BEING SMART IN INFORMATION PROCESSING

Technological And Social Challenges And Opportunities

Hans Akkermans
Free University Amsterdam VUA, The Netherlands

Abstract: A very exciting development in current intelligent information processing is the Semantic Web and the innovative e-applications it promises to enable. This promise will not come true, however, if research limits itself to the technological aspects and challenges only. Both supply-demand sides and business-technology sides need to be investigated in an integrated fashion. This implies that we simultaneously have to address technological, social, and business considerations. Therefore, a comprehensive research strategy for the next decade of intelligent information processing must be of an integrated socio-technical nature covering different levels: (1) Definition and standardization of the baseline infrastructures, content libraries and languages that make up the Semantic Web; (2) The associated construction of generic smart web services that dynamically bridge the low-level (for the end user) infrastructures and the high-level user applications; (3) Designing and studying innovative e-services, information systems, and business processes at the domain, customer, and business level; (4) Understanding and influencing the business and market logics and critical success factors that will determine the social adoption of smart web-based innovations.

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1. EXCITING NEW TECHNOLOGIES

A very exciting development in current intelligent information processing is the Semantic Web (cf. [Berners-Lee et al., 2001] [Fensel et al., to appear]) and the innovative applications it promises to enable. The Semantic Web will provide the next generation of the World Wide Web. The current Web is a very interesting and successful, but also passive and rather unstructured storage place of information resources. This makes it increasingly difficult to quickly find the right information you need, a problem that becomes even

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more pressing with the scaling up of the Web. The vision of the Semantic Web is to make the Web from a passive information store into a proactive service facility for its users. This is done by equipping it with information management services, based on semantic and knowledge-based methods, that let the Web act - in the eyes of its users - as understanding the contents and meaning (rather than just the syntax) of the many information resources it contains and, moreover, as capable of knowledge processing these resources. In the words of Tim Berners-Lee: "The Semantic Web will globalise knowledge representation, just as the WWW globalised hypertext". This globalised semantic approach offers concrete research lines how to solve the problem of interoperability between systems and humans in a highly distributed but connected world.

Designing the infrastructure of the Semantic Web poses major technical and scientific challenges. This is already evident if we look at the envisaged technical architecture of the Semantic Web (see Figure 1) that somewhat resembles a delicately layered cake made from a variety of cyberspace ingredients.

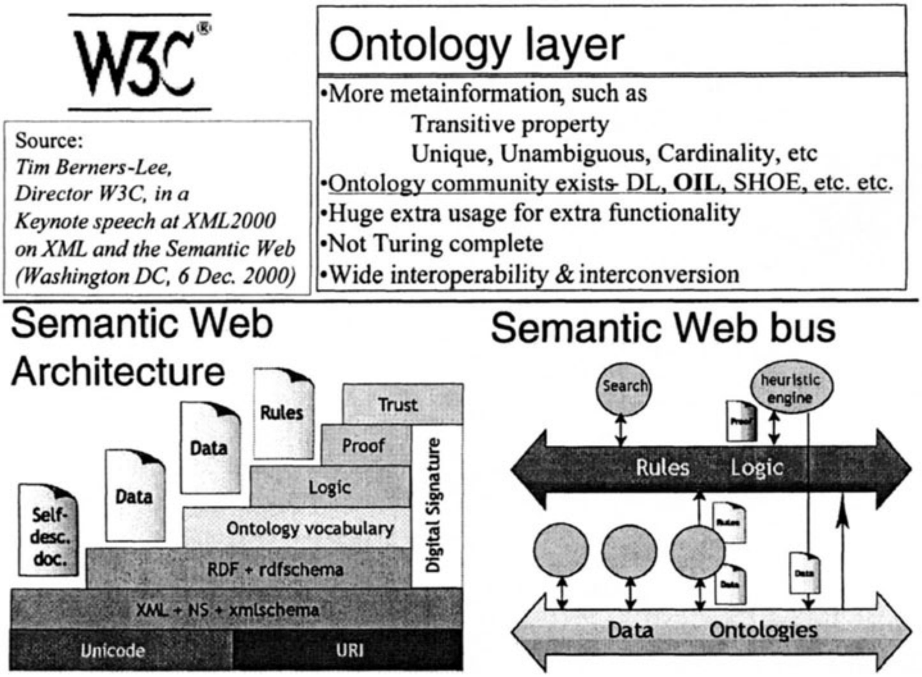

Figure 1. Ingredients and envisaged technical architecture of the Semantic Web.

Some of these ingredients are based on combining existing results and experiences that stem from research areas such as intelligent systems, knowledge representation and reasoning, knowledge engineering and management, or ontology and agent technology. Others are still in the process of invention. Recent progress is reported in the proceedings of this and other conferences and journals (e.g. [Harmelen & Horrocks, 2000], [Staab et al., 2001]).

Challenging and interesting as this is, it is a necessary but not yet sufficient condition to realize the full potential of the Web. For a comprehensive R&D strategy it is necessary to look at the broader picture (depicted in Figure 2) of the Semantic Web: how it is going to be useful in practical real-world applications, and how it will interact with and be beneficial to its users.

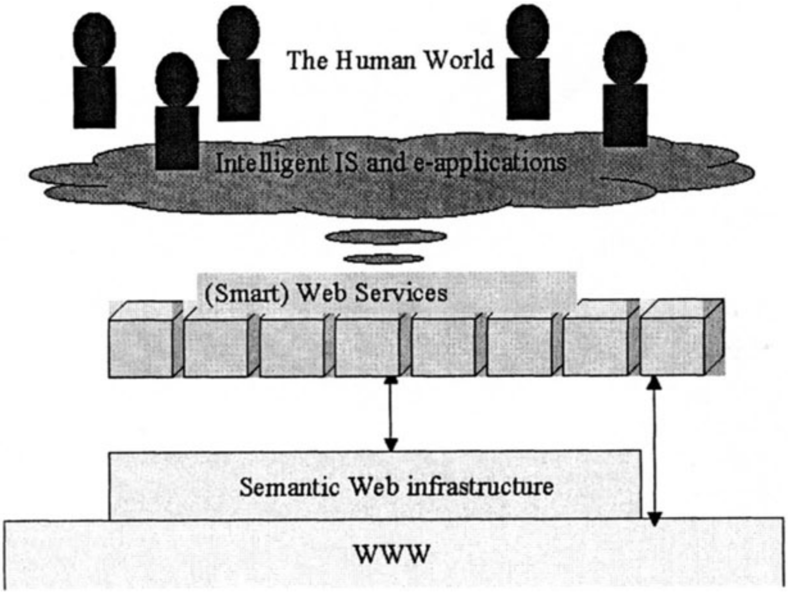

Figure 2. The broader picture: Semantic Web infrastructure, smart services, e-applications and their human-world context.

The ongoing worldwide research effort related to the Semantic Web currently shows an emphasis on those technological issues that are indicated in Figure 2 as web infrastructure and, to a lesser extent, smart web services. This is highly important research because generic semantic infrastructure (such as web ontology languages and content libraries) and associated generic smart web services (such as semantic search, semantic browsing, reasoning, knowledge processing and ontology management services – these services are highly non-trivial because they must be able to deal with the unavoidable evolutional dynamics of web-based knowledge) are a *conditio sine qua non* for the Semantic Web. Nevertheless, it is also important to look already from the start from an *outside-in* perspective. What are the new business, domain, or user/customer applications that are not yet possible today but will be tomorrow as a result of the Semantic Web? Why would businesses, markets or individuals be willing to adopt such innovations? After all, many great innovations fail or have very long lead times because of significant upfront investments. These are in many cases not just of a financial nature: in addition they require behavioural or -even more problematic- cultural changes from their adopters (whether individuals or organizations). We must recognize that the Semantic Web is such a great innovation. Consequently, there is no reason to assume that the new wave of intelligent information processing is immune to the age-old established social laws that govern innovation adoption [Rogers, 1995].

2. INNOVATIVE E-APPLICATIONS

To illustrate some of the pertinent issues I will consider a few specific examples of advanced intelligent information processing that aim the creation and introduction of innovative e-applications for end users (the third level in Figure 2). In addition to the Web becoming smarter (which is denoted by the Semantic Web effort), it will also become more universal in the sense that it will not just connect computers, but essentially any device. This is variously referred to as "ambient intelligence", "universal connectivity" or "pervasive computing". Mobile commerce applications are one step in this direction, but basically all equipment, including home appliances such as personal audio and video, telecom and home control systems, and even heaters, coolers or ventilation systems, will become part of the Web. This enables a broad spectrum of e-applications and e-services for end consumers in many different industry areas: home security, e-health, e-entertainment, e-shopping, distance learning, digital media services, and smart buildings that are able to manage themselves. All of these new imagined e-services are technically challenging, but will also require and induce different behaviours and attitudes from the end consumers as well as from the businesses delivering these e-services.

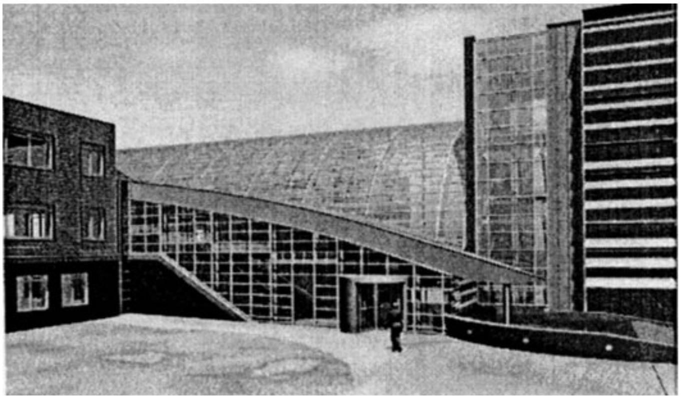

Figure 3. Smart building field experiment site at ECN, Petten, The Netherlands.

As a specific example, I take smart buildings. With several colleagues from different countries, we are researching how smart buildings can serve those who live or work in it [Ygge & Akkermans, 1999], [Gustavsson, 1999], [Kamphuis et al., 2001]. This work has progressed to the point that actual field experiments are carried out (Figure 3), whereby the social aspects are investigated as an integrated part of the research. One of the issues studied is comfort management: how buildings can automatically provide a optimally comfortable climate with costs and energy use that are at the same time as low as possible.

Technically, smart comfort management is based on intelligent agents (so-called *HomeBot* agents) that act as software representatives of individual building users as well as of various types of equipment that play a role in the energy functionality, usage and production in a building (e.g. heaters, sun-blinds, ventilators, photovoltaic cells). These *HomeBot* agents communicate with each other over Internet and PLC media, and negotiate in order to optimise the overall energy efficiency in the building. This optimisation is based on multi-criteria agent negotiations taking place on an electronic marketplace. These take place in the form of a multi-commodity auction, where energy is being bought and sold in different time slots. They are based on the current energy needs, local sensor data, model forecasts (e.g. weather, building physics), and the going real-time power prices. The e-market outcome then determines the needed building control actions in a fully distributed and decentralised way.

The calculation model optimises the total utility, which is a trade-off between cost and comfort, over the coming 24 hours, taking into account both the customer preferences and the actual energy prices. This optimisation is redone every hour, because expected energy prices, outside temperatures, etc. may change, which results in different optimal device settings. Needed forecasts of comfort aspects in a building are based on simple thermodynamic climate models. Energy prices are in general known a certain period (typically 24 hours) in advance. The system reacts on electricity prices, trying to use as little energy as possible when prices are high. In simulations we have concentrated on two dimensions: the economic aspect and the inside climate. The economic aspect is illustrated by a scenario featuring two archetypes: Erika, a yuppie who wants to make no concessions to her comfort level whatsoever irrespective of cost; and Erik, a poor student who wants to keep comfort levels acceptable when at home, but also needs to economise as much as possible. Some typical results are presented in Figure 4. They do show that significant savings without loss of comfort are possible in smart self-managing buildings.

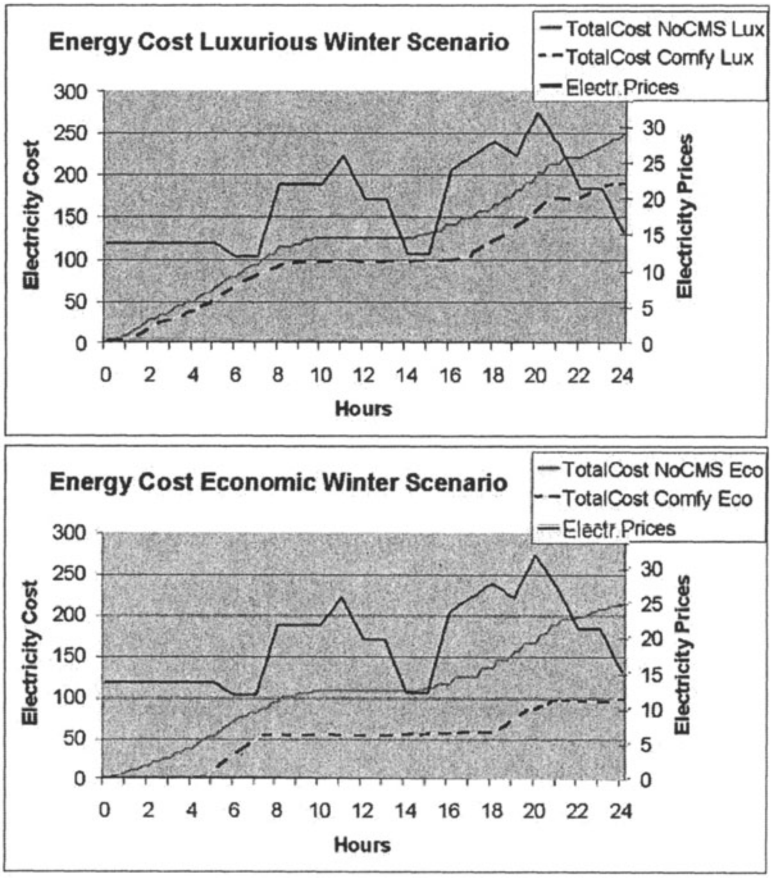

Figure 4. Cumulative costs for a smart building scenarios on a Winter day: savings vary from 20% in the luxurious setting (yuppie Erika) to 45% in the economic setting (student Erik).

There are several general points beyond the specific e-application that are worth noting here in the context of intelligent information processing. First, most current multi-agent applications carry out information and transaction services. This application does that as well but it goes a significant step further: it is an example where agents carry out control tasks through an electronic marketplace that is an alternative to common industrial central controllers [Ygge & Akkermans, 1999].

Second, this e-application is a good example illustrating how much domain knowledge is actually needed to make real-life applications work. *Homebot* agents must for example have knowledge of: building physics, the impact of weather forecasts, the economics of energy purchase and use, etc. All this domain knowledge is actually built into this e-service in a distributed way. It is testimony to the correctness of a major conclusion of knowledge-systems research over many years: generic intelligent techniques are just not strong enough, structuring and processing *domain knowledge* is key to developing successful applications.

Finally, technical and social considerations come together in the notion of comfort. In this application, comfort is the specialization of what counts as "customer satisfaction", an inherently qualitative and perceptual notion for most customers:

- People will typically be able to say whether or not they "like" the climate in a building, but they will find it extremely hard to make this explicit beyond qualitative statements.
- Comfort is a personal concept: users will generally differ in to what extent a given building climate is perceived as comfortable, and what climate they personally prefer.
- Comfort is a sophisticated multi-dimensional concept, as it causally depends on many interacting factors such as air temperature, radiant temperature, humidity, air velocity, clothing, and a person's metabolism (a measure of the person's activity).
- Delivering comfort in buildings is an economic issue: from marketing studies it is known that the financial costs of energy and equipment needed for heating, cooling, air quality, and climate control are key issues for customers and building managers.

Nevertheless, for an automated application we need to turn the central question *"what is customer satisfaction?"* into a causal and quantitative notion of utility. This is a socio-technical issue that is key but known to be hard in many areas (e.g. also in illegal downloading of digital music, cf. [Gordijn, 2002, Ch. 7].)

3. THE SOCIAL CHALLENGE: BUSINESS AND MARKET LOGICS

These illustrations point to the general observation that intelligent information processing and, specifically, the Semantic Web will become a societal success only if it is able to deal with three very different logics of value, that are stated in terms of not necessarily compatible considerations of technology, business models, and market adoption (Figure 5).

To start with the market considerations, the recent rise and fall of many e-commerce initiatives is testimony to the importance of correctly understanding market logics. Extensive customer surveys were done related to the smart building applications discussed in the previous section, with interesting conclusions [Sweet et al., 2000],[Olsson & Kamphuis, 2001],[Jelsma, 2001] such as:

- There actually *is* a strong customer interest in a broad variety of new-e-services, with a variability of this interest across different market segments.
- However, price and cost considerations are primary in this sector, with typically a window for incurring extra costs to the customer for new e-services of no more than 5-10%.
- Design logics of modern buildings (cf. the one of Figure 3) can be such that they run counter the use(r) logics, so that sometimes they prevent their users from doing the right thing, even if both share the same goal of energy efficiency or comfort optimization.

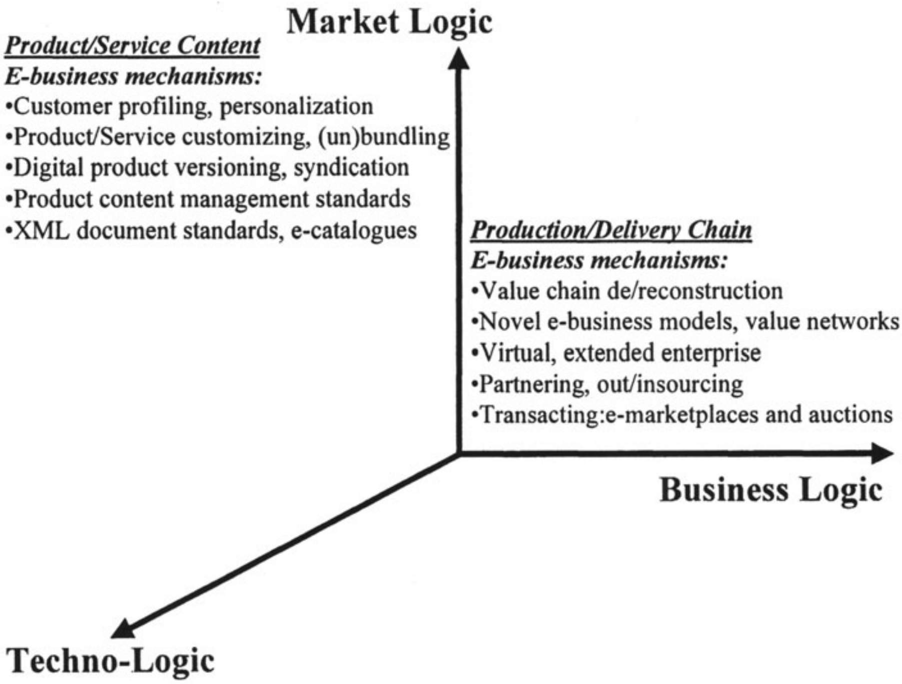

Figure 5. Three different value logics at play in e-applications [Akkermans, 2001].

Market logics refers to the demand side. Business logics refer to the supply side. Due to the developments of the Web, the same (digital) product or service can be created by wholly different value constellations. The degrees of freedom in designing business models have therefore significantly increased. An example of this is depicted in Figure 6. It shows two very different networked e-business models relating to the offering of the same online news service (as considered in a commercial project, see [Gordijn & Akkermans, 2001], [Gordijn, 2002, Ch. 8]). They differ significantly on many different counts, including customer ownership and sensitivity to changes in important financial parameters in the business model. Such considerations similarly apply in the discussed smart building services, because many actors come into play also there and there is quite some freedom in designing the value constellation.

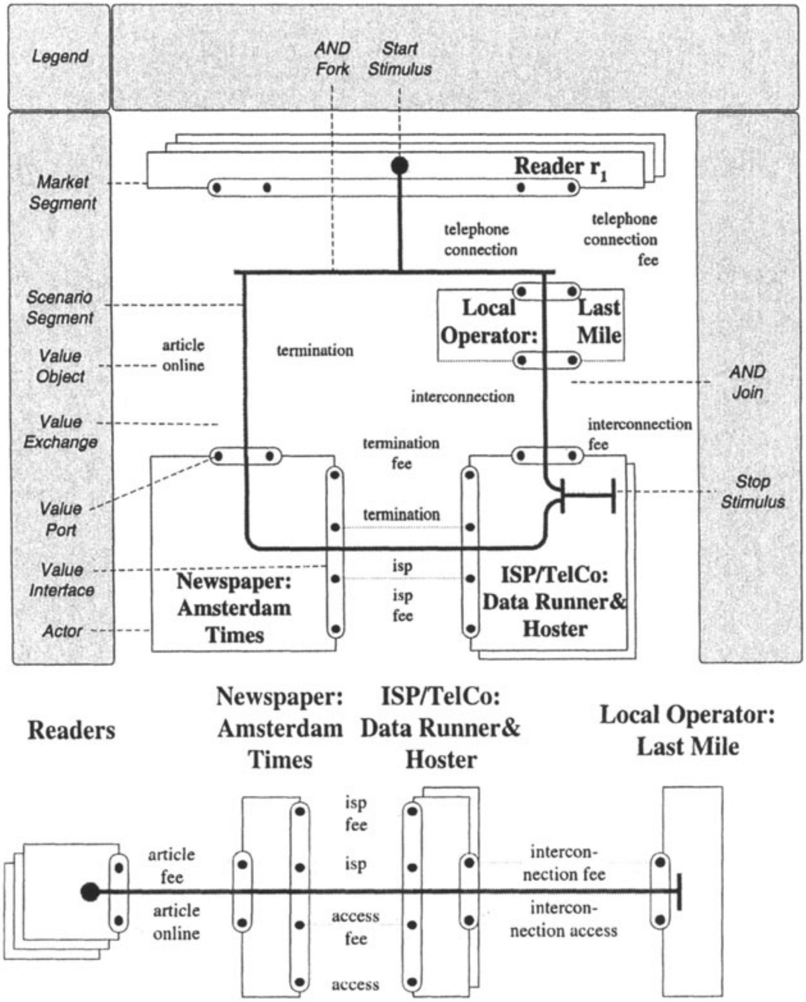

Figure 6. Contrasting e-business models for an online news service.

Generally, the Semantic Web must ultimately enable the creation of *value webs*. Hence, there is a clear need to develop scientifically grounded business analysis tools that help in understanding and designing the intertwined business-technology aspects of the next wave of intelligent information processing applications.

4. CONCLUSION

We are on the eve of a new era of intelligent information processing that centres around the Semantic Web and its applications as a truly promising development. In order to realize its full potential, however, we have to take it for what it is: a great innovation. This implies that we simultaneously have to address the technological, social, and business considerations that play a role in innovations and their adoption by the society at large.

Therefore, a comprehensive research strategy for the next decade of intelligent information processing must be of an integrated socio-technical nature covering all levels indicated in Figure 2:

1. Definition and standardization of the baseline infrastructures, content libraries and languages that make up the Semantic Web.
2. The associated construction of generic smart web services that dynamically bridge the low-level (for the end user) infrastructures and the high-level user applications.
3. Designing and studying innovative e-services, information systems, and business processes at the domain, customer, and business level.
4. Understanding and influencing the business and market logics and critical success factors that will determine the social adoption of smart web-based innovations.

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