Problem Statement

► **Problem:** Robustify mission planning to uncertainty caused by classification errors in situational awareness

► Robust mission planning of TV

$$\max \sum_{i=1}^{N} f(C_i)x_i$$

s.t. \(x_i \in \{0,1\} \) and \(\sum x_i \leq n\)

where \(f\) maps reward distribution \(C\) into a score

► Reconnaissance also an explicit task – assign EV to reduce uncertainty

$$\max \sum_{i=1}^{N} (g(C_i) - E_y g(C_i|z_i)) y_i$$

s.t. \(y_i \in \{0,1\}\) and \(\sum y_i \leq m\)

► Decoupled approach of allocating EV and TV can lead to inefficient assignments

► How to explicitly relate the Vol in the uncertainty reduction to the mission performance with non-Gaussian errors?

Approach: Vol Based Coupled Planning

► Combines TV and EV optimizations to explicitly accounts for score improvements associated with exploration that are most relevant to mission

$$\begin{align*}
\max & \sum_{i=1}^{N} E_{x_i} f(C_i|x_i) + f(C) x_i(1 - y_i) \\
\text{s.t. } & x_i, y_i \in \{0,1\}, \quad \sum x_i \leq n, \quad \sum y_i \leq m
\end{align*}$$

► Recovers Vol by coupling exploration into tasking

► Consensus-Based Bundle Algorithm (CBBA)

► incorporate system dynamics

► decentralized

► polynomial in number of targets and vehicles

Algorithm 1 Vol Based Coupled Planning

1: initialize candidate solution queue \(Q\)
2: while UTV requirement not satisfied do
3: \(P = \text{nextBestCandidate}(Q)\)
4: \(Q = \{Q, \text{sub-candidates}(P)\}\)
5: call CBBA to assign UTVs
6: \(A_T = \text{CBBA}(P, \text{agents, tasks})\)
7: call CBBA to assign UEVs
8: \(A_E = \text{CBBA}(A_T, \text{agents, tasks})\)
9: check whether UTV requirement
10: checkMatch \((A_T, A_E)\)
11: end while
12: return \(A_T, A_E\)

Test Algorithm in Hardware

► Robot perform missions over targets with cameras to identify target classification

► Hardware setup:

> TV: iRobot Create

> EV: PTZ security camera

> Targets: Colored paper on floor

- Dominant color represents target classification
- Other colors add noise/uncertainty

Information Gathering

► Measurement Process

(a) camera picture

(b) target hue

(c) color histogram

(d) class prob.

- Camera reports a pixel of the picture as a measurement
- Picture not pure in color
  => measurement has noise

Measurement Model:

- Extract color information, Fig. (b)
- Histogram of color values, Fig. (c)
- Probability of report 4 (yellow, green, blue, red) classifications, Fig. (d)

► Effect on mission performance

- Measurements are imperfect
- Uncertainty can be further reduced by taking more measurements
- Longer dwell time
  => More information
  => Less uncertainty
  => Higher score

Execution Result

► Coupled outperforms Decoupled

- Evaluate information gathered by improvement in mission score
- Encourage collaboration between exploration and tasking agents
- Has less uncertainty thus higher score when executing tasks

Summary

► Evaluate information gathering directly by improvement in mission score

► Developed a planning algorithm that explicitly ties information gathering to mission performance

► Tested proposed algorithm on hardware testbed with context of classification uncertainty

Refs[1–3]

