P, \mathcal{D})}}{\text{surprising}(P, \mathcal{D}, \text{jsd}(P, \mathcal{D}))}
 \end{array}$$

Dynamic Surprisingness!

SUMO: *Suggested Upper Merged Ontology*

- 25K terms
- 80K axioms
- Covers many domains
 - Economy
 - Finance
 - Food
 - Sports
 - Music
 - ...
- Open Source

Domain: Geography

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  (ListLink
    (LambdaLink
      (VariableNode "$X")
      (PresentLink
        (InheritanceLink
          (VariableNode "$X")
          (ConceptNode "SaltWaterArea")
        )
        (InheritanceLink
          (VariableNode "$X")
          (ConceptNode "MaritimeClaimArea")
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      )
    )
  )
  (ConceptNode "sumo")
)
```

Domain: CountriesAndRegions

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(EvaluationLink (stv 0.99387284 1)
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        (VariableNode "$Y")
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      (PresentLink
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          (ListLink
            (VariableNode "$X")
            (ConceptNode "WesternEurope")
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        )
      )
    )
    (EvaluationLink
      (PredicateNode "dependentGeopoliticalArea")
      (ListLink
        (VariableNode "$Y")
        (VariableNode "$X")
      )
    )
  )
)
(ConceptNode "sumo")
)
```


Domain: CountriesAndRegions

```
(EvaluationLink (stv 0.98713296 1)
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  (ListLink
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        (VariableNode "$Y")
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      (PresentLink
        (EvaluationLink
          (PredicateNode "dependentGeopoliticalArea")
          (ListLink
            (VariableNode "$Y")
            (VariableNode "$X")
          )
        )
      )
    )
    (MemberLink
      (VariableNode "$X")
      (ConceptNode "EuropeanNation")
    )
  )
  (ConceptNode "sumo")
)
```

Domain: CountriesAndRegions

```
(EvaluationLink (stv 0.98350379 1)
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      (PresentLink
        (EvaluationLink
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          (ListLink
            (VariableNode "$X")
            (ConceptNode "NorthAtlanticOcean")
          )
        )
      )
    (MemberLink
      (VariableNode "$X")
      (ConceptNode "AmericanState")
    )
  )
)
(ConceptNode "sumo")
)
```

Domain: Economy

```
(EvaluationLink (stv 0.97436702 1)
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  (ListLink
    (LambdaLink
      (VariableNode "$X")
      (PresentLink
        (EvaluationLink
          (PredicateNode "economyType")
          (ListLink
            (VariableNode "$X")
            (ConceptNode "AdvancedEconomy")
          )
        )
      )
    (EvaluationLink
      (PredicateNode "economyType")
      (ListLink
        (VariableNode "$X")
        (ConceptNode "DevelopedCountry")
      )
    )
  )
)
(ConceptNode "sumo")
)
```

Examples