Task-Oriented Information Value Measurement based on Space-Time Prisms

Yingjie Hu¹, Krzysztof Janowicz¹, Yuqi Chen²

¹ Department of Geography
² Department of Statistics and Applied Probability
University of California Santa Barbara

April 1st, 2016
Information plays an important role in our everyday tasks
The role of information from a cognitive perspective
Mobile devices: major tools for retrieving and displaying information
When small screens encounter big data
Can we prioritize information?

A framework that integrates information value theory with space-time prisms

<table>
<thead>
<tr>
<th>Information item 1</th>
<th>High priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information item 2</td>
<td></td>
</tr>
<tr>
<td>Information item 3</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>Information item n</td>
<td>Low priority</td>
</tr>
</tbody>
</table>
Problem

• An individual has $m$ tasks to complete
  – Each task has its spatiotemporal properties: Locations, preferred arrival time, duration, waiting

• The mobile device has access to $n$ information items
  – Each information item indicates certain spatiotemporal change of the current status

• **Goal**: measure the values of the $n$ information items with regard to the $m$ tasks
Problem

- Introduction
- Problem
- Framework
- Example & Experiment
- Future Work
Information Value Theory (IVT)

• Originally proposed in economics and artificial intelligence
• Measures the value of information with regard to decisions
  \[ V(I) = U(d') - U(d) \]
• Applied to investment analysis and clinical assessment
  – Focusing on monetary value
  – Ignoring spatiotemporal properties
Integrating IVT with time geography

\[ V(I) = U(d') - U(d) \]

- Decision maker: the individual
- Decision \( d \): to make a plan to complete the \( m \) tasks
Integrating IVT with time geography

\[ V(I) = U(d') - U(d) \]

- Space-time prisms for representing the spatiotemporal properties of tasks

- \( U \): extending the utility function from space-time accessibility studies
  - Burns (1979), Miller (1999)
  - Ettema and Timmermans (2007)
Integrating IVT with time geography

\[ V(I) = U(d') - U(d) \]

- Utility function in accessibility study (*Burns, 1979, Miller 1999*):
  \[ U = a^\alpha D^\beta \exp(-\lambda T) \]

- An extension to include early and late arrivals (*Ettema and Timmermans, 2007*):
  \[ U = a^\alpha D^\beta \exp(-\lambda T) \exp(-\gamma_1 SDE) \exp(-\gamma_2 SDL) \]
Integrating IVT with time geography

\[ V(I) = U(d') - U(d) \]

- A plan as completing a sequence of tasks:

\[ \text{plan} = \{s_1, s_2, s_3, \ldots s_m\} \]

- The utility of a plan:

\[ U(\text{plan}) = \sum_{j=1}^{m} U(s_j) \times \exp(-\lambda \sum_{j=1}^{m} T_{(j-1),j}) \]
Integrating IVT with time geography

\[ V(I) = U(d') - U(d) \]

- For each task, one location is selected from the candidate locations:
  \[ s_{jk} = < l_{jk}, a_{jk}, PAT_{jk}, AAT_{jk}, D_{jk}, D'_{jk} > \]

- The utility of completing one task:
  \[ U(s_{jk}) = a_{jk}^\alpha f(D_{jk}, D'_{jk}) h(PAT_{jk}, AAT_{jk}) \]

- Measuring the value of information:
  \[ V(I) = U(plan') - U(plan) \]
Integrating IVT with time geography

- A workflow for ranking the priorities of multiple information items

1. Optimal task plan without information $i_k$
2. Actual utility of the optimal task plan
3. Optimal task plan with information $i_k$
4. Actual utility of the new optimal task plan
5. $U(\text{plan'}) - U(\text{plan})$ - The value of information $i_k$ in this iteration
6. The most valuable information in this iteration
7. Remove $i_k$ from the information set, and repeat (1) to (6)
A simplified example
A simplified example

- Traffic congestion information $I_{traffic}$
A simulation based on a road network

- Tasks: 1) breakfast; 2) workshop
- Information: $I_{traffic}, I_{loc}, I_{temp}, I_{wait}$
A simulation based on a road network

\[ I_{loc} > I_{traffic} > I_{wait} > I_{temp} \]
Conclusions and future work

• A **theoretical framework** for measuring the value of information
• An integration between **space-time prisms and information value theory**
• **Prioritized information display** on small-screen mobile devices
• Further evaluations based on human participant experiments are necessary
Questions and suggestions?

Yingjie Hu

PhD Candidate
Email: yingjiehu@umail.ucsb.edu
Web: http://geog.ucsb.edu/~hu
\[ U(S_{jk}) = \alpha_{jk}^\alpha f(D_{jk}, D'_{jk}) h(PAT_{jk}, AAT_{jk}) \]

\[ f(D_{jk}, D'_{jk}) = \left[ \min \left\{ \frac{D'_{jk}}{D_{jk}}, 1 \right\} \right]^\beta \]

\[ h(PAT_{jk}, AAT_{jk}) = \exp(-\gamma_1(PAT_{jk} - AAT_{jk})^+) \exp(-\gamma_2(AAT_{jk} - PAT_{jk})^+) \]