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Intelligent agents as innovations

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Abstract This paper explores the treatment of intelligent agents as innovations. Past writings in the area of intelligent agents focus on the technical merits and internal workings of agent-based solutions. By adopting a perspective on agents from an innovations point of view, a new and novel description of agents is put forth in terms of their degrees of innovativeness, competitive implications, and perceived characteristics. To facilitate this description, a series of innovation-based theoretical models are utilized as a lens of analysis, namely Kleinschmidt and Cooper's (J Prod Innovation Manage 8:240–251, 1991) market and technological newness map, Abernathy and Clark's (Res Policy 14:3–22, 1985) competitive implications framework, and Moore and Benbasat's (Inf Syst Res 2:192–222, 1991) list of perceived innovating characteristics. Together, these models provide a theoretical foundation by which to describe intelligent agents, yielding new insights and perceptions on this relatively new form of software application.

Keywords Diffusion of innovations · Innovation · Intelligent agents

1 Introduction

The overall purpose of this paper is to examine intelligent agents from an innovation-based perspective. More specifically, the goal is to analyze intelligent agents in terms of the characteristics that distinguish innovative intelligent agents from non-innovative ones, to present a spectrum over which various degrees of agent innovativeness can be assigned, as well as to discuss the competitive implications of producing intelligent agents that are truly innovative.

Intelligent agents are long-lived software programs which act autonomously, monitor and react to the environment, and communicate and collaborate with other agents and users (Detlor 2004). Past work in this area has focused on the technical merits and internal workings of agent-based solutions. This paper

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presents an alternate perspective on intelligent agents by viewing them as innovations. An innovation is an idea, practice, product, or service that is perceived as being relatively new by an individual, group, or organization. By viewing agents as innovations, it is hoped that new insights on intelligent agents can be found which can, potentially, complement prior technical descriptions in this area and advance our understanding of the adoption and use behavior of intelligent agent end users.

Specifically, this paper employs three distinct innovation-based models to serve as a lens of analysis. The first is Kleinschmidt and Cooper's (1991) market and technological newness map, which is used to evaluate various degrees of intelligent agent innovativeness. The second is Abernathy and Clark's (1985) competitive implications framework, which is utilized to analyze the competitive implications of agent innovations. The third is Moore and Benbasat's (1991) list of perceived characteristics of innovating, which is used to assess agent innovation features. In applying these theoretical models, the paper distinguishes between three broad categories of intelligent agents: service agents, agents embedded into existing software products, and stand-alone agent applications.

This paper is important for several reasons. First, intelligent agents are a burgeoning area of growth and interest. For the last decade, the agent research community has devoted substantial efforts towards creating intelligent agents that assist software users in performing complex or repetitive tasks. As of today, intelligent agents are incorporated in various end-user computer applications in the form of Web guides, personal advisors, shopping assistants, virtual educators, and entertainers. Many researchers predict that intelligent agents will become part of most computer applications in the future.

Second, new perspectives on agents are needed. According to Nwana and Ndumu (1999), a technology-focused approach alone to studying agents is one of the major impediments to the future development and adoption of intelligent agents by the end-user population. Most previous agent studies that explore the technical characteristics and capabilities of intelligent agents value the technical realization of agent-based systems over that of addressing the needs and requirements of agent end users. A discussion on agents from an innovation perspective would help address this void.

Last, an innovation perspective seems warranted. Based on the authors' review of the literature in this area, there is little (if any) prior work which examines agent technologies as innovations. Moreover, no study or paper could be found which explicitly examines agents with respect to the various degrees of innovativeness that intelligent agents may exhibit, the competitive implications of agent-based innovation, nor the perceived innovation characteristics of agents.

A discussion on innovation is always important since it deals with the success of the technological progress of society and civilization. First, technological innovations are one of the key elements in determining productivity that affects people's standard of living. Second, technology directly and indirectly influences the non-economic quality of our lives in either a positive or negative way. Last, advances in technology demand that skills and knowledge become recognized as highly precious commodities which bring new values to society (Tornatzky et al. 1990).

The extensive body of innovation-related literature recognizes the magnitude of these issues. Innovation research is conducted in various areas, such as marketing (Martinez et al. 1998; Mahajan et al. 1990; Bass 1969), manufacturing (Majchrzak and Cotton 1988), social psychology (Ajzen and Fishbein 1980), organizational behavior (Salem et al. 2002), and the emerging discipline of knowledge management (Davenport and Bruce 2002; Hall and Andriani 2002). For the past several years, information systems researchers have also been heavily involved in investigating, applying, and developing the phenomenon of innovation in the computer field (Agarwal et al. 1997; Allen 2000). This interest and work has yielded results in the form of models, frameworks, concepts and approaches that may be successfully utilized in other disciplines interested in the study of innovations. It seems reasonable to apply and extend these models to the intelligent agent domain.

2 Intelligent agents

The notion of intelligent agents has been around for the past 50 years; it was first introduced by McCarthy (1956, 1958) and later coined by the prominent MIT Lincoln Laboratory computer scientist Oliver Selfridge. In the beginning of the 80s, this idea was promoted by agent visionaries such as Marvin Minsky and Alan Kay and further utilized in the recent works of Pattie Maes, Nicolas Negroponte, and Jeffrey Bradshaw. For the past decade, intelligent agents have been successfully incorporated in real-life commercial applications.

An intelligent agent is a software entity which functions continuously and autonomously in an environment, often populated by other agents and processes (Shoham 1997). In other words, an intelligent agent is long-lived and independent. It carries out activities in a flexible and intelligent manner without constant user guidance or intervention. Working autonomously, an ideal agent should be intelligent enough to learn from its experience, which requires basic reasoning capabilities (Gilbert et al. 1995). An intelligent agent should also be reactive—it should monitor the external environment and adequately react to any changes (Hayes-Roth 1995). Last, the agent should be capable of communicating and collaborating with people or other software agents (Etzioni and Weld 1995). Other optional characteristics of an intelligent agent may include personalization (Garrido and Sycara 1996; Maes and Kozierok 1993; Sen et al. 2000), which is defined as a capability of user profiling in order to understand his or her behavior, habits or preferences, and mobility (White 1997; Lange and Oshima 1999), which is defined as an agent's ability to transport itself from one machine to another in a heterogeneous network. To date, all attempts at creating a software entity that successfully imitates human behavior by passing the Turing test (Turing 1950; Saygin et al. 2000) as proof of its true intelligence have failed. Despite this, agent technologies have been successfully incorporated into commercial end-user applications.

There are two general types of intelligent agents: user agents and service agents. User agents are intelligent agents that assist human users by interacting with them, knowing their preferences and interests, and acting on their behalf. Examples of this category of agents include personal news editors, electronic shoppers, and Web guides. For instance, Aria, developed by Lieberman et al.

(2001), is an agent designed to assist computer users by proactively looking for opportunities for image annotation and retrieval. The agent works continuously and autonomously in the background by observing all user e-mail activities. Particularly, when a person types a message, Aria constantly analyzes the input, produces keywords from the context surrounding the text cursor, and attempts to find an image (i.e., a graphical file) that is relevant to the text. The agent presents a sequence of images, annotated with keywords, which a user may want to attach to the message. User feedback demonstrates that the deployment of Aria dramatically reduces interface overload, increases e-mail productivity, and eliminates missed opportunities for image use.

In contrast to user agents, service agents are intelligent agents that collaborate with different parts of a complicated computer system and perform more general tasks in the background. Human users are usually unaware of an agent's existence. Examples of this class of agents include Web indexing, information retrieval, and phone network load balancing agents.

There are many potential benefits of using agent technologies for business. First, agent-based computing allows organizations to reduce product support costs by automating customer service processes (Raisinghani 2000). Many companies have incorporated intelligent auto-response e-mail systems, which automatically read every customer's message, understand its contents, and either provide an intelligent response or forward the request to an appropriate customer service representative. This approach not only offers cost reductions, but it also enhances the customer's experience with the company, leading to increases in satisfaction and loyalty.

Second, intelligent agents help software users deal with complex applications in heterogeneous networks (Jennings et al. 2000). Here, agents may serve as an interface between different and remote parts of a large and complicated software system, such as airline ticket reservation systems or SAP (DStar 2001). Agents may also provide users with an intelligent and customizable interface, which interacts with other software applications, reporting back only final high-level results and thereby hiding task complexity.

Third, the use of intelligent agents helps online organizations to collect, analyze, and utilize information about their customers (Maes 1999). In this way, agents link business goals and consumer interests. For example, shopping bots are an important agent innovation for electronic commerce (Rowley 2000). A shopping bot accepts a user's purchasing request, visits a variety of online vendors, analyzes product details, and presents this information back to the user in the most efficient and convenient way possible.

Last, the employment of intelligent agents brings innovation into many different areas, such as health-care (Mea 2001; Smith et al. 2003), business intelligence (Descouza 2001), decision support systems (Turban et al. 2001; West and Hess 2002), agent-assisted user training (Norman and Jennings 2002), and even jurisprudence (Sartor and Branting 1998).

In addition to reducing work and information overload, the use of intelligent agents may have several long-term socio-economic impacts on organizations that have not been foreseen by technology developers (Serenko and Cocosila 2003; Serenko et al. 2004). The effects that transpire over time at the organizational level include electronic commerce transformation, operational encumbrance, and security overload. First, intelligent agent technologies may potentially alter user behavior, commoditize many products and services available on the Internet, and transform the entire electronic commerce market. Second, before organizations may start reaping the planned productivity and efficiency related benefits of intelligent agent systems, various operational challenges need to be addressed. Examples of those exigent issues include agent communication, cooperation, representation, and manipulation of knowledge that will require extra expertise and resources. Third, organizations will become overloaded with complex security issues that will transpire due to the usage of this new technology.

3 Degrees of innovativeness in intelligent agents

Many contemporary innovations are technology-based. These innovations embody inventions from industrial arts, engineering, applied sciences, and the pure sciences. Examples of technological innovations span the electronics, aerospace, pharmaceuticals, and information systems industries (Freeman 1991; Garcia and Calantone 2002). Technical innovations may differ in terms of their *degree of innovativeness* and their impact on technology, society, and individuals. The degree of innovativeness metric is the most frequently utilized and widely accepted measure of newness of an innovation (Garcia and Calantone 2002). In general, highly innovative products are viewed as having a high degree of newness, whereas low innovative products are seen as exhibiting a low extent of novelty.

In order to estimate the degree of innovativeness in intelligent agents, this paper applies the categorization schema developed by Kleinschmidt and Cooper (1991). This model was chosen from a variety of alternative innovation theories, for example, Utterback (1994) or Chandy and Tellis (2000), because it more accurately reflects the character of a technical innovation and offers a widely recognized viewpoint of innovation classification. This typology schema has been frequently utilized in various innovation investigations (Garcia and Calantone 2002), and it may, therefore, contribute towards our understanding of the innovative nature of agent technologies.

Kleinschmidt and Cooper's (1991) famous study of 195 new product cases from 125 industrial product items introduces a six-category schema which is based on the original Booz-Allen and Hamilton (1982) model. Figure 1 presents Kleinschmidt and Cooper's (1991) market and technological newness map.

This typology identifies the three categories of innovativeness: low, moderate, and high. These innovation types are mapped along the two dimensions of technological and market/manufacturer newness. According to the diagram, highly innovative products consist of new-to-the-world, market, and manufacturer products and new product lines. Moderately innovative products include less innovative items, which are not new to the market, as well as new products in existing product lines of the firm. Low innovative products comprise modifications to existing items, cost reductions, revisions, and repositioning of the products familiar to the market and the manufacturer. According to their study, high, moderate, and low innovative products represent 30.2, 47.2, and 22.6% of all innovations, respectively.

With respect to intelligent agents, it is argued that this technology represents a complex phenomenon which cannot be evaluated as a uniform software

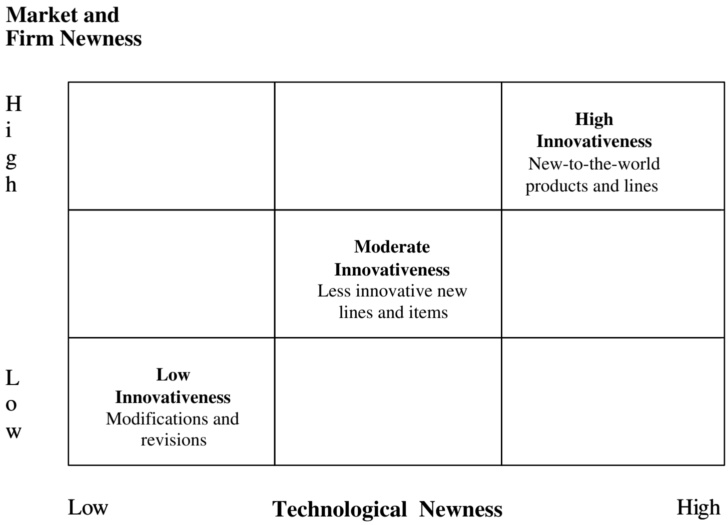

Fig. 1 Kleinschmidt and Cooper's (1991) market and technological newness map

product. Contemporary agent research, as well as the emerging market trends, reveals that there are at least three stand-alone types of intelligent agents: (1) service agents, for example, e-mail traffic managing agents, (2) intelligent agents embedded into previously existing software applications, for instance, virtual e-mail assistants included into mail systems, and (3) totally independent agents, such as electronic shopping agents. It is argued that the market and technological newness map should be applied to each category of these agents individually.

Recall that service agents are agents which are seamlessly incorporated into different parts of a complicated computer system. They perform general tasks in the background. In most cases, people are unaware of a service agent's presence. The typical goals of service agent implementations are to increase the efficiency or flexibility of existing systems, facilitate fast data exchange, reduce costs of information processing, and re-distribute network traffic intelligently. Service agents are included in computer applications which have been already utilized by an organization or an individual and they slightly enhance those applications. Service agents represent low market/firm newness and weak technological novelty and, therefore, correspond to *low innovativeness*, according to the market and technological newness map.

Agents embedded into conventional computer applications are agents which interact with users and the system, thereby, hiding task complexity, delivering new features that the system does not provide, and making the overall user experience more exciting and enjoyable. For example, SwiftFile, formerly known as MailCat, is an intelligent assistant embedded into Lotus Notes that helps users file all incoming e-mail messages (Segal and Kephart 1999, 2000). The agent monitors user actions, analyzes all messages that have been added to or deleted from the mailbox, learns user profile characteristics, and makes suggestions. Web browsing agents are usually embedded into either Microsoft

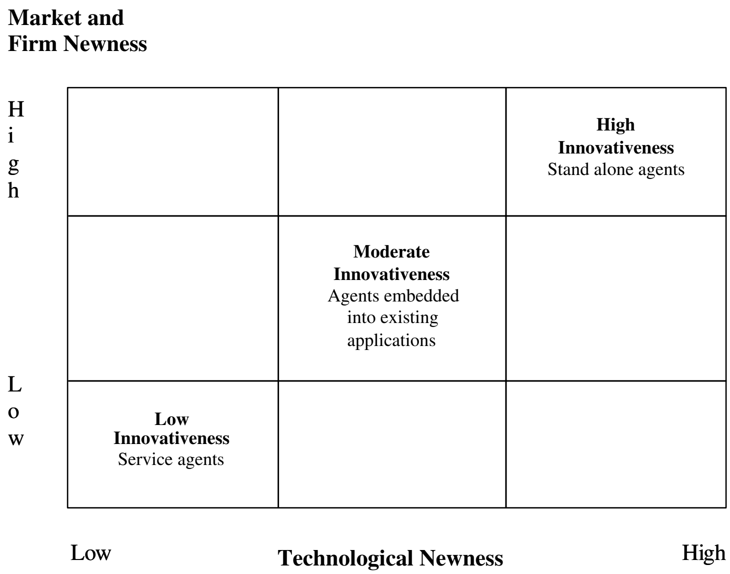

Fig. 2 Kleinschmidt and Cooper's (1991) market and technological newness map applied to agents

Outlook or Netscape and they actually enhance browsers rather than replace them. All these agents correspond to moderate market/firm newness and medium technological novelty, which reflects *moderate innovativeness*.

Totally stand-alone agents intend to replace previously existing applications and business models. For example, WhenUShop is a Web shopping comparison agent which is a free toolbar appearing next to the browser when an Internet user accesses a popular electronic commerce Web site. The agent analyzes the commercial site and presents relevant shopping information to the person. This group of intelligent agents refers to high market/firm newness and high technological novelty, and, therefore, relates to *high innovativeness*. The rationale behind this argument is that these agents employ leading edge unexplored agent technologies, and they are targeted to unknown markets.

Figure 2 summarizes the above discussion in the form of Kleinschmidt and Cooper's (1991) market and technological newness map.

The introduction of any new technology is always associated with high uncertainty and risk[1]. In their study, Kleinschmidt and Cooper (1991) conclude that the relationship between the degree of product innovativeness and commercial success is U-shaped. High and low innovative items are more likely to be commercially successful than moderately innovative products.

By following a similar line of reasoning, it may be hypothesized that low and high innovativeness in intelligent agents will lead to greater commercial success and reduced risk. Thus, the deployment of service and stand-alone intelligent

[1]Here, risk is defined as the probability of an innovative product or service being commercially successful.

agents may carry lower risk for businesses than the rollout of intelligent agents which are embedded into existing applications.

The reasons for this depend on the functionality of the agents and the characteristics of their user base. For example, service agents are mostly invisible to end users, and, thus, those people utilizing them will likely pay attention to the positive outcomes associated with agent usage, and attribute those advantages to software improvements rather than to a totally unknown technology. Users of stand-alone intelligent agents are typically individuals with a high degree of personal innovativeness in the domain of information technology (Agarwal and Prasad 1998), and, thus, this group of users will probably tend to ignore uncertainties, risks, and possible negative consequences of utilizing these applications. However, users of agent technologies embedded into existing software products will likely comprise individuals from the general population who may not instantaneously trust, like, or believe in agent technologies and, thus, pose a greater risk in terms of adopting and accepting such agent-based solutions.

4 Competitive implications of agent innovations

To investigate the potential future impacts of intelligent agents on existing business strategies, this paper utilizes Abernathy and Clark's (1985) framework to analyze the competitive implications of agents as innovations. This framework is based on the concept of transilience—the capacity of innovations to influence the established systems of production and marketing. The framework suggests that innovations affect both markets and technology in quite different ways. The competitive impact of the innovation is determined by the particular combination or pattern of technology and market transilience. Fig. 3 illustrates this transilience map.

The framework identifies four different categories of innovations: architectural, niche, regular, and revolutionary. These types are positioned along two transilience dimensions: technology and production on the horizontal axis, and market and customer linkage on the vertical axis.

The framework postulates that *architectural innovations* represent new technologies that depart from existing systems of production and create new linkages to markets and users. These types of innovations lay down the foundation for industry architecture; they form new industries and reformat existing ones. Examples of such architectural innovations include the introduction of computer graphical user interfaces and computer mice, both of which shaped future standards, principles, and approaches to software development across the entire computer industry.

Niche innovations refine, improve, or change established and well-specified technologies to create a new product or service niche markets. Some niche innovations may represent only incremental or trivial modifications of existing markets, whereas others may facilitate dramatic shifts in customer offerings. Fashion clothing and consumer electronic products provide good examples of these types of innovations.

In contrast to niche innovations, which are clearly visible to all market players, *regular innovations* are often hardly observable. They involve renova-

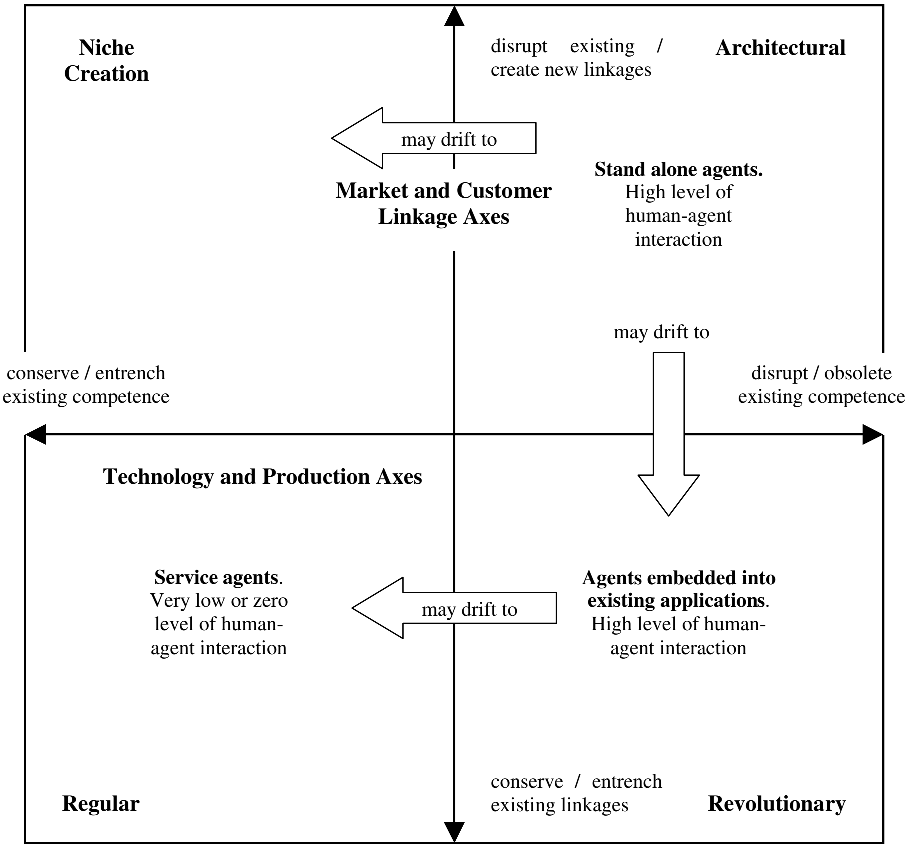

Fig. 3 Abernathy and Clark's (1985) competitive implications of innovations framework applied to agents

tions that build on existing technical and production competencies and are targeted to established markets and customers. The purpose of regular innovations is to conserve and entrench current skills and resources. Contemporary research on computers often results in these kinds of innovations. For instance, improvements in computer CPUs facilitate the creation of faster and more powerful machines, which are directed towards existing groups of customers.

Revolutionary innovations is the last innovation category identified by Abernathy and Clark (1985). Similar to regular innovations, revolutionary innovations are applied to established markets and customers, but they disrupt and render previous technological competencies obsolete. For example, the introduction of word processing programs has made typewriter technologies outdated, yet this software was directed to the typewriter's current market segment.

Abernathy and Clark's (1985) framework presumes that the same technological invention may be mapped in different quadrants, depending on a firm's focus and target customer segments. Over a product's lifespan, innovations may shift from one quadrant to another. This explains how a niche type of innovation may later converge into a regular innovation as markets become more familiar with new products.

Abernathy and Clark's (1985) framework not only offers a categorization of technological evolutions but also provides a lens of analysis by which to examine the relationships among innovations, market competition, and the development of industries. This transilience map has been successfully utilized in various innovation studies. For example, Thomson Corporation's ISI Web of Science Social Sciences Citation Index (SSCI) lists 200+ journal citations to the original journal article that introduced this framework, giving credence its general wide recognition and acceptance.

Recall that this paper differentiates between three categories of intelligent agents: service agents, agents embedded into existing software applications, and agents implemented as stand-alone products. Service agents are delivered to established markets in the form of improvements in software technologies that have already been in place. In most of these cases, end users do not notice the agent's presence and attribute any improvements in these technologies to minor renovations or incremental enhancements. Therefore, service agents represent a *regular innovation*, which "is often almost invisible yet can have a dramatic cumulative effect on product cost and performance" (Abernathy and Clark 1985, p 12).

Agents embedded into existing software products, like service agents, are targeted towards established markets and customers. However, these technologies are often observable and new to end users and, as a result, often force users to make changes in the ways they interface with software applications. Initially, agents incorporated into pre-established software products most likely correspond to a *revolutionary innovation*. However, as individuals become more familiar with these embedded agent technologies and perceive interactions with agents as a trivial activity, these types of agents will be perceived as *regular innovations* over time.

Stand-alone agents are more likely to disrupt and shake well-established software markets and are of interest to new types of users with their own adoption behaviors, interests, and preferences. Stand-alone agent applications which depart from existing software products may lay down the foundation for new architectures, standards, and formats of agent-based computing. Hence, a stand-alone agent system is most likely characterized as an *architectural innovation*, which "defines the basic configuration of product... and establishes the technical and marketing agendas that will guide subsequent development" (Abernathy and Clark 1985, p 7). Further, as agent technologies expand and agent market structure changes, stand-alone agent products may transform into either *niche or revolutionary innovations*.

Various advantages of applying the transilience map to intelligent agent technologies exist. First, it allows both researchers and practitioners to comprehend competitive implications of agent-based innovation by positioning the type of agents under investigation in an appropriate quadrant. This offers understanding of past, current, and future markets. Second, the framework serves as a roadmap for agent development that can help agent vendors monitor the state of agent technologies, make future projections, and adjust their development and marketing strategies. For example, vendors of virtual electronic shopping assistants, which are currently considered as architectural innovations, may be better positioned to recognize a shift in their target market from brand-new to well-established markets as the technology matures and gains general acceptance. Recognizing this shift would allow such vendors to adjust their business strategies in a timely fashion so that they can compete more effectively.

5 Perceived characteristics of agent-based innovating

With respect to innovation adoption, two major streams of research may be identified: the first examines the characteristics perceived by users that influence innovation diffusion (Rogers and Shoemaker 1971; Rogers 1962; Moore and Benbasat 1991); and the second utilizes mathematical models to describe diffusion patterns (Martinez et al. 1998; Mesak and Clark 1998; Astebro 1995; Teng et al. 2002; Bass 1969). In order to facilitate an in-depth discussion on the more salient reasons why individual users may choose to adopt or reject agent technologies, this paper adopts the former approach to innovation adoption. This approach originates from diffusion of innovations (DoI) theory, introduced by Rogers (1962). DoI is a broad sociological and psychological theory which helps analyze, evaluate and explain the patterns of adoption of innovations in different areas. DoI is associated with research that investigates the manner by which new innovational ideas, technologies, or techniques migrate from initial creation to final use.

According to DoI, an innovation is an idea, practice, or object that is perceived as being new by an individual or any other unit of adoption. Diffusion is the process by which an innovation is communicated through certain channels over time among members of a social system. The perceived newness of an idea for individuals determines their reaction to it. The four major elements in the diffusion process are the innovation itself, the communication channels, the social system, and time (Rogers 1962, 1995).

In order to explain how individuals decide whether to adopt or reject an information technology, Moore and Benbasat (1991) synthesize the findings of previous information technology innovation studies and expand Rogers' original set of four constructs. Their investigation generated and empirically tested a list of innovation features, coined the perceived characteristics of innovating (PCI). Consequently, PCI has received substantial support and recognition in technology innovation adoption research (Plouffe et al. 2001). A list of Moore and Benbasat's (1991) perceived characteristics of innovating is presented below:

- *Relative advantage* is the degree to which an innovation is superior to the ideas, practices, or objects it supersedes
- *Compatibility* is the degree to which an innovation is consistent with the existent values, previous experiences, and current needs of adopters
- *Ease of use* is the degree to which an innovation is perceived as being relatively difficult to understand and use
- *Results demonstrability* is the degree to which the benefits and utilities of an innovation are readily apparent to the potential adopter
- *Image* is the degree to which innovation usage is perceived to enhance an adopter's image, prestige, or status in his or her social system

- *Visibility* is the degree to which the results of an innovation are visible to others
- *Trialability* is the degree to which a potential adopter believes that an innovation may be experimented with on a limited basis before an adoption decision needs to be made
- *Voluntariness* is the degree to which innovation use is perceived as being voluntary, or of free will.

These perceived characteristics, as determined by members of a social system, influence the rate of adoption—the higher the level of these innovation attributes, the faster the innovation is accepted. In terms of this paper, the authors suggest that each of these characteristics would play a role in end users' decisions to adopt intelligent agent solutions.

For example, the authors suggest that intelligent agents may offer a substantial *relative advantage* over previously existing software products because they represent the only available computer technology which is implemented in the form of personal assistants acting on their owners' behalfs. In addition, agents have the potential to alter the way people interact with computers by reducing the need to tell the software what to do; this is expected to increase productivity, decrease costs, reduce work and information overload, raise effectiveness and efficiency of contemporary software systems, and make the human–computer interaction process more enjoyable.

In terms of *compatibility*, intelligent agents are both compatible and incompatible. They are compatible with present computer applications because they are themselves software entities. Further, intelligent agents tackle the same problems previously tackled by traditional software applications. However, intelligent agents are incompatible in that they may require users to adapt new methods of interacting with computer applications and to make changes in their mental models. In this sense, the use of agents does not match an individual's prior experiences with conventional software systems. An example of this is Letizia—an autonomous interface agent for Web browsing (Lieberman 1995). This agent continuously runs in the browser, locates, reads, and analyzes all Web pages visited by a user, and understands his or her needs. After compiling a profile of user interests, Letizia starts looking for Web pages that the person may find relevant. The agent presents its findings as list of URLs with a brief site description displayed in a separate browser window. Although the agent dramatically enhances the user's browsing experience, this process requires a new mental model on behalf of users, which is likely incompatible with their previous Web experiences.

Although *ease of use* has received considerable attention in computer, information systems, and Web adoption research (Moon and Kim 2001; Venkatesh and Davis 2000; Davis 1989), no study yet has explored the ease of use of intelligent agents. The importance of an agent's ease of use grows as the level of human–agent interactivity increases. The level of user–agent interactivity reflects user awareness of an agent's existence in a system and the extent of interaction, communication, and collaboration between the human user and the intelligent agent.

With respect to *results demonstrability*, the easier the benefits and advantages of utilizing an intelligent agent can be told and demonstrated to others, the quicker the adoption rate. This may be a quick process if real benefits, such as increased productivity, reduction in workload and time costs, and enjoyment with interacting with agents, can easily be made aware to others.

According to Rogers (1962, 1995), *image* is one of the most important motivational factors with respect to innovation adoption. Intelligent agents are considered to be the technology of the future and their usage is often associated with leading edge software tools. This may increase an adopter's social status as being a highly innovative person, especially if the social group strongly values technology.

Visibility is likely to play a large role in the adoption and use of intelligent agents. Here, a user can interact with his or her own agent directly, as well as interact with agents sent from other members of the user's social system who want to communicate and collaborate on their owners' behalves. It is this latter scenario which is more important in raising awareness of an agent's existence. For example, it seems unlikely that the results of utilizing a personal Web assistant like Letizia, which augments someone's Web browsing experience, would be made clearly visible to the friends or colleagues of the agent adopter. Rather, agents that make themselves apparent to other users are likely to increase the visibility and adoption of intelligent agent technologies.

In terms of *trialability*, a quick overview of the contemporary agent technologies available on the market demonstrates that agent vendors follow a conventional model of software distribution where a product may be used on a trial basis over a short period of time. For example, users can often download agent software for free for a limited-time offer as a means of allowing potential buyers to experiment with the technology prior to making a final purchase decision. During these trial periods, it is important for individuals to have full control over an agent's behavior, since trust is a crucial issue regarding the acceptance of agent technologies (Maes 1994). Users should be able to observe an agent's actions fully, being able to adjust its performance, program it when necessary, and monitor its results. Users should be able to terminate the agent and go back to previous ways of interacting with a computer system at any time.

It is expected that *voluntariness* would be a strong determinant of intelligent agent user adoption decisions. A user's decision on whether to adopt the technology may be totally independent, influenced by subjective norm (Fishbein and Ajzen 1975), or ultimately mandated by superiors. Perceptions of voluntariness are important for initial user acceptance because utilizing an agent requires that people alter their human–computer interaction behavior. In addition, external influences such as peer pressure or superior directives may also provide the requisite motivation to start using an agent. However, as an individual continues to utilize an agent, the magnitude of voluntariness influence declines over time.

6 Discussion and conclusions

Recall that the purpose of this paper was to analyze intelligent agent technologies by using innovation theories as a lens of analysis. The investigation employed Kleinschmidt and Cooper's (1991) market and technological newness map to evaluate the degrees of intelligent agent innovativeness, utilized Abernathy and Clark's transilience map to analyze the competitive implications of agent innovations, and used Moore and Benbasat's (1991) list of perceived innovating characteristics to assess agent innovation features.

Figure 4 illustrates the overall findings of this investigation. The figure identifies three broad categories of intelligent agents: service agents, agents embedded into existing applications, and stand-alone agents. *Service agents* represent low market/firm newness and weak technological novelty and, thus, correspond to low innovativeness. They are more likely to be commercially successful and represent regular innovations. *Agents embedded into existing applications* demonstrate moderate market/firm newness and medium technological novelty and, therefore, pertain to moderate innovativeness. They carry high uncertainty to the general user population they serve and, thus, are less likely to be commercially successful. In the early stages of innovation, these agents tend to disrupt pre-established software technologies and, therefore, are perceived as revolutionary. However, as computer users become more familiar with agent-based systems, this category of agents is expected to transform into a regular innovation. *Stand-alone agents* exhibit high market/firm uniqueness and technological novelty and, hence, are associated with a high degree of innovativeness. Consistent with Kleinschmidt and Cooper's (1991) argument, it is hypothesized that the implementation of stand-alone agent systems can lead to greater commercial success and reduced risk. Stand-alone agent products employing leading edge technologies and targeted to new markets correspond to architectural innovations. However, over time, agent products originally considered architectural innovations may transform into revolutionary or niche

Agent adoption is influenced by **perceived innovating characteristics** such as relative advantage, compatibility, ease of use, results demonstratability, image, visibility, trialability, and voluntariness.

↕

Type of Agent	Innovation Characteristics
Service agents	•Low innovativeness •More likely to be a commercial success •Regular innovation
Agents embedded into an existing application	•Moderate innovativeness •Less likely to be a commercial success •Revolutionary innovation (initially) •Can evolve into a regular innovation
Stand alone agents	•High innovativeness •More likely to be a commercial success •Architectural innovation (initially) •Can evolve into niche or revolutionary innovations

Fig. 4 Summary of findings of intelligent agents as innovations

innovations as newer, fresher technologies replace these agent products. Regardless to which of these three categories an agent may belong, Fig. 4 also illustrates how several perceived innovating characteristics influence the extent to which an agent is potentially adopted. These characteristics consist of relative advantage, compatibility, ease of use, results demonstratability, image, visibility, trialability, and voluntariness.

Overall, Fig. 4 presents insights on intelligent agents from an innovations vantage point. Rather than delve into the technical nature of agents, the figure describes the characteristics of agents which generally impact the degree to which they would be adopted by end users, as well as the kind of innovations these agents would represent based on their underlying type. However, it is recognized that the figure is constrained by several limitations.

First, it employs only two distinct theories to evaluate the degrees of innovativeness and competitive implications of intelligent agent technologies: Kleinschmidt and Cooper's (1991) market and technological newness map and Abernathy and Clark's (1985) transilience map. In addition to these two models, the research community has yielded a variety of innovation concepts, models, and frameworks. According to a recent review of innovation research by Garcia and Calantone (2002), there are at least 15 constructs and 51 distinct scale items that have been employed in just 21 empirical product innovativeness projects. The lack of consistency in defining both innovativeness and different categories of innovation has resulted in the interchangeable use of similar innovation labels under different circumstances. For example, the electric typewriter is classified differently by three innovation theories. Kleinschmidt and Cooper (1991) would call it a moderate; Abernathy and Clark (1985) would describe it as revolutionary; and Utterback (1994) would label it as a radical innovation. Therefore, the application of different innovation models would generate different labels for the same category of intelligent agents. To address this issue, future researchers may utilize a method recently introduced by Garcia and Calantone (2002) for classifying innovations, which synthesizes findings from diverse viewpoints in marketing, management, and engineering.

Second, this paper offers only a theoretical discussion of perceived characteristics of agent-based innovating. The authors recognize that it is very difficult to predict accurately the relevance and importance of each innovation feature without doing empirical research. In order to identify the most important innovation characteristics of intelligent agents, future researchers may wish to adopt the instrument originally developed by Moore and Benbasat (1991) and utilized by Agarwal and Prasad (1997) in information technology research in their empirical investigations.

However, despite these concerns, this paper has merit. It is the first attempt to analyze intelligent agents from an innovations perspective. One of its major contributions is that it calls both academics and practitioners to analyze the innovative potential of this burgeoning technology. The authors hope that the insights offered in this paper may serve as a starting point for future examinations in this area.

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