Agents and Semantics for Human Decision-Making

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Agenda

- Introduction
  - Decision Making and Support Systems
  - Agents and Semantic Technologies
- Agent-Based Semantic Decision Support
  - Showcases
  - Challenges
Recently at the airport…

Cognitive process of an individual, or a group which results in a final choice, or an opinion of choice of a course of action among alternative scenarios to accomplish given objective(s) ….
Decision-Making Model

Since the 1950s

- Detailed in more specific (multi-criteria) models based on perspectives of human decision-making
  - Psychological: Needs, preferences, values
  - Cognitive: Cont. deliberation integrated w/ environment
  - Normative: Rational (logical, utility-driven) vs. Irrational choice
e.g. Recognition Primed Decision Model (Klein, 1989)

- Decision support systems (DSS)

  Early: Medical diagnosis, financial management, ...
  - Mathematical models, Statistical methods, data mining/OLAP, logical rule-based ...
Since late 1970s: Intellige\nt DSS
(Holsapple & Whinston 1977; Turban & Aronson 1998)

- Use of AI techniques to exhibit "intelligent behavior" of DSS

Since 1990s: Use of agents in IDSS

- autonomous, proactive, reactive coordination of data, knowledge, services
- needed for personal and group decision support

In distributed environments: collaborative (MAS)

Examples

Prominent and mature applications of agent-based decision support include:

**Manufacturing, Transport & Logistics**
- MAS for production and fleet management DS via distributed planning, scheduling, etc.

**E-Business**
- Negotiation support for online marketplaces, auctions
- Product recommendation
- Service brokerage, matchmaking

**E-Health**
- MAS for clinical decision support

**Virtual Worlds**
- User avatars for group decision support in virtual team meetings

To better cope with problems of **semantic interoperation and reuse** of decision support data, services and knowledge ...
Since 2001: Intelligent DSS also use semantic Web technologies

- Modelling of decision domain semantics with W3C standardized and formal ontology and rule languages (OWL2, RDF/S, OWL-S, SA-WSDL, RuleML, SWRL)
- Supported with methods for ontology selection, evaluation, and alignment
Examples

Prominent and standard models of semantic decision domains include:

Domain ontologies (OWL)
- Negotiation [W3C]
- Medical [SNOMED, NIST]
- Sensor Networks [W3C SSN]
- Provenance [W3C PROV-O]
- etc.

User profile / context ontologies
- GUMO (OWL), schema.org, ODP
- AmbiSense

Semantic service collections
- OWLS-TC, SAWSDL-TC, hRESTS-TC
  @semwebcentral.org, >3k services

Various domains: Linked data sets (RDF/S)

More than 30 billion RDF triples as linked factual knowledge available ....
Semantic Decision Support

... and a large number of methods for ontology-based querying and reasoning:

- Semantic data
  - Facetted, Link-Traversal, P2P, Federated search (e.g. with SPARQL1.1)
  - Stream reasoning (e.g. with C-SPARQL)
  - Hybrid semantic and statistical analysis
  - Explanation of results

- Semantic services
  - Discovery, Selection (Matchmaking)
  - Composition planning

Depending on
- Application
  - Environment
  - Semantic model

Agent-Based Semantic Decision Support

SHOWCASES IN INFOTAINMENT
Recommender Agents in the Web

Provide personal decision support:

What, where, why to buy, watch, read, listen to, etc.?

by recommending relevant items to the user

- pull and/or push mode
- content-based, social, or hybrid (profile, text similarity-based relevance)
- user/item context-sensitive (time, season, location, companion, etc.)

How can semantics help here?
Semantic Recommender Agents

Use of semantic model of decision domain

- User profile and domain ontologies (OWL)
- Knowledge graph with linked data sources (RDF/S)

To compute semantic relevance of items

- Logical (item) concept subsumption relations
- Knowledge graph analytical heuristics, etc.

✓ Improved accuracy compared to non-semantic approaches
✓ Better explanation of recommendations

- J Pazos Arias et al. (2012): Recommender systems for the social Web. Springer
- R De Virgilio et al. (2012): Semantic search over the Web. Springer
Example: Semantic Relevance

Path-based item relevance heuristic SPrank:

**Frequency of different user-item path types** (features) \( j \)

Semantic model of decision domain: 
**Knowledge graph**

User profile \( \hat{S} \)

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\( \text{u: user, } i: \text{ item } \) 
\( \text{e: entity (new user/item) } \) 
\( \text{p: property} \)

\( \hat{S} \)

Regression-based learning of rank \( f(x_{ui}) \): **Higher accuracy than common standards**

(up to 0.6 recall >> BPRLin, SLIM, SMRMF with test data from MovieLens, Last.fm)

\( \hat{x}_{ui}(j) = \frac{\# \text{path}_{ui}(j)}{\sum_{d \in D} \# \text{path}_{ui}(d)} \in R^D \)

Semantic relevance feature vector of item \( i_1 \) for user \( u_3 \):

\( x_{31} = (2/5, 2/5, 1/5), \ |p| < 5 \)

- **collaborative**
  \( \# \text{path(1)} = (\text{likes,likes,likes}) \): 2

- **content-based**
  \( \# \text{path(2)} = (\text{likes}, p_2, p_1) \): 2
  \( \# \text{path(3)} = (\text{likes}, p_2, p_3, p_1) \): 1

- **hybrid**, \( |p| \geq 5 \)
  \( \# \text{path(4)} = (\text{likes}, p_2, p_1, \text{likes}, \text{likes}) \)

For Best Performance: Semantic or Non-Semantic?

Fixed combination of non-semantic predictors of movie ratings

- Won the contest but with **low precision** (accuracy RMSE \(_n\) 0.8567)
- Not suitable for top-N recommendation

Since 2011: Open contest on learning the best combinations

(Corr.: multi-armed bayesian bandit problem solving)

Current research and development of recommenders:

Make **use of semantic** relations to **avoid cold start** problem, and to **compensate** for **non-semantic misclassifications**.

Search for best **hybrid recommender** for given context is still ongoing ...

- R Yan et al. (2013): Using semantic technology to improve recommender systems based on Slope One. Springer
- JW Ha et al. (2014): EPE – An embedded personalization engine for mobile users. IEEE Internet Computing, 18(1)
Example: Semantic Explanation

Use of semantic relevance methods to summarize the most relevant properties of top-ranked items in multimedia panel...

...as you know it also from e.g. dbpedia, Google or Facebook knowledge graph search.
Example: Semantic Explanation (2)

For N-Item relational queries:
Display the shortest item-item paths in the knowledge graph ....
(Corr. NP-hard Steiner tree problem solution)

.... and learn to improve accuracy based on implicit/explicit user feedback:

Please give Horst a thumb for this path - he is willing to learn!
Example: Context-Sensitive

BMW SmartCarAgent provides personal decision support to a driver based on his current context:

That looks nice, is it worth to visit?

Yes, this church can be of interest to you. Here is why: [facts].

- Recognize object, cognitive activity: Eye tracking system eye-viu, Semantic image retrieval
- Semantic fact search in associated knowledge graph (profile, LD sources)

- Cognitive activity level constrains presentation (voice, text on panel, extent of information): Reduced distraction, cognitive overload in driving situation

We Have That Already in Practice?

State of the art example for in-car entertainment, since mid 2013

Apple’s Siri Eyes Free system allows drivers “to make calls, dictate text messages, play music or podcasts, and access everything else the voice-controlled virtual assistant has control over.”

Uses semantic knowledge graph search for selection of registered data and services .. but no personal context-sensitive action, no explanation of results ..
Example: TIFF MyMedia Agent

Provides **personal** and **group decision support** in social media

(1) **Semantic P2P search** of annotated media data and services
(2) Network-adaptive **real P2P live streaming** of videos

(1) *Any SciFi movies on play?*

- Movie „Gravity“ [Trailer].
  Playing next @CinemaZ

(2) *Shall we all go watch it at CinemaZ?*

- Share & jointly watch trailer with buddies Sheila and Carl

  *So, yes, we like to - but only in a nice cinema* ...........................

EU IP SocialSensor 2011 – 2014 (WP Semantic Middleware; DFKI & U Klagenfurt)
Semantic P2P Search in MyMedia

- Each peer **observes** semantics of query q and traversing items during **k-walker search**

- **Semantic routing** of item query q:
  - **Shortest** path (within TTL) with **maximal** # of peers with **semantic expertise** for the topic of q
    - *Logic-based* semantic relevance of media data (OWL)
    - *Hybrid semantic* media service selection (OWL-S)

- **Dynamic semantic replication** of items (optional)
  - Demand-driven in query topic-based peer groups
  - Maximized utility of replication (semantic gain vs. traffic costs)

- Avg. Precision: **0.82** (1M peers, RPLG networks, random/Zipf), robust
- Real **P2P live streaming** with MPEG-DASH: **4s** latency (4 Nexus7, G2)

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Example: Semantic Service Mashup

TIFF-MyMedia Agent 2.0 with personal action planner:

Where to best have lunch on my way to watch movie A in which cinema in time?

- Uses profile, context and mobile semantic service planner OWLS-Xplan 2.2
- KPI-driven offloading of planning processes to (private/TIFF) cloud

Other examples @aimashup.org

2013: 50,000 web services [sousuo 4/2013]
2017: 10 billion mobile connected devices
2050: 50 billion things as services [CISCO 2013, W3C XG SSN]
Selected Challenges

- **Usability & Scalability**: Multimodal, contextual user interaction for dynamic, energy-efficient service selection/planning on mobiles
  - HCI, Mobile cloud computing [Fernando+ 2013; Ha+ 2014]

- **Interoperability** across mobile telco providers
  - WebRTC (W3C, IETF) e.g. for web-based (mobile) P2P apps

- **Security & privacy** of data, processes, user/group profiles that are offloaded to cloud or distributed in peer group:
  - Semantic inference problem + technical security threats

- Semantic-empowered **trusted recommendation**
  - Semantic item/user relevance for (social) trust computation
  - [Martin-Vicente et al., 2012]
Agent-Based Semantic Decision Support

SHOWCASES IN MANUFACTURING
ISReal Framework for Web-Based Virtual Engineering

Provides **personal decision support** for the commissioning or revision of (parts of) a production line before or during its physical development:

- Functional simulation of physical line in its **annotated virtual 3D model**
- Representation of user as intelligent **avatar** (BDI agent) in 3D scene
Integrated Technologies

Web-based 3D visualization of scenes in XML3D

Verification of time-/space-based object properties (safety)

3D Web

Formal Verification

Semantic Web & Services

Intelligent Agents

Semantic annotation of 3D scene objects with facts, services
(Common scene ontology in OWL, Object services in OWL-S)

Hybrid BDI action planning on perceived 3D scene semantics
(e.g. for 3D object service composition in functional simulations)

Q/A-based interaction with user

Example: Decision Support Scenario

Interactive **query-answering on functionality** of machines:

*Can I produce 20 pills with this machine within 30 secs?*

→ **Planning** of machine **services** to reach goal

→ **Time verification** of plan

→ Plan **execution** (functional simulation)

→ **Explanation** (text2speech, animate plan execution)

*Yes, this pill filling station can do it. I show you how to do it.*
Agent identifies and **explains failures of machines or their handling**, and **creates alternative(s)** for its user:

Why did my handling of this machine fail?

→ Time-based **verification** of plan execution
→ Visualization of failure trace (**explanation**)
→ Building of **alternative plan** with revised state

You lifted the carriage stopper too late (11s > 2.5s).

*Here is your updated control plan for handling this machine.*
C3D Framework for Web-Based Collaborative Engineering

Provides **group decision support** for the design of virtual production lines. **Multiple** designers represented by avatars in **shared**, annotated XML3D scene.

- High-precision local and P2P search of 3D models
- Synchronized **joint view and design** of 3D objects
- Functional **verification** of designed objects

BMBF project Collaborate3D (2011 – 2015): c3d.dfki.de

Selected Challenges

- **Scalability**
  - Web-based simulation of very large-sized, annotated 3D scenes (>>20 interacting user agents)

- **Collaborative** hybrid BDI planning agents under uncertainty

- **Virtual** condition monitoring of (designed) machines
  - Semantic *stream reasoning* with CEP and verification of real-world sensor data for fault detection/diagnosis in virtual world

Agent-Based Semantic Decision Support

SHOWCASES IN SMART RETAIL
CARAMEL: Virtual 3D Design of Store Layouts

Provides **personal decision support** for choosing the right layout of retail stores: **How to best position the shelves to increase sales for which types of customers?**

*Simulation* of preset types of **customers** in **annotated 3D layout** as **avatars** (BDI agents) with type-specific capabilities and goals:

- different perception and wayfinding strategies
- different goals: max duration of visit, path length to, max price of preferred products

Based on C3D Framework, ongoing.
ADIGE: Smart Re-Ordering of Goods

Provides **personal decision support** for manager for re-ordering of goods:

*When to re-order from which provider?*

Problem: Service-based **process model** for re-ordering can **change** or become **invalid** at any time due to changes in services performance, availability, prices

- ADIGE agent adapts the **annotated** process model (OWL) to these changes by **semantic selection** and **re-planning** of actual process services (OWL-S)

CeBIT 2014
Take-Home Messages

For decision support, agents can make use of semantics to

✓ facilitate semantic data and service interoperation
✓ perform more precise search for relevant items
✓ create and recommend more accurate alternatives
in a more context-sensitive, explanatory way.

Many agent-based semantic decision support apps
in various domains already available or in development.

Main challenges: Scalability, usability, privacy and trust
Special Thanks

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