Intelligent Guidance and Suggestions Using Case-Based Planning

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Abstract. This paper presents a multiagent system that provides guidance on leisure facilities and suggestions for shopping in malls. This paper presents a deliberative agent which incorporates a case based planner that provides suggestions in execution time. This agent is described together with its guidance and suggestion mechanism. The multiagent system has been tested, and the results obtained are presented in this paper.

Keywords: Planning; Learning; Shopping mall multiagent system; RFID.

1 Introduction

A shopping centre is a dynamic environment, in which shops change, promotions appear and disappear continuously, etc. This paper presents a multiagent system, developed for guiding and advising users in Shopping Centres (also known as shopping malls). The proposed system, SHOpping MulitAgent System (SHOMAS), helps users to identify a shopping or leisure plan as well as to identify other users within a given shopping mall. SHOMAS is an open wireless multiagent system and users require a wireless device (mobile or PDA) to download their own agent and to interact with the multiagent system. The user agents interact directly with a deliberative Case-Based Planning - Beliefes Desires Intentions (CBP-BDI) guiding agent which uses a case-based reasoning (CBR) [1], [21] architecture, that allows it to respond to events, to take the initiative according to its goals, to communicate with other agents, to interact with users, and to make use of past experiences to find the best plans to achieve goals. Moreover, SHOMAS incorporates Radio Frequency Identification (RFID) [28] technology to ascertain users' location in order to provide security and to optimize their time in the mall.

The core of SHOMAS is the CBP-BDI guiding agent. This particular agent uses a special type of CBR systems which we call Case-Base Planning (CBP) [12] system, specially designed for planning construction. CBP-BDI agent is a deliberative agent that works at a high level with the concepts of Believe, Desire, Intention (BDI) [7].

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The CBP-BDI agent has learning and adaptation capabilities, which facilitate its work in dynamic environments. A CBP-BDI agent is therefore a particular type of CBR-BDI agent [10], which uses case-based reasoning as a reasoning mechanism, which allows it to learn from initial knowledge, to interact autonomously with the environment as well as with users and other agents within the system, and to have a large capacity for adaptation to the needs of its surroundings.

This paper, then, presents a distributed architecture whose main characteristics are the use of a CBP-BDI guiding agent, wireless agents and RFID technology. The aim of this work is to obtain a model for recommending plans in dynamic environments. The proposal presented has been used to develop a guiding system for the users of a shopping mall that helps them to identify bargains, offers and leisure activities. An open wireless system has been developed, which is capable of incorporating agents that can provide useful guidance and advice services to the users not only in a shopping centre, but also in any other similar environment such as the labour market, educational system, medical care, etc. Users (clients in the mall) are able to gain access to information on shops and sales and on leisure time activities (entertainment, events, attractions, etc) by using their mobile phone or PDA. Mechanisms for route planning when a user wants to spend time in the mall are also available. Moreover, it provides a tool for advertising personalized offers (a shop owner will be able to publicise his offers to the shopping mall users), and a communication system between management, the commercial sector or shoppers.

SHOMAS has been tested in the Tormes mall in Salamanca (Spain) with interesting results. The system performance has been positive, after a period of technical adaptation, the user response has also been positive, and some aspects of the mall's management have improved substantially. The shops owners were the most reticent to using the system for several reasons as explained in the conclusions. Section two presents related work about planning, section three presents the SHOMAS wireless multiagent system, then section four introduces the CBP-BDI planning Agent and finally, the system is evaluated and the conclusions discussed.

2 Related Work

A shopping centre is a cluster of independent shops, planned and developed by one or several entities, with a common objective. As such, a shopping mall can be seen as a large dynamic problem, whose administration depends on the variability of the products, users, opinions, etc. [6]. The unstoppable advance of technology implies the need for alternatives to traditional commercial strategies. Between the new strategies it is worth mentioning the development of different E-Commerce systems [15], [22], [27]. E-Commerce allows users to shop through the Internet, receive personalized promotions or request guidance. The incorporation of artificial intelligence techniques has led to further studies and to the modelling of the mall problem in terms of agents and multi-agent systems [13], [14], [16], [23], [24]. These authors focus on the shopping problem and on the suggestions that can be made to users. The growing use of handheld devices in recent years has led to new necessities as well as to a great opportunity to extend traditional commerce techniques and apply new techniques.

These new devices facilitate the use of new interaction techniques, for instance, some systems focus on facilitating users with guidance or location systems [11], [13], [30] by means of their wireless devices. Bohnenberger *et al.* [6] present a decision-theoretic location-aware shopping guide in a shopping mall as a kind of virtual shop assistant. SHOMAS uses the CBP-BDI mechanism for replanning in execution time and incorporates RFID technology to automatically asses a user's location. Furthermore SHOMAS uses past experiences to take new decisions, which increases the personalization and adaptation capabilities of the system as well as the success of the guidance.

The generation of a new plan is made from plans or fragments of plans that have been previously generated [21], [25], [29]. The different planners based on cases differ from each other in the way that they represent and store the cases and the way in which they execute the CBP cycle (in algorithms executed in each of its stages). The case-based planner proposed within the framework of this article incorporates an adaptation algorithm that allows dynamic replanning in execution time. This fact means that our system is unique in terms of the response that it offers to changes in the environment during the execution of the plan.

The applications of the planning agents are increasingly prolific, especially in fields such as the web, games, tourism applications etc. Case-based Tactician (CAT) introduces a case-based planner with a plan retrieval algorithm that, by using three key sources of domain knowledge, removes the assumption of a static opponent [2]. In [25] it is ïdescribed an application of hierarchical case-based planning that involves reasoning in the context of real-time strategy games. Multiagent planning in the web (MAPWeb) presents a multiagent system for cooperative work among different intelligent software agents whose main goal is to solve user planning problems using the information stored in the Web [9]. The RETSINA agent architecture presents a planner module for every task agent, which interleaves HTN planning and process execution [19]. Furthermore [18] ïdescribe a prototype in which a conversational case-based reasoner, NaCoDAE, was agentified and inserted in the RETSINA multi-agent system. Some case-based planners have been used in tourism applications, such as the one presented by Corchado [11] in order to improve the traditional tourism techniques. Users of the case-based planner tourism application noticed the utility of the dynamic replanning, since it is quite usual for them change opinions/objectives in the middle of a plan. Another application field is intelligent guidance and suggestions in leisure or shopping. ïBohnenberger *et al.* [6] propose the use of decision-theoretic planning, but their system can't provide the option of replanning in execution time. SHOMAS uses the CBP-BDI mechanism for replanning in execution time and incorporates RFID technology to automatically asses a user's location. Furthermore SHOMAS uses past experiences to take new decisions, which increases the personalization and adaptation capabilities of the system as well as the success of the guidance. The CBP-BDI mechanisms enables the system to offer efficient plans in execution time that make it possible to choose optimum routes, and to react to changes that may be produced in the execution of the plan, responding with a dynamic replanning that avoids "retracing one's steps".

3 SHOMAS Architecture

The architecture of the SHOMAS multiagent systems incorporates “lightweight” agents that can reside in mobile devices, such as notebooks, phones or, PDAs [6], and therefore support wireless communication (Wi-Fi, Bluetooth) which facilitates the portability to a wide range of devices. These user agents make it possible for a user to interact with the MAS in a very simple way, downloading and installing a personal agent in his mobile phone or PDA. The system also incorporates one agent for each shop in the shopping mall. These agents can calculate the optimal promotions (those of greater sales success) and services at a given moment by considering the retails data and the user profiles. The core of the MAS is a guiding agent in charge of the generation of plans (routes) in response to a user’s request, looking for the best shopping or leisure time alternatives. The agent has to take into account the user profile, the maximum amount of money that the user wants to spend and the time available. The generation of routes must be independent of the shopping mall management, in the sense that it is not appropriate to use the same knowledge base (or all the knowledge) controlled by the management. Only the knowledge corresponding to the offers and promotions at the moment of guidance should be used. Otherwise the user will be directed to the objectives of the shopping mall management. As can be seen in Figure 1 there are three types of agents in SHOMAS: the CBP-BDI guiding agent, Shop agents situated in each shop and User agents situated in the user mobile device. Each User agent communicates to the nearest shops and can communicate to the CBP-BDI agent. Shop agents communicate to CBP-BDI agent and User agents.

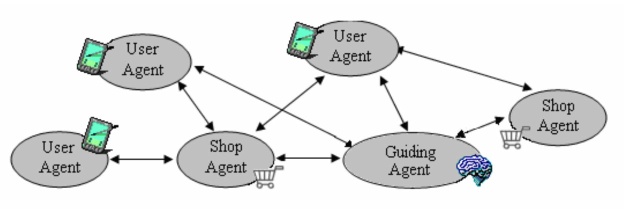

Fig. 1. SHOMAS: CBP-BDI agent, Shop agents and User agents

The User Agent plays three roles, the Communicator role manages all the communications of a user; the Finder role looks for devices nearby, trying to identify other users with similar preferences or locate a given user (in this case the use of RFID technology is fundamental); finally the Profile Manager role obtains a user profile.

The Shop agent plays two roles, the Store Operator is in charge of managing the store (operations on stored products database), and, moreover, monitors product shortages, in order to prevent under-supply; and the Promotions Manager role controls the retails in each shop, as well as the promotions that every shop is offering to its clients.

The CBP-BDI guiding agent plays four roles which are divided into seven capabilities: the Clients Manager role deals with the management of user profiles and controls the connected users at any given moment; the Analyst role carries out periodic evaluations on retails, promotions and surveys data trying to provide a good quality of service; the Incidents Manager role manages incidents in the mall, such as sending suggestions (user changes preferences, or a change affecting the time or economical restrictions happens), or solving a wide range of problems (security, alerts, lost children); the Planner role is the most important role in our system. The Planner creates a route printing the most suitable shops, promotions or events to the user profile and available resources at one particular moment. As can be seen in Figure 2, the Planner role is implemented through three capabilities (Update, KBase and VCBP – Variational CBP –), that make up the Case-based planning cycle explained in detail in section four of this paper. The use of RFID technology allows the CBP-BDI agent to locate persons in the mall for security or strategic reasons. Where there is a safety concern - as with young children or the elderly, for example - microchips or tags can be used (Sokymat ID Band Unique Q5 with a chip Hitag S 256) mounted on bracelets worn on the wrist or ankle [28]. These chips or transponders use a 125 kHz signal. The door readers (Hitag HT RM401 and mobile WorkAbout Pro RFID) sensors [28], are installed in strategic areas within the mall. Each reader sends a pulse of radio energy to the tags and listen for the tag's response. The signal received from a tag is sent to the CBP-BDI agent in order to be processed.

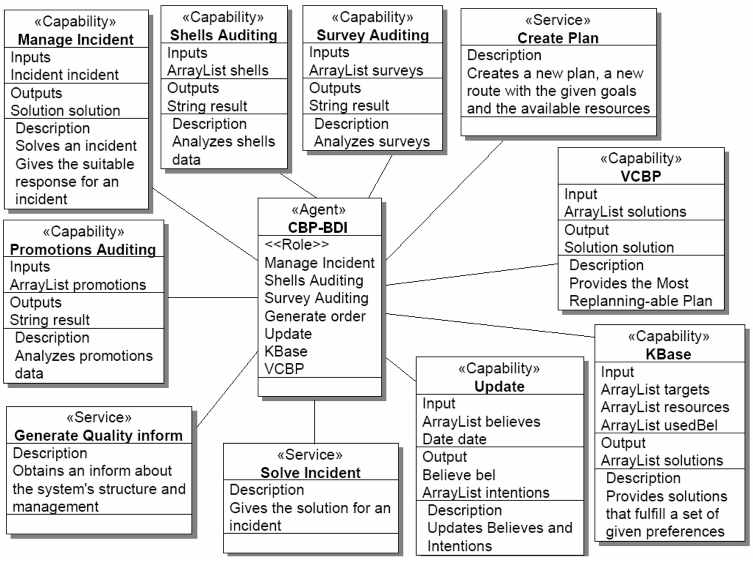

Fig. 2. CBP-BDI agent class diagram

3.1 SHOMAS in Operation

In the MAS presented in this paper the following protocols have been considered: RequestPromotionsData when the CBP-BDI or user (through his User agent) ask about promotions data and a Shop agent sends the response, RequestProductState when the CBP-BDI agent asks for the situation of any products. SolveConsult when a user in the mall interacts with the User agent and makes a query to a Shop agent and receives the response, AlertShortage for a Shop agent to inform the CBP-BDI agent about a product shortage, InformOrderSupplier for a Shop agent to inform the CBP-BDI agent about an order being carried out, InformProductsState when a Shop agent informs the CBP-BDI agent about the state of its products; InformPromotionsState for a shop to send periodic information about promotions to the CBP-BDI agent, SolveIncident for a Shop or User agent to indicate to the CBP-BDI agent that an incident has occurred and to receive the response, SolveGuidance when a user requests guidance from the User agent and the User agent asks the CBP-BDI agent about a plan and receives the response; finally, Notify is used for the CBP-BDI agent to send suggestions to User or Shop agents. For example, when an user asks for a new route, the User agent uses the SolveGuidance protocol. The CBP-BDI agent sends the guidance and keeps receiving the results of each of the subgoals proposed (each of the intermediate states proposed in the plan). If necessary a re-planning will be made.

The interactions have been implemented using a robust wireless LAN. In SHOMAS Wi-Fi and Bluetooth devices coexist together with RFID devices. A secure and authenticated access to the data is provided. The use of different authorisations for users, logins and passwords, and the encryption of messages using a public key infrastructure and SSL (Secure Socket Layer) have already been implemented. Moreover, the RFID tag only contains the user's identification number, and not personal data. The communication mechanism is provided by the Jade platform [4].

Table 1. User Profile Case Fields. A case corresponding to a user profile contains the description of the problem (personal data on the user and information about his purchases or attendance at activities within the commercial centre) and the solution to the problem description (interests of the user, tastes and tendencies)

Case Field	Measurement
PERSONALDATA	User Personal Data (UserData)
RETAILDATA	Retails (RetailsData)
INTEREST	User interests (UserInterest)

The main concept when working with CBR systems is the concept of case. The case structure for a user profile shown in Table 1. The items, attributes and their values and weights are labelled. In our problem, three main attributes have been considered: personal data, retail/leisure time data and interest data. The retail/leisure attribute is composed of business type, business identification, product type, product identification, price, units and date attributes. The interest data attribute is composed of retail time and frequency, monthly expense both business and product, extracted from retail data, and the explicit attributes obtained from questionnaires. Each attribute has a value, noun or adjective, and a weight assigned. Since the number and type of business is extensive, they were classified into leisure time (cinema and recreational), catering (restaurant, fast food and pizza) and public retail (clothes, shoes, computing, supermarket and optical). The products have been also classified, for example the films are divided in action, comedy, terror and drama.

The agent in charge of providing suggestions is a CBP-BDI agent and the case structure for guidance is shown in Table 2. The agent deals with multiple objectives, as shown in Figure 2, derived from the task of coordinating all the shops, user management and planning and optimising routes. The routes and promotions proposed to a user take into account the user profile and his resources (money and time) at the moment that the request for guidance is made. It contains a mall map and an estimation of the time employed walking by the user. The CBP-BDI agent is able to generate routes, analyze retails and promotion data, manage incidents and manage users at the same time. To solve the problem of routes guidance the CBP-BDI agent uses an innovative planning mechanism: the Case Based Planning. CBP provides the agent with capabilities for learning and adaptation to the dynamic environment. Moreover, the CBP-BDI is able to apply a dynamic replanning technique, which allows the agent to change a plan at execution time when an incident happens [21]. The CBP-BDI agent implements the reasoning cycle of the CBP system [12], [21] by means of three capabilities as can be seen in Figure 2: Update, KBase and VCBP (Variational CBP) capabilities. The Update capability implements the retrieve (the cases memory is organized as an efficiency pyramid, and only those plans with at least 4 similar businesses visited in the past, with the same user profile and restriction's limits are retrieved) and retain stages. The KBase capability implements the reuse stage (the optimum solution is sought among the base of solutions proposed in the retrieve stages) and the VCBP capability, the revise stage (system trusts user evaluation). The VCBP capability is also in charge of the dynamic replanning task. The use of the RFID technology enormously facilitates the planning and replanning processes incorporating a dynamic location within SHOMAS. Moreover, the RFID devices allow SHOMAS to provide a voluntary location service for its users.

Table 2. Guidance case fields

Case Field	Measurement
USER	User profile (UserProfile)
MONEY	Money to spend (Money)
TIME	Time (Time)
INIT	User initial location (Location)
PREF	User preferences (Preference)
SOLUTION	Solution and efficiency (Solution)

The platform chosen for the implementation was Jadex [26]. The Jadex agents deal with the concepts of beliefs, goals and plans. A belief can be any type of java object and is stored in the beliefs base. A goal is also a java object that has influence on the agent behaviour. A plan is a java procedure and is executed in order to achieve goals. Jadex has the advantage of allowing programmers to include their own deliberative mechanisms. Moreover it offers all the communication advantages that Jade [4] provides (including the LEAP add-on).

4 CBP-BDI Guiding Agent

The purpose of case-based reasoning (CBR) is to solve new problems by adapting solutions that have been used to solve similar problems in the past [1]. The CBP is a variation of the CBR which is based on the generation of plans from cases. The deliberative agents, proposed in the framework of this investigation, use this concept to gain autonomy and improve their guiding capabilities. The relationship between CBP systems and BDI agents can be established by implementing cases as beliefs, intentions and desires which lead to the resolution of the problem. In a CBP-BDI agent, each state is considered as a belief; the objective to be reached may also be a belief. The intentions are plans of actions that the agent has to carry out in order to achieve its objectives [7], so an intention is an ordered set of actions; each change from state to state is made after carrying out an action (the agent remembers the action carried out in the past, when it was in a specified state, and the subsequent result). A desire is any of the final states reached in the past (if the agent has to deal with a situation, which is similar to one in the past, it will try to achieve a similar result to the one previously obtained). Below, the CBP guiding mechanism, used by the CBP-BDI guiding agent, is presented: Let $E = \{e_0,...,e_n\}$ the set of the possible interesting places to visit and shop at.

$$a_j : \underset{e_i}{E} \underset{\rightarrow}{\rightarrow} \underset{a_j(e_i)=e_j}{E} \tag{1}$$

An Agent plan is the name given to a sequence of actions (1) that, from a current state e_0, defines the path of states through which the agent passes in order to offer to the user the better path according to each user's characteristics. Below, in (2), the dynamic relationship between the behaviour of the agent and the changes in the environment is modelled. The behaviour of agent A can be represented by its action function $a_A(t)\ \forall t$, defined as a correspondence between one moment in time t and the action selected by the agent,

$$Agent\ A = \{a_A(t)\}_{t \in T \subseteq N} \tag{2}$$

From the definition of the action function $a_A(t)$ a new relationship that collects the idea of an agent's action plan (3) can be defined,

$$p_A : \underset{(t, a_A(t))}{TxA} \underset{\rightarrow}{\rightarrow} \underset{p_A(t)}{A} \tag{3}$$

in the following way,

$$p_A(t_n) = \sum_{i=1}^{n} a_{iA}(t_i - t_{i-1}) \tag{4}$$

Given the dynamic character that we want to print onto our agent, the continuous extension of the previous expression (4) is proposed as a definition of the agent plan, in other words (5) –

$$p_A(t_n) = \int_{t_0}^{t_n} a_A(t)dt \tag{5}$$

The variation of the agent plan $p_A(t)$ will be provoked essentially by: the changes that occur in the environment and that force the initial plan to be modified, and the knowledge from the success and failure of the plans that were used in the past, and which are favoured or punished via learning. O indicates the objectives of the agent and O' are the results achieved by the plan. R is the total resources and R' represents the resources consumed by the agent. The efficiency of the plan (6) is the relationship between the objectives attained and the resources consumed.

$$E_{ff} = \frac{\#(O^{'} \cap O)}{\#R^{'}} \tag{6}$$

Where # means cardinal of a set. The objective is to introduce an architecture for a planning agent that behaves – and selects its actions – by considering the possibility that the changes in the environment block the plans in progress. This agent is called CBP-BDI because it continually searches for the plan that can most easily be re-planned in the event of interruption. Given an initial point e_0, the term planning problem is used to describe the search for a way to reach a final point $e_i \equiv e^* \in E$ that meets a series of requirements. Given a problem *E* and a plan *p(t)* the functions *Ob* and *Rc* accumulated are constructed from the objectives and costs of the plan (7). For all time points t_i there are two associated variables:

$$Ob(t_i) = \int_a^{t_i} O(t)dt \qquad Rc(t_i) = \int_a^{t_i} R(t)dt \tag{7}$$

This allows us to construct a space representing the environment for planning problems as a vectorial hyper dimensional space where each axis represents the accumulative variable associated with each objective and resource. The planning space, defined in this way, conforms to the following properties:

Property 1: The representations of the plans within the planning space are always monotonically growing functions. Given that *Ob(t)* and *Rc(t)* are functions defined as positive, function *p(t)* expressed at these coordinates is constant or growing.
Property 2: In the planning space, the straight lines represent plans of constant efficiency. If the representations of the plans are straight lines, the slope of the function is constant, and coincides with the definition of the efficiency of the plan (8).

$$\frac{d}{dt} p(t) = cte \Leftrightarrow \lim_{\Delta \to 0} \frac{\Delta O(t)}{\Delta R(t)} = cte \tag{8}$$

In an n-dimensional space, the extension of the straight concept line is called a geodesic curve. In this sense, the notion of geodesic plans can be introduced, defined as those that maintain efficiency at a constant throughout their development. This way, only the plans of constant efficiency (geodesic plans) are considered, because they are the ones of minimum risk. In an environment that changes unpredictably, to consider any different plan to the geodesic plan means to accept a certain risk. The agent must search for the plan that determines a solution with a series of restrictions *F(O;R)=0*. In the plans base the plans sought are those that are initially compatible with the problem faced by the agent, with the requirements imposed on the solution according to the desires and in the current state [1]. If all the possible plans $\{p_1,...,p_n\}$ are represented within the planning space, a subset of states that the agent has already attained in the past will be obtained in order to resolve similar problems. With the mesh of points obtained (generally irregular) within the planning space and using interpolation techniques, a working hyperplan *h(x)* can be obtained. The hyperplan encapsulates the information on the set of restrictions from restored experiences, which, by definition verify that $h(x_j)=p_j$ $j=1,...,n$ and the planning space is the dimension n). From this hyperplan, geodesic plans can be calculated and the variation calculation is then applied. Suppose, for simplicity's sake, a planning space of dimension 3 with coordinates $\{O,R_1,R_2\}$. Between the point e_0 and the objective points $f_s\ f=\{e_1,..., e_m\}$ and over the interpolation surface $h(x)$, the Euler Theorem [20] guarantees that the expression of the geodesic plans will be obtained by resolving the system of equations in (9), where R_i is the function accumulated R, O is the function of accumulated O and L is the distance function on the hyperplan $h(x)$, $L=\int_h dl$.

In order to obtain all the geodesic plans that, on the surface $h(x)$ and beginning at e_0, allows us to reach any of the points $e^* \in f_s f$, a condition must be imposed on the surroundings: the initial point will be $e_0=(O_0,R_0)$. Once an efficient plan is developed, the plan around it (along its trajectory) is used to create a denser distribution of geodesic plans. The tool that allows us to determine this is called the minimum Jacobi field associated with the solution set. Let $g_0:[0,1]\rightarrow S$ be a geodesic over a surface S. Let $h:[0,1]\ x[-\varepsilon,\varepsilon]\rightarrow S$ be a variation of g_0 so that for each $t \in (-\varepsilon,\varepsilon)$, the set $\{h_t(s)\}_{t\in(-\varepsilon,\varepsilon)}$: $h_t(s)$ for all $t\in(-\varepsilon,\varepsilon)$ are geodesic in S and they begin at $g_0(0)$, in other words, they conform to $h_t(0)=g_0(0)$ for all $t\in(-\varepsilon,\varepsilon)$. The differential limit of the variations is (10).

$$\begin{cases} \frac{\partial L}{\partial R_1} - \frac{d}{dO}\frac{\partial L}{\partial R_1^{'}} = 0 \\ \frac{\partial L}{\partial R_2} - \frac{d}{dO}\frac{\partial L}{\partial R_2^{'}} = 0 \end{cases} \tag{9}$$

$$\lim_{t\to 0}\{h_t(s) = g_0(s+t)\} = \lim_{t\to 0}\{h(s,t)\} = \frac{\partial g_0}{\partial t}\Big|_{(s,0)} = \frac{dg_0}{ds} \equiv J_{g_0}(s) \tag{10}$$

The term $J_{g0}(s)$ is given to the Jacobi Field of the geodesic g_0 for the set $\{g_n(x)\}_{n\in N}$, and in the same way as the definition has been constructed, it is possible to give a measurement for the distribution of the other geodesics of $\{g_n(x)\}_{n\in N}$ around g_0 throughout the trajectory. Given a set of geodesics, some of them are always g* that, within their environment, have a greater distribution than other geodesics in a neighbouring environment. This is equivalent to saying that it presents a variation in the distribution of geodesics lower than the others and therefore the Jacobi Field associated with $\{g_n(x)\}_{n\in N}$ reaches its lowest value at J_{g^*}. Let's return to the CBP-BDI agent problem that, following the recuperation and variation calculation phase, contains a set of geodesic plans $\{p_1,...,p_n\}$. If the p^* is selected with a minimum Jacobi Field value, it can be guaranteed that in the event of interruption it will have around it a greater number of geodesic plans in order to continue. This suggests that given a problem with certain restrictions $F(O;R)=0$, the geodesic plan p^* with minimum associated Jacobi field associated with the set $\{g_n(x)\}_{n\in N}$ is called the most re-planable solution. The behaviour model G for the CBP-BDI agent is (11).

$$G(e_0, p_1, \cdots, p_n) = p^* \Leftrightarrow \exists n \in N / J_{g_n} \equiv J_{g^*} = \underset{n\in N}{Min} J_{g_n} \tag{11}$$

If the plan p^* is not interrupted, the agent will reach a desired state $e_j \equiv e^* \in f_s f$, $j\in\{1,...,m\}$. In the learning phase, a weighting $w_f(p)$ is stored. With the updating of weighting $w_f(p^*)$, the planning cycle of the CBP motor is completed. In Figure 3, it is possible to see what happens if p^* is interrupted. Let's suppose that the agent has initiated a plan p^* but at a moment $t>t_0$, the plan is interrupted due to a change in the environment. The geodesic planning meets the conditions of the Bellman Principle of Optimality [5], in other words, each one of the plan's parts is partially geodesic between the selected points. This guarantees that if g_0 is geodesic for interrupted e_0 in

t_1, because e_0 changes to e_1, and g_1 is geodesic to e_1 that is begun in the state where g_0 has been interrupted, it follows that: $g = g_0 + g_1$ is geodesic to $e = e_0\,(t_1 - t_0) + e_1\,(t_2 - t_1)$ The dynamic process follows the CBP cycle recurrently: each time a plan finds itself interrupted, it generates from the state reached so far, the surroundings of the plans from the case base and adjusts them to the new problem. With this it calculates the geodesic plans and selects the one which meets the minimum conditions of the associated Jacobi field. In this way, the dynamic planning model of the agent *G(t)* is characterised as shown in Figure 3. A minimum global Jacobi field *J(t)* also meets Bellman's conditions of optimality [5], in other words, a minimum global Jacobi field, must select minimum Jacobi fields "in pieces" (12).

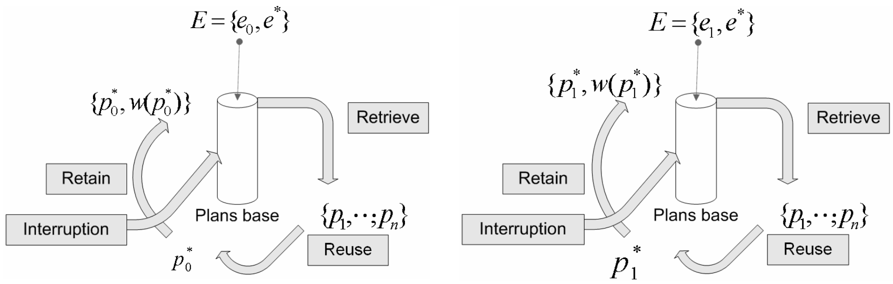

Fig. 3. Model for behaviour G(t)

If on the one hand, successive Jacobi fields generate one Jacobi field, and on the other hand, minimum Jacobi fields generate a minimum Jacobi field, the CBP-BDI agent that follows a strategy of replanning *G(t)* as indicated to survive a dynamic environment, generates a global plan $p^*(t)$ that, faced with all possible global plans $\{p_n(t)\}_{n \in N}$, presents a minimum value in its Jacobi field $J_{g^*}(t) \equiv J_{p^*}(t)$. As such, an agent has been formally defined which in a dynamic environment seeks plans that lend it greater capacity for replanning.

$$J_{\min}(t) = \{J_{\min}(t_1 - t_0), J_{\min}(t_2 - t_1), \cdots, J_{\min}(t_n - t_{n-1})\} \qquad (12)$$

5 Results and Conclusions

The system described in this paper was tested at the Tormes Shopping Mall in the city of Salamanca during 2005 and 2006. This Shopping centre has 86 different businesses including shops, restaurants, cafes, cinemas, hairdressers and a day nursery. The multiagent system prototype has been tuned and updated during this period and the initial results have been very successful from the technical and scientific point of view. The construction of the distributed prototype has been relatively easy using previously developed CBR-BDI libraries [3], [11], especially since the Mall has a Wi-Fi network and has provided the businesses with Bluetooth and RFID technology (75 readers have been installed). The formalism defined in [20] facilitates the straight mapping between the agent definition and the CBR construction. The security problem in data transmissions (data privacy) was tackled by using the FIPA https protocol and a private network to connect Shop agents with the guiding agent.

The fundamental concept when working with a CBR system is the concept of case, so it is necessary to establish a case definition. A case managed by the CBP-BDI agent, is composed of the attributes described in Table 2: the user profile - the money available to spend, the time available, the user's initial location, the user's preferences when guidance is given through the PDA interface between the options shown and the solution proposed; The guidance and the result obtained for the guidance - success, failed, user opinions, sales results. Cases can be manipulated manually or automatically by the agent during its revision stage, when the user evaluation obtained through questionnaires is given to the system. The agent plans can be generated using different strategies since the agent integrates different algorithms. The metrics mechanisms proposed in [8] facilitate the retrieval stage, but the products base and the promotions base must be defined and sorted including metrics that allow it to find similitude, such as the time expected to spend buying each product. The user profile is obtained from retail data and periodic questionnaires.

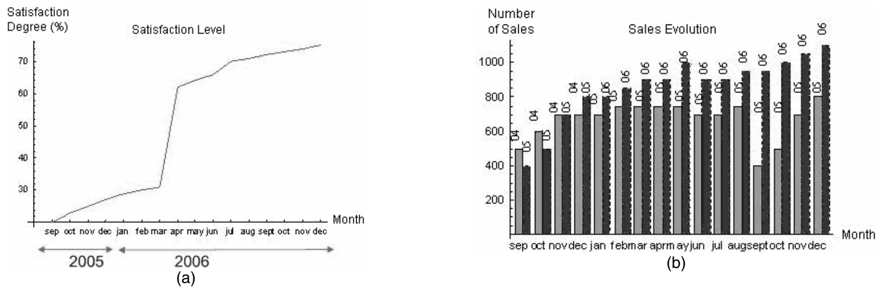

Fig. 4. Users satisfaction degree and sales evolution

The e-commerce techniques have facilitated user motivation since a user can easily find the products he/she is interested in, spend their leisure time more effectively and contact other users with whom he/she can share hobbies or opinions. So the degree of user satisfaction has been improved as observed in the surveys. The first autonomous prototype was implemented in October 2005 with a test set of 30 users and 23 business; presently there are over a 2400 different users and 62 business. The users were selected among users with specific models of terminals supporting the application (they use their own Wi-Fi, Bluetooth devices). The results obtained show that the greater part of users, nearly 67%, were people between 16 and 30 years old, while the percentage of people older than 40 is less than 3%. However there were no significant differences with respect to user gender. Figure 4(a) shows the users satisfaction level over time, which increased substantially, especially after a second prototype was launched in February 2006, that was more consistent and containing more information about promotions and special offers. At the beginning, the system obtained a low evaluation, basically due to the fact that the system was new and had some bugs; but as cases were incorporated, the products being promoted became closer to the user profile. The user satisfaction is measured from user opinions and by indirect observation on the sales results. The user opinions are obtained from a questionnaire that the user completes every month. Moreover, every time the system provides guidance, it asks the user about his/her degree of satisfaction.

Figure 4(b) shows the evolution of sales for the set of special offers, used as a reference over the years to evaluate the evolution of purchases at the commercial centre. They represent a set of 23 promotions that gradually diminish over time. Although the evolution of sales is not a significant index (it can be affected by other factors), the use of reference promotions allows us to observe the impact of the multiagent system in the mall. From this data we can see that, comparing the sales of each promotion over the time that the prototype was introduced with the sales from the previous year (within the same time period and similar social and economic conditions), the percentage of sales slightly increased. The promotion of these products through the guiding system helped to change tendencies.

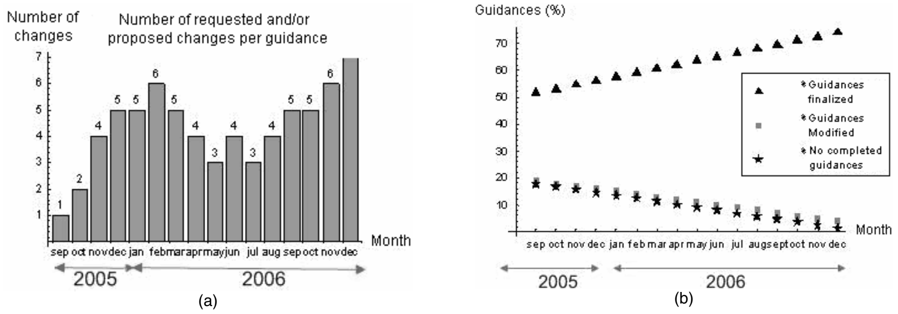

Fig. 5. Guidance system evolution

Users have noticed the utility of the dynamic replanning, since it is quite usual for them change opinions/objectives in the middle of a plan. CBP-BDI is a highly appreciated tool that optimizes the time spent in the shopping mall. Figure 5(a) shows how the number of replannings requested per visit stabilised between 3 or 4 among visitors who requested guidance. Figure 5(b) shows how the number of plans completed without a request for guidance continually increased because of the capacity of the system to learn and adapt to the interests of the users. This occurred at the same time as the number of users who did not complete the plan requested or that requested modifications to the initial plan. A guidance is composed of the problem description (user profile, money, time available, initial location of user and preferences) and the solution (guidance proposed, and result obtained after following up the guidance) given for the problem description given. As SHOMAS obtains more information about user profiles, products and habits, the system knowledge increases and the CBP-BDI agent provides more optimal plans. The users also need time to get used to the system. The proposed guiding system has been improved to be able to provide adequate guidance in a dynamic way and in execution time. In this sense it is a unique system useful for dynamic environments and open enough to be used in other environments such as health care residences, educational environments or tourist related environments.

One of the most demanding services of SHOMAS is the location of a given user by means of the RFID technology or the identification of someone with a given profile, in the same line of web services such as Match.com or similar sites. This service is used by an average of 46% of the users. The shop owners are the most reticent about using the guiding system for several reasons: (i) they do not trust the partiality of the guiding systems, since they cannot control whether it is biased or not, (ii) updating the information about products and offers of the shop agents requires specialised human resources and time, since they are not currently integrated with their software packages, (iii) they believe that the CBP-BDI agent may favour big shop stores with many offers and (iv) some of them argue that the SHOMAS may confuse some users. Nevertheless most shop managers believe that SHOMAS has more advantages than disadvantages and that the system has helped their businesses attract more customers and, in general, to sell more. They tend to argue that SHOMAS should incorporate a method that guarantees impartiality. This is our next challenge as well as an improved system evaluation in comparison to similar planning or recommender systems.

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