Enhancing the Efficiency and Effectiveness of Heuristic Search through Fractional Progress

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June 2015
Project Description

✓ Local Minimum is common throughout heuristic cost-based search

✓ Standard technique: Gradient Descent in cost

✓ Standard method gets stuck in the local minimum
Objectives

✔ Develop an algorithm that improves heuristic performance

✔ Implement the algorithm in **Robot Navigation & Neural Network**

✔ Benchmark with standard method
Robot Navigation
Local Minimum Problem in Navigation

✓ Robot can get stuck upon entering inside of C-shape obstacle

✓ To escape from that region, the potential cost have to temporarily going up

✓ The standard method always minimize the potential cost
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Fractional Progress Design

\[
\text{Past} \quad \text{progress} = \frac{\text{Past}}{\text{Past + Future}}
\]

Move to B or C? Move to B

\[
B: \quad \frac{\text{Cost } AB}{\text{Cost } AB + \text{Cost } BG} = \frac{3}{3 + 6} = 33.3 \%
\]

\[
C: \quad \frac{\text{Cost } AC}{\text{Cost } AC + \text{Cost } CG} = \frac{4}{4 + 9} = 30.7 \%
\]
Potential Fields in Navigation (1)

✓ Potential fields associate next moves with *potential values*

✓ Represent the *desirability* towards the optimal solution

✓ High potential value $\rightarrow$ less desirable position

  lowest point on the field $\rightarrow$ considered as an optimal solution
Potential Fields in Navigation (2)

✓ Goal Potential:

\[ Potential_{goal}(x, y) = (x - x_G)^2 + (y - y_G)^2 \]  \hspace{1cm} (1)

✓ Obstacle Potential:

\[ Potential_{obstacle}(x, y) = \begin{cases} 
  0, & d_i \geq \text{fall off range} \\
  \sum_{i=1}^{n} \left( \frac{1}{a_i} \right) e^{-\frac{d_i}{a_i}} - e, & d_i < \text{fall of range} 
\end{cases} \]  \hspace{1cm} (2)

✓ Total Potential:

\[ Potential_{total}(x, y) = Potential_{obstacle}(x, y) + Potential_{goal}(x, y) \]  \hspace{1cm} (3)
Fractional progress algorithm in Navigation (1)

STEP 1: Get current robot configuration
   Current and goal position, sensors data

STEP 2: Generate all sample points from current position
Fractional progress algorithm in Navigation (2)

STEP 3: For each sample point, Calculate the % fractional progress

past effort: Potential change from start to sample point

future effort: Potential change from sample point to goal

STEP 4: Apply the ‘best sample point’ (most % progress)

STEP 5: If agent robot has reached the goal, terminate

or else do step 1-4
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Robot Simulator

From previous work

Robot Simulator

Robot Controller

Controller factory
- Fractional Progress
- Standard Method

Create controller

Thread

Start

Process new sensor data

Compute control

Send control
Robot Navigation Evaluation
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<table>
<thead>
<tr>
<th>Non-Concave Obstacle</th>
<th>Low Concave Obstacle</th>
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<tbody>
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<td><img src="image1.png" alt="Non-Concave Obstacle" /></td>
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<table>
<thead>
<tr>
<th>Moderate Concave Obstacle</th>
<th>Highly Concave Obstacle</th>
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<td><img src="image4.png" alt="Highly Concave Obstacle" /></td>
</tr>
</tbody>
</table>
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Standard Method

Fractional Progress

Shallow Concave Obstacle

Moderate Concave Obstacle
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Highly Concave Obstacle

Standard Method

Fractional Progress
Robot navigation evaluation

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Summer School 2015
Neural Network
Introduction to Neural Network

Classification Task

\[ H1 = -\frac{w1}{w4} x - \frac{w3}{w4} \]
\[ H2 = -\frac{w2}{w5} x - \frac{w6}{w5} \]
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Introduction to Neural Network

Update the weights

**y**

h2

h1

x

Update the weights

**y**

h2

h1

x
Local Minimum Problem in Neural Network

✓ The standard back-propagation algorithm uses gradient descent.

✓ Standard algorithm works by minimizing the network error.

✓ At some point, network error has to temporarily go up, but the standard method does not allow to do so.
  → stuck in the local minimum problem.
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Fractional progress algorithm in Neural Network (1)

**STEP 1: Initialize the network**
- Initial weight configuration = \([w_1, w_2, w_3, w_4, w_5, w_6, w_7, w_8, w_9]\)
- Start = initial network error
- Goal = 0

**STEP 2: Generate list of sample points**
- Example: \([w_1, w_2]\)
- Rate of change \((rc)\)
Fractional progress algorithm in Neural Network (2)

STEP 3: For each sample point, Calculate the % fractional progress
- Validate the sample point
- Potential = network error
- Past effort: Potential change from start to sample point
  Future effort: Potential change from sample point to goal

STEP 4: Apply the ‘best sample point’ (most % progress)

STEP 5: If stopping condition is true, terminate or else do step 1-4
In order to evaluate the general performance of the fractional progress, initial hyperplane(s) position was set to random position.

Average Execution time per cycle

<table>
<thead>
<tr>
<th>Method</th>
<th>Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Method</td>
<td>0.007</td>
</tr>
<tr>
<td>Fractional Progress</td>
<td>8.22</td>
</tr>
</tbody>
</table>
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Enhancing the Efficiency and Effectiveness of Heuristic Search through Fractional Progress

Standard Method

Fractional Progress

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Conclusion
Conclusion

- Implement the fractional progress technique in the robot navigation and neural network.

- Design local minimum problems

- Evaluate the performance of fractional progress against the standard method.
Thank you