User Intention Market: Social Coordination in Physically-Grounded Agent Architecture

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Purpose

Mechanism of Social coordination in daily life.

Mutual concession of social resources, e.g., space, time, and information resources, and so on.

By cooperating agents embedded in physical context.

- Automatic negotiation by software agents rather than explicit and verbal communication.

Infrastructure

- Physically-grounded agent architecture for ubiquitous computing.

Agents are grounded to physical world and conscious of social resources, e.g., space, time, and information.

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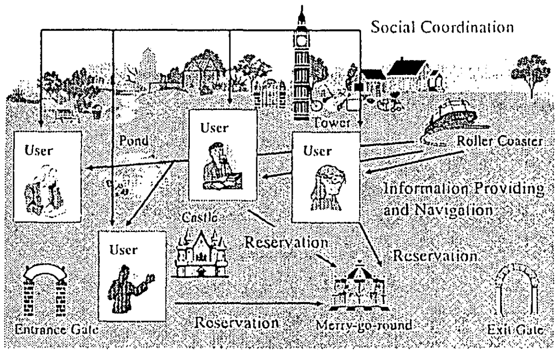
Information Services in Amusement Park



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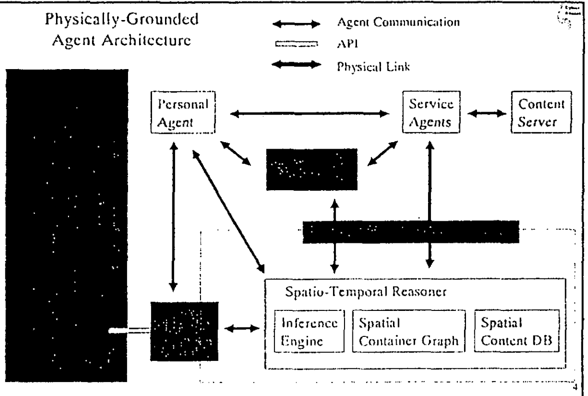
Physically-Grounded Agent Architecture



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Mass-User Navigation - Example of Social Coordination in Daily Life

Navigate users to their favorite places according to intention and preference

- Visiting Plan
- Visiting Expectation
- Moving Distance and Time
- Guidance Information

Control social resources

- Decreasing Traffic Congestion
- Decreasing Summation of Total Moving Distance and Time of All Users

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User Model

intention (u), $u \in U$:

A set of resources (spatial segments) which u should achieve within a fixed period, e.g., one day.

- *preference* (u):

A set of resources (spatial segments) which u tries to achieve if possible.

- *attribute* (u):

Static attribute of user. It can be used to retrieve suitable information.

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Formalization of Mass-User Navigation Element

User: $U = \{ u_i \mid i \in (1..n_u)\}$, $n_u = |U|$.

Temporal Segment: $T = \{ t_i \mid i \in (1..n_t)\}$, $n_t = |T|$.

Simple discrete representation of time.

Spatial Segment: $S = \{ s_i \mid i \in (1..n_s)\}$, $n_s = |S|$.

Qualitative representation of space.

- E.g. A region of neighborhood of an attraction.
- E.g., A region in which users can access a specific LAN access point.

Resource: $R = T \times S = \{ r_{ij} = (t_i, s_j)\}$.

Capacity of Resource: $cap(r)$: $R \to \mathbf{R}$.

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Plan

Plan: Point sequence in R along time.

- There is no same temporal segment in the sequence of any plan (users cannot consume two or more spatial resources at a time).

$plan = (p(t_1), \ldots p(t_n))$, $plan \in \underbrace{R \times R \times \ldots \times R}_{n}$.

$t_1 < t_2 < t_3 < \ldots < t_n$.

Resource on time t_i is specified as:

$plan(t_i) = p(t_i) = r_{ij} = (t_i, s_j) \in R$.

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Plan Connection

Two plans can be connected to become a new plan, if there is no common t_i in the two plans.

$plan_3 = \text{connect}(plan_1 + plan_2) = \cup\ (plan_1,\ plan_2)$,

if $\neg\exists\ t_i\ (p(t_i) \in plan_1 \wedge p(t_i) \in plan_2)$.

To generate new plans from simple short plans which partially satisfy user's intention and preference.

- Complexity:

Order of search space (space of whole plans: *Plan*):

$O(Plan) = |S|^{|T|}$.

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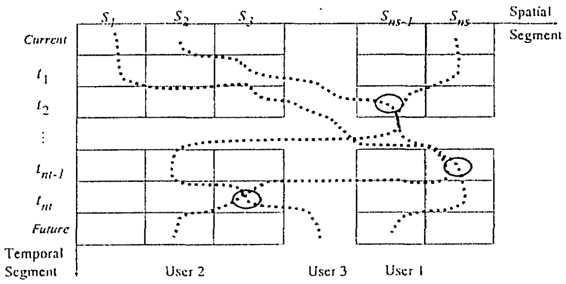
Plans for Individuals and Congestion



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Utility for Individual User

Utility on a plan for an user:

$util(u, plan)$: $U \times (R \times R \times \ldots \times R) \to \mathbf{R}$.

$util(u, plan) = util\_sum + util\_seq$.

1) Summation of utility values of the component:

$util\_sum(u, plan) = \Sigma_i\ util(u, r_i)$, $r_i = plan(t_i)$.

$util(u, r)$ is defined on each resource for each user.

2) Utility increases when a special sequence is included in the plan:

$util\_seq(u, plan) = \Sigma_i\ util(u, c_i)$.

$c = (p(t_i), \ldots p(t_j)) \subset plan$, $c \in SpecialSeq$.

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Utility for Society

Utility for society is defined as macro-attribute of society:

- (Negative) Degree of Congestion
- Use ratio of Resources
- Environment

- Basically, utility functions can be defined arbitrarily to control reasoning process.

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Definition of Problem
Mass-User Navigation

Find a set of plans which maximize the utility.

[Constraints]

- Each plan in the set corresponds to a certain user.
- Equality:
  The utility achieved by the assigned plan should (nearly) equal to all users.

  Balance of individual users and society:
  Maximizing both of utilities for individual and for society is best, although usually it cannot be achieved.

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Approaches

	Effectiveness	Real-Time Response
• Planning (e.g., Collaborative MA)	△	×
• GA or Reinforcement Learning	◎	×
	△	○
(e.g., CSMA/CD (IEEE802.3))		
• Market Mechanism	○	△

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Algorithm

Plan for user u : $plan(u)$. Initial Value: $\forall\ i\ (plan(i) = \phi)$.

- for($t = t_1$; $t <= t_{nt}$; t ++) {
  for($u = u_1$; $u <= u_{nu}$; u ++) {
  $plan(u) = connect(\ plan(u)$, {one of $intention(u)$}); }
  if (there exists r_{ij} s.t. $cap\ (r_{ij}) < |\{r_{ij} \in plan\ (*)\}|$) {
  run social coordination; }
  }
- If there exists u_i s.t. $util\ (u_i,\ plan\ (u_i))$ is extremely less than the average utility, run again social coordination for $intention\ (u_i)$.

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Social Coordination

Stochastic Distribution:
It alters the assignment of resources to users in a stochastically equal way to all users.

- User Intention Market (Market Mechanism):
  A couple of users exchange resources that have been assigned to them, by watching the bulletin board (market) where all the assignments are shown.

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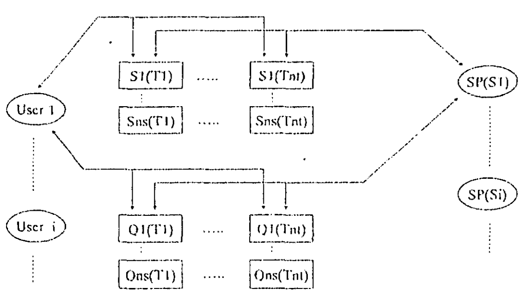
Market Structure for ST-Resource Allocation



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Conclusion

Proposal of social coordination in daily life as a new problem in AI and economic context.

- Analysis of its characteristics.
- Proposal of combined reasoning method of:
  Plan generation (GA-like)
  - Stochastic distribution
  - Market mechanism of users' intention and preference, for plan generation and distribution.

Future Work

Evaluation by simulation under several settings, especially in longer time duration and capacity change of resources.

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