Minesweeper Solver

Project proposal

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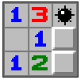

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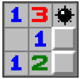

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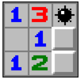
Notation

For any block x, y on the board, we have 3 states:

1. Undetected $U_{x,y} = True/False$
2. Detected with the number of mines around it $D_{x,y}^{num} = True/False$, $num \in (0, 1, \ldots, 8)$
3. With mine underneath $M_{x,y} = True/False$

We could encode all the information on the board with these 3 states.



Translating the rules

1. each block that is detected with the number have number of mines that are the same of number of this block $\forall(x, y)$, $mines\_around(x, y) == num(x, y)$
2. each block contains exactly one number $\forall(x, y)$, $exactly\_one(D_{x,y}^{num})$, $num \in (0, 1, \ldots, 8)$

Ask queries

We will query each block on the frontier whether it is mine. If it is possible to give a satisfiable assignment in limited steps, we will take this action and update knowledge base to keep inference which block is possible mine.

If SAT solver could not find satisfiable assignment in limited time, we would stop it and use other methods.

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Minesweeper CSP Model

With current observation K (i.e. the knowledge matrix), we can enumerate all configurations compatible with K, then

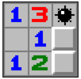
- deduce for each cell c whether it is safe (no configuration where c is mined)
- deduce for each cell c whether it is mined (c is mined in all configurations)
- compute the probability for c to be mined as the ratio

$$p_m(c) = \frac{\#\ \text{(cfgs where c is mined)}}{\#\ \text{(all cfgs)}}$$

CSP Formulation

Searching for a single configuration compatible with K can be formulated as a CSP as follows:

- $\forall c = (i, j),\ x_{i,j} \in \{0, 1\}$
- $\forall c = (i, j),\ (K_{i,j} \geq 0) \Rightarrow (x_{i,j} = 0)$
- $\forall c = (i, j),\ (K_{i,j} \geq 0) \Rightarrow (\sum_{c'=(i',j') \in a(c)} x_{i',j'} = K_{i,j})$
- $(\sum_{c=(i,j)} x_{i,j} = m$



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POMDP Model

POMDP: Partially Observable Markov Decision Process

- Generalization of a Markov decision process (MDP)
- Agent cannot directly observe the underlying state
- Maintain a probability distribution over the set of possible states

Minesweeper POMDP Model

Minesweeper game can be modeled as a POMDP $< S, S_e, A, T, R, O, \Omega, b_0 >$ where:

- set of states S: init state, normal states, failure state
- terminal state S_e: success state, failure state
- actions in A: try hidden cell c
- transition function T
- reward $R(s, a, s')$
- observations in O
- observation function Ω: updates the knowledge matrix according to the last action
- b_0: initial probability distribution over states

POMDP Challenges

Belief space is huge:

- $2^{W \times H}$ states!
- Solving POMDPs exactly is computationally intractable
- MOMDP: Mixed Observability Markov Decision Process
  - we can derive a compact lower-dimensional representation of the belief space
- Monte-Carlo Tree Search

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Sample frame title

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- Text 1
- Text 2
- Text 3
- Text 4

In this slide

In this slide
the text will be partially visible

In this slide

the text will be partially visible

And finally everything will be there

Sample frame title

In this slide, some important text will be highlighted because it's important. Please, don't abuse it.

Remark

Sample text

Important theorem

Sample text in red box

Examples

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Two-column slide

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$$E = mc^2$$

- First item
- Second item

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