IoT and Transport: An Agent Approach to Exploiting and Managing IoT

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POSITIONING

TRANSIT SITES: Cyber-Socio-Technical Space
POSITIONING

TRANSIT SITES: Cyber-Socio-Technical Space

TECHNICAL SPACE
- Deployment of Things: real-time information, states, services
  - Real-time information: sensors, information screens
  - Services: smart plugs, connected trolleys, smart lights, …

SOCIAL SPACE
- Travelers:
  - User: improve traveling experiences (e.g. enriched itinerary, navigation)
  - Actor: give reviews on services (e.g. crowdsourcing, social networks)
- Personnel:
  - Facilitate the management and enhance provided services (e.g. maintenance and monitoring of resources and services)

CYBER SPACE
- Other kinds of services (e.g. web services, websites)
A connected object installed in the airport, (e.g. plugs, sensors, trolley, light)
ADDRESS PROBLEMS

- Discovery problem
  - Discovery of static information sources of transit sites (airport map on a website) - E.g. locating a plug
  - Discovery of dynamic sources
    - People’s reviews and experiences – E.g. finding a good restaurant
    - Information sources of Things – E.g. availability of a plug

- Finding the best solution/path
  - Access to information sources (e.g. plug and elevator availability, crowdedness of escalators/corridors) – E.g. locating an easily accessible and available plug

RESULTING PROBLEMS: Managing the Cyber-Socio-Technical Space

- Dynamics
- Heterogeneity
- Interoperability
SOCIO-TECHNICAL NETWORK (STN) (Ciortea et al., 2015)

- **Application**: Agent and artifact logic (Business logic of SWoT applications).
- **Normative**: Norms (Norms are externalized, monitored and regulated. (Regulation principle)).
- **Typed relations**: Typed relations (Relations among entities are externalized. (Social connectivity principle)).
- **Social**: Agents and artifacts (Things are endowed with autonomy. (Autonomy principle)).
- **Agency**: Things (IoT devices are integrated into the Web. (Conformity to REST principle)).

Our focus - Social layer
- With more specialized relations for the context of transit sites

APPROACH

DISCOVERY PROBLEM

- *Socio-Technical Network*: Representation of relations in Socio-Technical Space
  - Review, OwnedBy, ConnectedTo, …
- *Domain graph*: Representation of relations between components (Things, human, cyber-resources), Space, and Time
  - Locate, AccessibleThrough, IsAvailable, …
- *Discovery algorithm*
  - Find locations by exploiting relations to satisfy a goal (e.g. Find the location of a restaurant or a plug)

FINDING THE BEST SOLUTION/PATH

- Representation of the search space problem
  - Potential paths and costs to the locations to satisfy a goal
- Pathfinding algorithm
  - Find the best path to the location to satisfy a goal
  - Heuristic for calculating the cost
  - Address the latency problem for accessing components (Things, human, cyber-resources) to calculate the path cost
Missing: Relations between components and Spaces in function of Time

Proposal: **DOMAIN GRAPH** as the spatial model of the components of the STN
**DOMAIN GRAPH - SPATIAL MODEL**

- Key points to form spaces
- Entity modeling: Clustering of key points according to space semantic
**PROPOSAL**

**ZONE 1**
- Restaurant A
- Shop B
- Waiting lounge
- Ticket office

**ZONE 2**
- Shop D
- Utility space
- Restaurant C

**DOMINANT GRAPH - SPATIAL MODEL**
- Hierarchical organization of key points clusters

**KNOWLEDGE MODEL**

**DOMAIN GRAPH - SPATIAL MODEL**
Objects 1, 2, 4, 5, and the traveler (if she/he is willing) can provide information or functionalities relevant to the location between P1 and P2.
PROPOSAL

SEARCH SPACE

ZONE1
ZONE2
Shop B
P1|P2
P2|P5
P4|P6
P6|P8
P8|P10

ZONE 1
ZONE 2
P1|P2
P2|P5
6

ZONE 1
ZONE 2
P1|P2
P2|P5

P1|P2
P2|P5
P6|P8
P8|P10

STATION

STN - CONNECTED THINGS

KNOWLEDGE MODEL
DOMAIN ENTITY

- Hierarchical division (e.g. zones)
- Location (e.g. restaurant A, shop B, P1\P2)

HIERARCHICAL DIVISION MODEL

- **Name**
- **Super division**
- **Sub division(s)**
- **Locations**
- **Connecting point(s)**

PROPOSAL

KNOWLEDGE MODEL

- **Name**: Zone 1
- **Super division**: Station
- **Sub division**: NONE
- **Locations**: P1\P2, P2\P3, ..., Shop B
- **Connecting points**: P4\P6
**PROPOSAL**

**DOMAIN ENTITY**
- Hierarchical division (e.g. zones)
- Location (e.g. restaurant A, shop B, P1|P2)

**LOCATION MODEL**
- Access point(s)
- Super division
- Resources
  - Cyber-resources – providing information relevant to the location
  - Contained Things – objects situated in the location
  - Relevant Resources – Things / Humans
    - providing qualitative information on the location

![Knowledge Model](image)

- **Name**: P1|P2
- **Access points**: P1, P2
- **Super division**: Zone 1
- **Objects**:
  - 1, 2, 4, 5

- **Name**: Shop B
- **Access points**: P4
- **Super division**: Zone 1
- **Objects**: 6
ALGORITHMS

DISCOVERY ALGORITHM

REQUEST

SUB-GRAF EXTRAXTION

EXTRACTED GRAPH

CONNECTIONS – relations between 2 locations (i.e. clusters)

- **R** - connecting resource(s) – components (e.g. Things, human, cyber objects) providing information for determining the path cost, for traveling between the origin and target, and for evaluating the target location

EXTRACTING PATHS AND RESOURCES
ALGORITHMS

PATHFINDING ALGORITHM

- **Search space** – extracted graph
- **Nodes** – locations
- **Edges** – connections between locations
- **Solution**
  - the best destination (if multiple exist)
  - Path between the origin and the destination
- **Path cost** is additive function based on distance, monetary cost, duration, etc.

**A***
- Goal: minimum sum-cost path
- \[ f(n) = g(n) + h(n) \]

**Adaptations**
- **Latency** - communication with resource agents for connection costs
- Separating search space by sharing connections
- Communicating search agents find the optimal path using connection
Search Agent execution cycle

1. Process messages [OL, CL, AL, PL]
2. \( n = \text{pop-min(OL)} \)
3. Expand(\( n \))
4. Solution-verification-procedure
   - Solution verified
   - Solution not verified
5. \( a = \text{pop(AL)} \)
6. Share discovered connections

- Open list (AL)
- Closed list (CL)
- Action list (AL)
- Pending list (PL)
COST FUNCTION

- Cost between 2 points is calculated by using information from relevant connecting resources. The different cost values are quantified in terms of duration.

SOLUTION VERIFICATION PROCEDURE

- Local verification by each search agent
- Verified goal node with the lowest cost (OL, PL, AL)

OPTIMALITY (cost optimal path)

Assuming the following properties:

- Search space is finite.
- All message arrive at their destinations.
- For every request for an action cost, we get a response.
- All operations take a finite amount of time.
CONCLUSION

THE APPROACH

- The approach is open and distributed, allowing components to enter and exit freely without any severe effects.
- Each path is dynamically computed and based on up to date information.
- Various components of the systems from Things to cyber objects even to Humans are connected, resulting in useful sources of information.

PERSPECTIVES

- Satisfy multiple objectives when finding a path
- Experiment in real conditions