Unsupervised Scoring for Scalable Internet-based Collaborative Teleoperation

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The Problem

- Many users simultaneously share control using browser-based point-and-click interfaces
- MOSR – Multiple Player Single Robot
Why do we care?

- Evaluate user performance in distance learning, automated methods
- Provides individual assessment/reward and incentive for active participation
- Other applications
Contributions

- “Unsupervised Scoring": a numerical measure of individual performance based on clustering and response time.
- It does not rely on a human expert to evaluate performance
- Performance based on “leadership”: how quickly users anticipate the decision of the majority
Contributions

- A new user interface incorporating this metric using Java is implemented.
- A distributed algorithm for rapidly computing and displaying user scores is described.
Methods

- Unsupervised scoring metric based spatial distributions of votes
- Task: location picking
- For each user $i$, for mouse click of $(x,y)$ on image $k$ at time $t$, define the corresponding vote $v_{ik}(t) = [x_{ik}(t), y_{ik}(t)]$
Methods

- Voter Interest function:

  \[ f_{ik}(x, y) \sim N(v_{ik}(t), \Sigma_{ik}(t)) \]

  - A truncated bivariate normal density function with mean at \( v_{ik}(t) \) (votel)
  - \( \Sigma_{ik}(t) \) is a 2x2 variance matrix, such that

  \[ \iint_{\sigma} f_{ik}(x, y) \, dx \, dy = 1 \]
Methods

- **Ensemble Interest Function**

  \[ f_k(x, y) = \frac{1}{n} \sum_{i=1}^{n} f_{ik}(x, y) \]

  - Normalized sum of voter interest functions

- **Consensus Region**

  - The cutting plane defines an iso-density contour in the Ensemble Interest Function that defines a set of subsets of voting image

  \[ S_k = \{(x, y) \mid f_k(x, y) \geq z_k\} \]
Methods

- Majority Consensus Region
  - Consensus region with most votels

\[
C_k = \text{Max}(\sum_{i=1}^{n} I_k(i, j))
\]

- Let:
  \[
  I_k(i, j) = \begin{cases} 
  1 & \text{if } [x_{ik}(T), y_{ik}(T)] \in C_{jk} \\
  0 & \text{otherwise}
  \end{cases}
  \]

Index for votels inside consensus region j
Unsupervised Scoring Metric

- How well the voter anticipated the majority consensus region
  \[ \frac{T_s - t_{s,i}}{T_s} I_{s,i} \]
  - \(I_s\) Outcome index for voter \(i\) and voting image \(s\) (majority consensus region)
  - \(t_{s,i}\) Duration of the time stay in majority interest region
  - \(T_s\) Total voting time for image \(s\)

- Pass the term to a low pass filter to stabilize “Leadership Score”

\[
L_{k+1,i} = (1 - \alpha)L_{k,i} + \alpha \frac{T_s - t_{s,i}}{T_s} I_{s,i}
\]
Tele-twister Application

- Distributed algorithm implemented in Java
- Two human players called “twisters”
- Players assigned to two teams
- View game status using low framerate video
Twister Application

- In 4 subsequent rounds, the team with highest average score consistently wins the round.
- A team have higher scores when the team collaborates, reaching consensus faster.

Average Score

- Blue Team
- Red Team
Conclusions

- An unsupervised scoring metric for collaborative teleoperation
- Encourages active participation and collaboration
- Distributed algorithm for automatically computing it