Hybrid Belief Pruning with Guarantees for Viewpoint-Dependent Semantic SLAM

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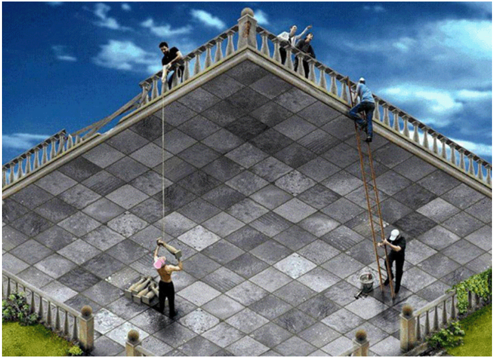
Introduction

- Today, robots performing complex tasks.
- Semantic maps are often needed.
- Advances in object recognition and classification enable the mapping.
- Usually it is assumed semantic observations are viewpoint independent $p(z^s \mid c_n)$.

Class- and Viewpoint-Dependent

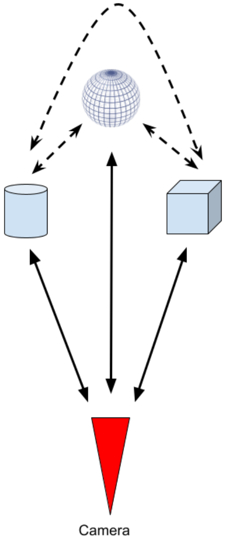
A viewpoint-dependent observation model is more natural.

- Looking on the people below - it's a floor
- Looking on the people above - it's a roof.



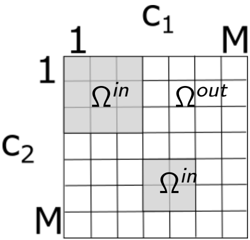
Problem Formulation

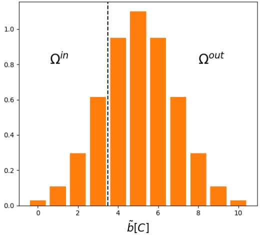
- View-dependent observation model $p(z^s \mid c_n, x^r)$.
- Classes and camera pose are dependent.
- Classes of different objects are dependent.
- $\#\text{classes}^{\#\text{objects}}$ hypotheses.
- Pruning hypotheses is essential.

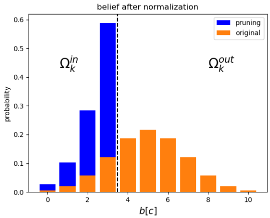


Problem Formulation - Continuation

- Ω^{in}, Ω^{out} - maintained and pruned sets
- $\tilde{b}[C]$ - unnormalized belief.
- $\eta = \left(\sum_{C \in \mathcal{C}} \tilde{b}[C]\right)^{-1}$ - normalizer.
- $\eta_{prun} = \left(\sum_{C \in \Omega^{in}} \tilde{b}[C]\right)^{-1}$ - after pruning.
- $b[C] = \eta \tilde{b}[C] \leq \eta_{prun} \tilde{b}[C]$.
- No indication about pruned hypotheses.







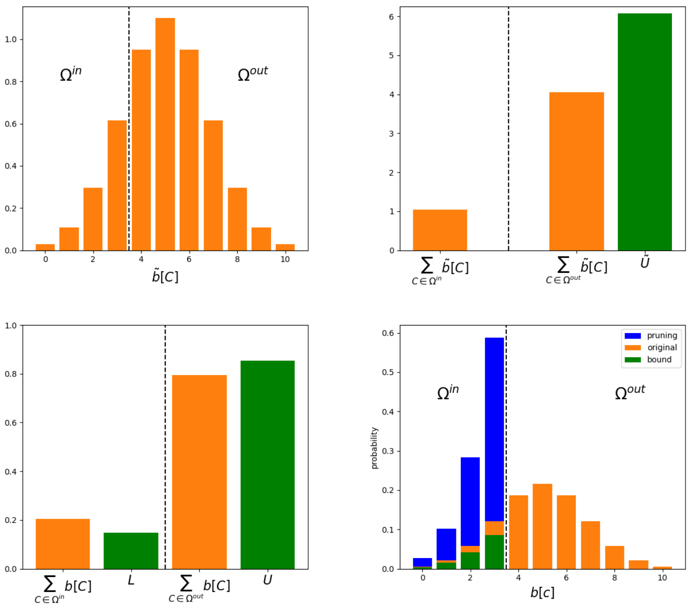
Approach

We consider two cases:

- Independent prior: $\mathbb{P}_0\left(C\right) = \prod_{n=1}^{N} \mathbb{P}_0\left(c_n\right)$.
- Dependent prior: $\mathbb{P}_0\left(C\right) \neq \prod_{n=1}^{N} \mathbb{P}_0\left(c_n\right)$.

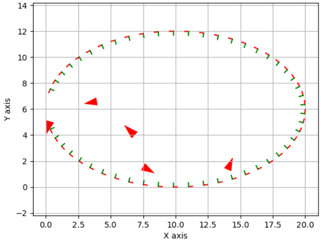
By obtaining the normalization factor/lower bound, we

- Probabilities/lower bounds.
- Indication of pruned hypotheses.
- Conservative belief.

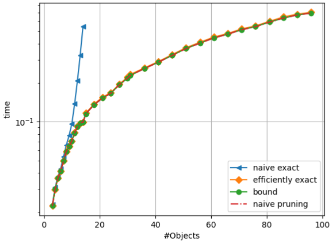


Ωin
Ωout
b̃[C]
∑ b̃[C] C∈Ωin
∑ b̃[C] C∈Ωout
Ũ
∑ b[C] C∈Ωin
L
∑ b[C] C∈Ωout
U
pruning
original
bound
probability
b[c]

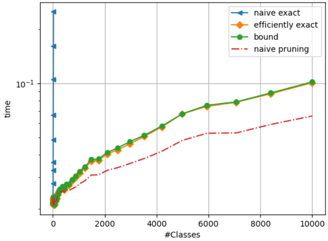
Experiments



simulated environment

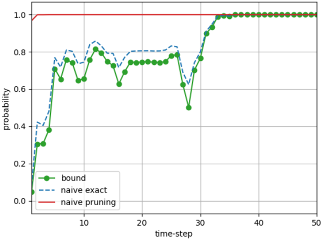


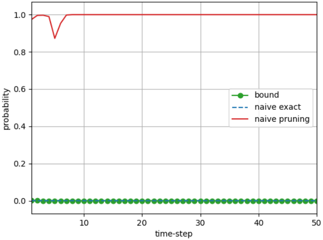
running time vs #objects



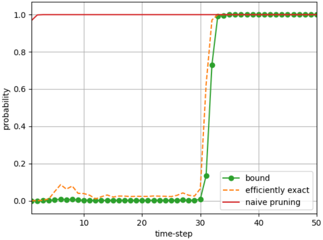
running time vs #classes

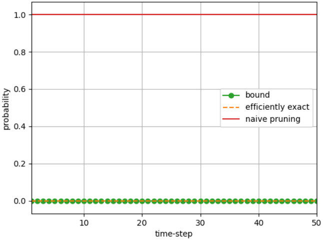
Experiments





$C^{(t)} \in \Omega^{in}$ *Dependent* prior (a) $C^{(t)} \notin \Omega^{out}$





$C^{(t)} \in \Omega^{in}$ *Independent* prior $C^{(t)} \notin \Omega^{out}$

Conclusions

- View-dependent model - coupling.
- Exponential number of hypotheses.
- Naive pruning - overconfident.
- The proposed alternatives:
  - Guarantee confidence in classification.
  - Runtime nearly same.
  - More accurate.