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 votel: $v_{ik}(t) = [x_{ik}(t), y_{ik}(t)]$

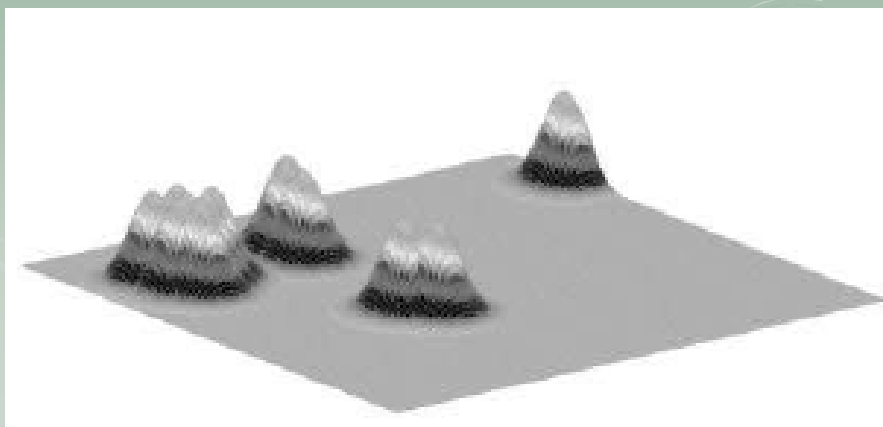
Methods

- 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)
  - $\sum_{ik}(t)$ is a 2x2 variance matrix, such that

$$\iint_{\sigma} f_{ik}(x,y)\, d_x\, d_y = 1$$



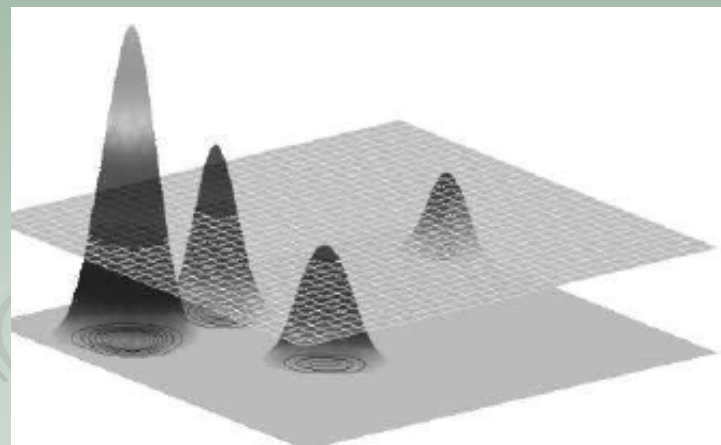
Methods

- 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

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

  - Let: $I_k(i, j) = 1 \text{ if } [x_{ik}(T), y_{ik}(T)] \in C_{jk}$

$= 0 \text{ if otherwise}$

Index for votels inside consensus region j

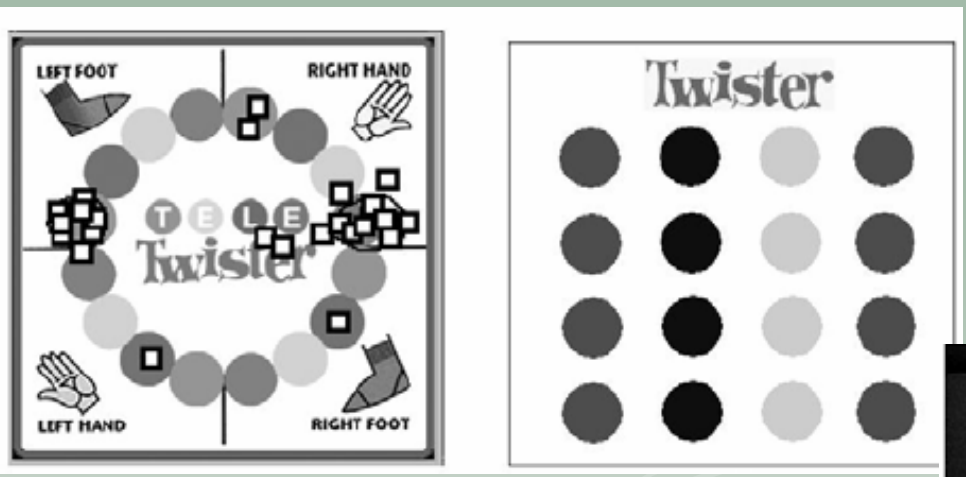
Unsupervised Scoring Metric

- 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



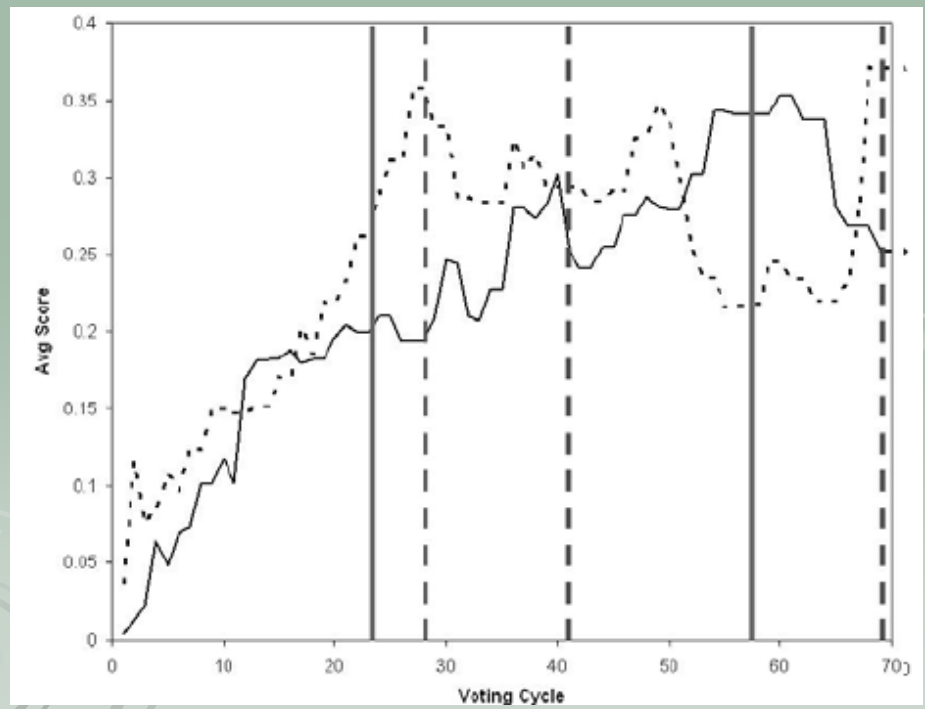
Twister Application

- 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