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Ambient Intelligence for a Personal Web Assistant

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Abstract

Modern mobile devices integrate a diverse collection of sensors, multiple modes of communication and an increasing amount of memory and computing power. The convergence of these technologies coupled with Semantic Web tools offers the promise of services that understand humans and their activities and can anticipate their needs. The focus of this project has been to develop a context aware "Internet Angel" that can sense information about the user and the user's activity in order to proactively search the internet for task-relevant information. The retrieved information would then presented to the user in non-obtrusive manner, such that it respects the user's attention and does not unnecessarily distract the user.

Without awareness of the human context, any attempt at proactive assistance simply generates an unwanted distraction, as a certain software manufacturer discovered with an animated paper clip. Few people would want to live in an environment populated with smart-objects that are constantly demanding attention in a misguided effort to be useful. Yet there is clearly a role for services that respond and assist human activity without direct command. To be useful, such services must operate with an understanding of human activity and social context.

Our approach to this problem has been to develop a cyclic process which continuously performs a set of operations to achieve situation awareness and accordingly provide information and services. To develop the computational model for this process, we have explored the operation of such a process operating in several common scenarios. The results are evaluated with a pilot experiment that aims to serve a users' need for information based on his current context, recognize a change in situation and update the information accordingly.

Keywords: context awareness, context-aware computing, situation awareness, situation model, ergonomics, cognitive psychology, attention management, reasoning, ontology

Résumé

Les appareils mobiles modernes intègrent une collection variée de capteurs, de multiples modes de communication et de plus en plus de mémoire et de puissance de calcul. La convergence de ces technologies couplées avec des outils du Web sémantique offre la promesse de services qui comprennent les humains et leurs activités et peuvent anticiper leurs besoins. L'objectif de ce projet a été de développer un contexte conscient "Internet Angel" qui peuvent capter des informations sur l'utilisateur et l'activité de l'utilisateur afin de rechercher de façon proactive l'information sur Internet des tâches pertinentes. L'information récupérée serait alors présentée à l'utilisateur le manière non intrusive, telle qu'elle respecte l'attention de l'utilisateur et ne distrait pas inutilement.

Sans prise de conscience du contexte humain, toute tentative d'assistance proactive génère simplement une distraction indésirable, comme un certain fabricant de logiciels l'a découvert avec un trombone animé. Peu de gens veulent vivre dans un environnement peuplé de smart-objets qui sont réclament constamment l'attention dans un effort pour être utile. Pourtant, il existe clairement un rôle pour des services qui répondent et assiste les hommes sans commande directe. Pour être utile, ces services doivent fonctionner avec une compréhension de l'activité humaine et du contexte social.

Notre approche de ce problème a été de développer un processus cyclique qui effectue en permanence un ensemble d'opérations pour atteindre sensible a la situation et en conséquence de fournir des informations et des services. Pour développer ce modèle, nous avons exploré le fonctionnement en opérant dans plusieurs scénarios. Les résultats sont évalués avec une expérience pilote de qui vise à servir le besoin d'information sur la base du contexte actuel, de reconnaître un changement de la situation et de mettre à jour l'information en conséquence.

Mots-clés : sensibilité au contexte, contexte, modèle de la situation, ergonomie, psychologie cognitive, gestion de l'attention, raisonnement, ontologie

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Last but not the least, I would like to thank my family for standing by my side through all the logical and illogical decisions I have taken throughout my life. Especially to my mother, who has always been my pillar of strength through thick and thin. [1]

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— 1 —
Introduction

1.1 Problem Definition

The goal of this research has been to develop an enabling technology for a context aware ”Internet Angel”. The ”Internet Angel” is a software system that can observe and model a user’s activity in order to proactively search and provide information from the internet that is relevant to the user’s current task or activity. In order to be useful, such a service must present information that is situated [44] and unobtrusive [14]. By situated, we mean that the system must be able to behave in a manner that is appropriate for the user’s task, activity and circumstances. Any information provided to the user must be relevant and useful. By unobtrusive, we mean that the system must be able to present the information in a manner that it respects the users limited attention resources [32] and does not unnecessarily distract the user from the current task. The presentation must respect the user’s attention.

With the growth of the internet, a wealth of data and information is at our disposal [13]. However more data does not necessarily mean more information. There are limits to the rate at which the human brain can assimilate information. To be useful, any service that seeks to provide information must respect these limits. This raises two problems: modeling the current situation of the user, and presenting relevant information in a unobtrusive manner.

1.2 Approach

Our research is based on the hypothesis that a situated and unobtrusive information service can be constructed using an explicit model of the user and task. We refer to this as a ”situation

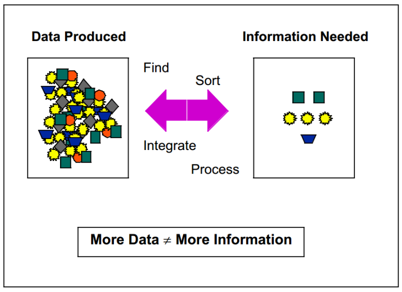

Figure 1.1: Relation of data and information (picture from [13])

model". We investigate the use of a process that maintains a model of the users situation in order to anticipate the user's needs, proactively search for relevant information and present this information in an appropriate manner. For this we propose a cyclic process that continuously observes the user's actions in order model the user's activities. We structure this cycle as a series of computational processes that perform the following tasks:

- Sensing: Acquisition and processing of information from the environment in order to recognize entities, activities and other relevant phenomena.
- Assimilation: Integration of sensed phenomena (entities, activities, relations) into the situation model of the user.
- Projection: Prediction of short term evolution of properties and configuration of the situation.
- Implication: Hypothesis of possible consequences including changes in the structure of the model, or information that could be useful to the user.
- Decision: Selection of the most appropriate actions, including information to retrieve or display.
- Action: Retrieval of information from the internet, presentation of information to the user
- Attention: Selection and configuration of sensors to obtain required information about the user and user activity.

To develop the computational model for this process, we have explored the operation of such a process operating in several common scenarios. These scenarios are essentially routine tasks that a user may perform in daily life that can be enriched by timely provision of information. Such tasks range from seemingly simple routines such as preparing a meal for guests, or searching for a book in the library to more complicated activities like driving or shopping. For each scenario, we analyzed the user's activity to determine what information would be useful, and what information would be needed about the user's current activity. Based on what the user is identified to be doing or looking for, the model predicts what the user could do next, and what information he would need to do so. The required information would then be retrieved from the internet and presented to the user.

At the heart of the situation model is an ontology. The ontology specifies the entities and relations that describe the user's task and activity. These entities, properties and relations provide the bases for a shared vocabulary that cam be used to understand and communicate with the user.

The situation model is maintained by a series of computational processes. The computational processes driving the model are developed in the form of rules. From analyzing the scenarios we have found that each of the reasoning processes can be accomplished using forward chaining rules.

1.3 Evaluation and Results

It was hypothesized that situated and non-obtrusive information, furnished from the web by the context-aware Internet Angel that proactively searches the web and renders situated information respecting the user's limited attention window, empowers the user, enabling him to be more proficient while performing the activity. To evaluate this hypothesis, we designed a pilot experiment that aims to serve a users' simple need for information based on his current context, recognize a change in situation and update the information accordingly. The objective was to help a user find a researcher working in a specific domain in a corridor of INRIA. The model is developed as an Android application that uses an ontology as the knowledge and reasoning base. It uses a QR code scanner for the purpose of user localization. The QR codes are placed at strategic locations within the corridor. The scanner is integrated in the application in such a way that it runs in the background and is not visible on the screen. When the user scans the code with the application, scanned code triggers an information retrieval cycle that retrieves stored and inferred knowledge from the model and displays it to the user in a non-obtrusive fashion. This information pertains to the profiles of the researchers who are seated at the location of the placed QR code. Thus, each QR code scan will retrieve some geolocalized information of researcher profiles from the model and display it in a non-disruptive fashion. It was then evaluated as to whether the information presentation mechanism at strategic points during the user task guided him to the correct person or not.

From the evaluation, the time taken to complete the task and overall user feedback were taken into account. From this, we concluded that situated information presented in a non-disruptive fashion helped most users to complete the task rapidly. In cases where information was not situated and inappropriate, the results were presumably different as users took more slightly more time to complete the task. Obtrusions like screen flashing and audio notifications were introduced into the application, and in most cases the users mentioned them as annoying in their feedback.

As a consequence of this initial investigation and evaluation, we converge upon the following conclusions:

- A context-aware Internet Angel can aid a user with task-specific situated information from the internet and allow him to perform better in the task.
- Information presented to the user in a non-obtrusive manner is effective for aiding the user.
- The notion of what features are obtrusive and to what extent they need to be present to be called obtrusive requires further work.
- From the adopted architectural design and analyzed scenarios, the "attention" phase of the model is unjustifiable. It is more of a placeholder as the task of focussed sensing already takes place in the assimilation phase.

1.4 Report Outline

The report is organized as follows.

Chapter 2 defines the problem statement of this research project with respect to the literature. It also introduces our proposed approach to address the problem. Electronic devices are becoming more and more aware of their physical surroundings and user activity. This awareness means that these devices are more informed of the informational needs of human tasks, and can strive to fulfil those needs. The imnternet, as a huge data store, can serve information specific to user situation. Ironically, the web stores huge data volume and humans have a limited attention span. Hence it is very likely that the users' limited attentional span is being supplied by irrelevant information that does not serve any purpose. Thus, awareness of the human activity and situation is important to serve relevant information. In other words, any service striving for the above mentioned objective is required to be "context aware". A context aware service should be able to perform situated actions, that is, actions relevant to the situation. To be able to perform situated actions, the service needs to have "situation awareness", that is, understand the current human task and predict future courses of action. This modelling of user task can be done by creating and maintaining a "situation model". The model should identify human activity, reason and eventually predict future courses of action. We propose a situation model that is anchored on four primary contexts for identifying human activity: location, person, task and time. The model is agenda-driven, that is, activities that occur in it are scheduled. The situation in which human activity occurs consists of entities and relations, with entities playing roles [9]. These entities and relations can be associated with the four primary contexts extend them in an object-oriented fashion. Thus every situation that is integrated into the model causes the model to grow in an object-oriented fashion. The proposed situation model is driven by the following computational phases in a cyclic manner: sensing, assimilation, projection, implication, decision, action and attention. Each of the phases has a specific function and is driven by a different computational process. Together, they perform all the functions from information acquisition to presentation.

Chapter 3 discusses in detail about the architecture, design and implementation of the proposed situation model. Each stage of the situation model may have a different architecture that is best suited to help it perform its function appropriately. Various designs and reasoning processes-both probabilistic and logical, have been investigated. The initial knowledge acquisition is beyond the scope of this project, and we assume a model that has an already acquired knowledge base. A rule-based approach was found to be most appropriate as it means that an action would occur only on the satisfaction of certain conditions, retrieving appropriate information from the knowledge base. Forward chaining is found to be the best approach as it implies that both assertions and inferences are stored in the knowledge base together. The decision phase, however is not so trivial as the model deals with the partial likelihood of many outcomes and chooses the best one. Thus, using decision trees is the best approach as it is both simplistic and comprehensive. For the purpose of implementation, recent developments in semantic web technologies has meant that situation modelling can be done with a semantic web foundation. We discuss the semantic web as a framework of concepts with relations. These frameworks are machine-readable because of various expressive languages for modelling the concepts. Various tools have been scrutinized while searching for tools that are easy-to-use, portable and have strong community support. We use SWRL as our rule language, and Protege as our ontology editor because it is easy-to-use, has SWRL and reasoner support as well. As the implementation would be designed as a mobile application, Androjena was chosed to be the semantic web framework for development. Androjena is the Android version of Apache Jena, that is a popular semantic web framework written in Java.

Chapter 4 describes a pilot evaluation to validate the functioning of the model as well as the strength of our hypothesis. We believe that situated, task-specific and non-obtrusive information retrieved from the web by the proposed situation model helps the user to become more efficient in the task. For this purpose we developed a mobile application that runs our context-aware service. The participants were given a tablet and asked to search for a researcher of a certain scientific domain within a corridor of the INRIA builiding as early as possible. The service would use QR codes placed at certain points in the corridor to localize the user and provide situated information to aid him in his quest. The quality and quantity of information was varied to test the impact on the users' ability to do the task. The intent was to evaluate four primary modes of information display-

- Manual/Automatic: Information display is user-initiated or self-initiated.
- Obtrusive/Non-obtrusive: Information is disruptive or blending into user perspective
- Minimal/Maximal: Bare minimum/insufficient or overwhelming amount of information.
- Appropriate: This is the best case with precise and most useful information.

The metrics used to evaluate each of these modes include [46], [35]:

- Acceptability: Extent of user assent/dissent with the used application.
- Effectiveness: Evaluate if the user is able to complete the task or not.
- Efficiency: Evaluate if the goal is reached with minimum time or effort.
- User Satisfaction
- Time

While we timed the user to record the task completion time, other information was recorded in a feedback session conducted with the user at the end of the task. From the results recorded and analyzed, the following was concluded:

- Situated and non-obtrusive information does indeed augment the user's efficiency to complete a task.
- Sounds and notifications (alert tones) in a device are found to be extremely annoying and obtrusive by the user. Interestingly, some notifications assumed to be annoying turned out to be otherwise. This finding however needs more investigation.
- Information presentation matters: In a series of mixed feedback about how information should be presented, the common emerging pattern is that provided information must be relevant and presented in a fashion that the user does not find the need to interact with the device (scroll, pinch) to get more information.

Chapter 5 summarizes and concludes this research project. The major contributions of this project are described which include a context definition, design mechanisms for computational processes, implementation strategies for each computational phase, and integration into a single mobile application. We conclude this report by affirming that a semantic-web driven context-aware service can aid a user performing an activity with information from the internet presented in a non-obtrusive fashion, allowing him to be more proficient at the activity. The notion of obtrusiveness, however, requires deeper investigation.

— 2 —

Information Requirements for Context-Aware Services

Digital devices are increasingly ubiquitous [50], bringing the physical world closer to the digital world. As this convergence takes shape, mobile devices are capable of taking on new functions. They are now able to sense information about user and user context. At the same time, the internet continues to grow exponentially, leading to an increasing availability of information in digital form. The combination of these two phenomena are driving the emergence of services that use mobile computing devices to continually present users with virtually unlimited quantities of information.

Unfortunately, the human brain is not designed for such a world. The human information processing system has limited capacity for attention [32]. In order to fully exploit ubiquitous access to information, we need to determine the relevance of information to the user's current activity, and how this information can be presented in a manner that respects the limits of the user's attention. This is the challenge currently posed by "context aware computing".

Without awareness of the human context, any attempt at proactive assistance simply generates an unwanted distraction, as a certain software manufacturer discovered with an animated paper clip. Few people would want to live in an environment populated with smart-objects that are constantly demanding attention in a misguided effort to be useful. Yet there is clearly a role for services that respond and assist human activity without direct command. To avoid disruption, such services must operate with an understanding of human activity and social context.

Context aware computing requires an explicit model to identify user situation and activity and provide situated information from the web in a non-obtrusive fashion. By situated, we mean that the system must be able to determine the relevance of information to the user's current task. By unobtrusive, we mean that the system must be able to present the information in a manner that it respects the users' limited attention resources and does not unnecessarily distract the user from the current task [32]. At the core of context-aware computing, is the notion of "context".

2.1 Defining Context

As observed by Winograd, context is composed of "con" and "text", that is, information that is required to understand the text [52]. More relevant to our problem, context refers to the information that is needed to model the user's current task and situation in order to anticipate information that can be useful to the user.

The use of context has been explored in a variety of areas of informatics, ranging from grammar and computing theory to artificial intelligence. For instance, in the field of computer vision, Strat et al. combined the results produced by simple procedures that analyze monochrome, color or stereo images driven by a context model to achieve object recognition [43]. Interpreting those results with contextual knowlwdge, a sound object recognition mechanism was achieved. In the field of mobile computing, the first substantial definition of context was given by Schilit and Theimer. They defined context as location, identities of objects, changes to those objects and people in the proximity [40]. Schilit et al. stated that context depends on where you are, who you are with, and what resources are nereby [39]. They defined context on the basis of environment, in particular:

- Computing Environment: Computing resources available.
- User Environment: User location and social situation.
- Physical Environment: Sound and luminosity level.

However, context is not necessarily dependent on environments, and may vary with situation. Context is more about classifying the situation that is relevant to an application and its users. The highighted aspects may be different in the case of every situation.

Context has been defined in various ways in the past. McCarthy et al. introduce contexts as abstract mathematical entities with properties useful in artificial intelligence [33]. Hull et al. define context as aspects of the current situation [22]. Franklin and Flaschbart define context as user situation [15]. Brown defined context to be the elements of the user's environment that the user's computer knows about [1]. Ward et al. define context as the state of the application's surroundings [49]. Rodden et al. define it to be the setting of the application [38]. Henricksen et al. define context with a temporal backdrop [19]. They state that context information is either static or dynamic. Static information is invariant over time, such as name or date of birth. Dynamic information, as the name suggests, refers to information that undergoes change over time.

From the previously mentioned definitions, the emerging pattern is that these definitions are plagued with specificity and tend to align themselves to a specific aspect (environment, location, user behaviour). Dey provides a more comprehensive definition of context, defining it by "Information used to characterize the situation of an entity; which could be any person, place or object relevant to the interaction between the user and application, including the user and application themselves" [11]. In other words, any information that characterizes situation is context.

Dey defines context in the form of location, activity, indentity and time. Activity defines the occurences of events around the subject. Dey's definition appears to be more comprehensive because it structures the constituents in the form of primary concepts (location, activity, identity and time) and secondary context types (that extend primary types).

Context awareness can provide important benefits for services on mobile devices. Various elements like location, surroundings, human activity and other entities that influence context, change over time. This means that context is not a static component, and may undergo temporal variations.

2.1.1 Context Aware Computing

Context aware computing implies that the application has the ability to adapt to user task and activity. Dey states that a context aware system provides relevant information and services to the user, where relevancy depends on the users' task [11]. This definition proves to be accurate because it is generic and user centric at the same time. He proposes a new contextual ecosystem that relies on three categories:

- Presentation: Of information and services to the user by combining proximate selection and contextual commands.
- Automatic service execution: This is known as contextual adaptation
- Tagging: Of context to information for later retrieval. This is known as contextual augmentation.

Resource discovery is not considered a context-aware feature. It is split into two parts: information presentation to user, and automatic execution of a service.

2.2 Objectives of Context-Aware Systems

Humans perform routine activities in their daily lives: commuting, shopping, recreation and so on. Some of these activities are agenda-driven, that is, structured as routines. Others are possible due to the continuous input of information: for example, a driving activity to an unknown location uses GPS navigation systems that aid the user to reach a destination. Such an activity is possible only if the driver continually receives GPS fixes en route. These activities can be enriched, enhanced and simplified by a timely presentation of information. For example, display of real-time traffic information to inform the driver of a congested route and aid him in choosing an alternate route can allow the driver to avoid traffic, while globally reducing the number and severity of traffic jams.

The quality and quantity of information needed by the user varies with activity. The Internet can serve as a rich repository of information. This information must be present in a universal standardized format for it to be retrievable and be machine readable. The retrieved information must be formatted, aligned with the user's current needs, and presented to him in a way that he can best use it to serve his needs. Thus, a context-aware service should meet the following objectives:

- Identification: Identify the user's current activity and situation that drives his need for information.
- Recuperation and Filtering: Based on the identified activity and situation, retrieve information that best serves the user's activity. The data must then be preliminarily processed to filter out the irrelevant and focus on the necessary parts.
- Anticipation and Decision: Based on what it known about the users' current situation, anticipate the users' future course of action in the form of listed options. Dealing with these options in the form of alternatives, the service should make a decision on the most certain future course of action of the user.

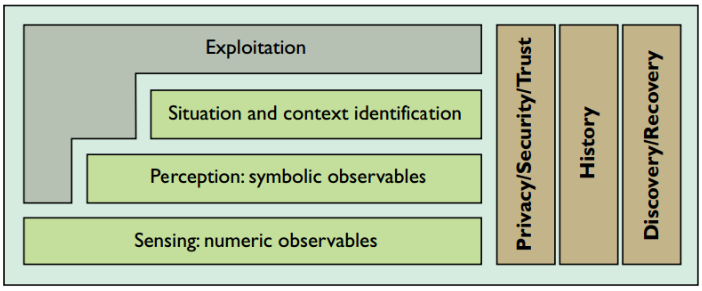

Figure 2.1: Perceptual Framework (picture from [8])

- Presentation: Present the data to the user in a fashion that does not interfere with his current focus of attention and supplements him with situated information at the same time. This information should be relevant and useful to the task.

2.3 Frameworks for Context-Aware Systems

Coutaz et al. describe context in a behavioral and equilibrial fashion [5]. They state that context is not a state but a process, and it is imperative that the system behaves correctly during the entire span of the process. There must be a sense of harmony between the users' mental model of the system and the system's model of interaction. They propose a framework anchored on two foundations:

- Ontological foundation: Context can be represented in the form of a digraph where nodes represent context, and edges represent the conditions for context change. Each context will be characterized by a set of entities, roles, relations and situations. Situations are specific configurations of entities, relations and roles. A change in context or situation indicates a possible change of entities, roles or relations between entities.

- Architectural foundation: Represents a layered model that filters assimilated information based on various criteria. The layers include:

  - Sensing layer: generates numeric observables.
  - Perception layer: generates symbolic observables.
  - Situation and Context indentification: identifies current context from observables. Services in this layer specify entities, roles and relations.
  - Exploitation layer: Highest layer of abstaction where applications request for context services.

Adaptation forms an essential part of the progress and success of such a system, as it must be able to maintain the same generic behaviour across all kinds of physical, social and computational barriers. Specific behaviour, on the other hand, is more likely to vary. The construction and adaptation is a continuous process that must occur by environment interactions in a way that does not disrupt the user activity.

Adaptation is done in many ways. Brdiczka advocates the following [16]:

- Machine Learning (ML) techniques: Using sensors to record human behaviour and use ML algorithms to build a model.
- Active Lezi Algorithm: A sequential prediction algorithm that analyzes information collected from various sensors and predicts human activity and behaviour.
- Probabilistic models: Bayesian and HMM models can be used to predict and reason about human behaviour and activity. This is done by using call logs, application usage and phone status (idle/overloaded/charging) as a source of information.

Crowley et al. describe context from a perceptual point of view [8]. The proposed context model is described as a federation of processes. It is demonstrated in the form of an ontology that has top-down components (derived from users and their tasks) and bottom-down components (bound to system interpretation). The context is decomposed as follows:

- User context: Focussed on the user and his goals. It represents the universe in the form of a graph where the states are connected by actions. The snapshot of the universe in real time represents the current state, while the desired final state is the goal state. The current and the goal state are associated by task. The user has the flexibility to choose his set of actions to reach the goal state. The current set of tasks is the users' activity, while the other tasks are referred to as background tasks.
- System context: Composed of the user context combined with some internal context. This internal context guides the model towards what it observes and how it interprets those observations. The observational work is carried out by a observation process.

  Observational processes have the following characteristics:

  - Auto-regulation: Processing is monitored and guaranteed to maintain a certain minimum standard or quality of service.
  - Auto-criticality: Estimates the confidence in the produced outputs.

  The states and capabilities of the observational processes are monitored by a meta-supervisor in order to ascertain as to whether the current process is capable of providing the desired service at the required instant of time.

  The observational process is further made up of a transformational and control component. The transformational component converts input events as well as associated meta-data into an output format. This output may further serve as input events for processes further down the line. The control component primarily supervises the execution of the transformational component. The Figure 2.2 is a demonstration of the same [9]:

  The system context is described in a hierarchial fashion where the sensors lie at the lowest level and pick up observational variables, that may be numerical or symbolic.

The model is described to be composed of entities alongwith relations between those entities. An entity is a predicate function of one or more observable variables. These entities may also be grouped by specialized grouping processes. Relations can be defined as a predicate function of the properties of entities. The relation between entities are also determined by observational processes. These observational processes may fall under the judistriction of a supervisory controller.

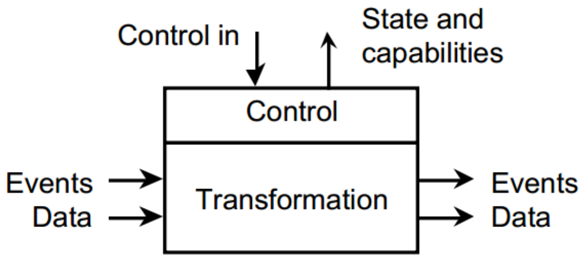

Figure 2.2: Processes (picture from [9])

A definition of context and situation emerges from the definitions of entities, relations and variables. An entity is a collection of roles to observe. A role is a set of actions in a task. When the entity enables an action of the role, it plays that role. An acceptance test determines whether or not an entity is capable enough to play a role based on its properties. Since the mapping of entities to roles is not bijective, one or more entities may play a role. It is this scheme of things that builds up a situation.

A situation is defined by an assignment of entities to roles, also involving a set of relations between the entities. In case the relations change, the role assignment to entities changes, and consequently the situation within the context also changes. This change is postulated to be data-driven.

2.4 Google Now, an example of a context aware service

An example of a context aware information service is provided by Google Now. Google Now is an voice-directed information service which is integrated with the Google Search feature and provides the user with information only at a time when the information is needed, without the user asking for it [24]. Google Now tracks the users' internet activity and supplements it with timely information and recommendations (based on his habits). This information is organized in the form of cards and presented to the user screen at a time deemed appropriate. The user is able to choose the cards that are displayed on the screen, discarding the ones he finds irrelevant with a simple swipe motion. The user is also able to get more detailed information by clicking on a card. Some of services provided by Google Now include:

- Airline Assistance: Real-time flight schedules and boarding pass information.
- Traffic Assistance: Real-time traffic update and traffic busters.
- Hotel and Restaurant reservations: Booking status and availability information.
- Time, Location and Event reminders: Updates of happenings around the user based on his interests and current location.
- Stock, Weather and Sports updates.
- TV sitcoms, Albums: Updated information of the release of new albums from the favorite singer of the user or new episodes of his favorite TV show.

Google Now draws inference from the user's everyday internet activities like searches, locations visited, traffic routes followed, to-do schedules and so on. It however draws most of its information from voice searches made with the device. The service also uses the Knowledge Graph feature, which is a powerhouse of interlinked semantic information helping the user to seamlessly navigate to information related to the current query [23]. The information is collected over time and is used to predict the future needs of the user.

2.5 Use-Case Scenario: User in a library

We consider the scenario of a user visiting a library. The objectives of such a user could be the following:

- Browse books: When the user is not looking for something in particular.
- Withdraw a Book: Check-out a book that caters to a genre or author he is looking for.
- Extend: Extend the validity of a book he has already issued.

A context-aware information service should help a user in the library in the following fashion:

- Identification: Identify where the user is at every point in time and postulate what his information needs would be at that instant. Depending on his situation, he would expect different information from the service. For instance, if he is at the entrance of the library, he might want to see the blueprint of the library with information about the various subjects and the aisles where he may find books related to those subjects. On the other hand, if he is in front of an aisle and searching for a specific author, he would be intested to find out about the books from that author that are on the aisle in front of him.
- Anticipation and Decision: Post-identification of the current situation, the service anticipates and decides on the most probable future course of action. For example, if the user is at the library check-out counter, it is likely that he would either be looking to issue/re-issue a book, or ask for information. In case he has a book in hand, it is most probable that he would issue/re-issue it.
- Recuperation and Filtering: Based on the action the service anticipates in the previous stage, there arises a need for information to complete that action. The information source being tapped depends on the kind of information needed at the time. For instance, if the user has a book in hand, he might be interested in the review of the book, what other people have said about it. The service should consequently be able to retrieve information from user review sites. On the other hand, if the user is at the entrance of the library, the service should show him other public libraries in the vicinity with information retrieved from websites that provide maps and navigation.

2.6 Use-Case Scenario: the Drivers Assistant

In this case, we consider a context aware service that can provide a user with information while driving. A limited form of such services are provided by dash-board GPS navigation units in the form of navigation information and advisories on traffic. In this scenario, we examine what would be required to proactively provide information relevant to a variety of other user needs that can arise during an extended automobile trip.

- Food: When the trip overlaps with meal time, providing advice on restaurants or other places to eat that correspond to the user's preferences.
- Rest: Anticipating the user's physiological needs for rest, and advising the user of the need and opportunities for rest breaks.
- Fuel: Monitoring travel time to estimate fuel consumption and providing advice to the user about when and where to refuel, based on fuel prices, need for a rest stop, or proximity of preferred restaurants.
- Weather: Monitoring forecasts of weather conditions to alert the user about difficult driving conditions and propose possible alternatives.
- Communications: Intercept and process phone calls or text messages to protect the user from distraction while alerting the user to communications that are relevant to the trip.

A context aware information service for this scenario should be composed of the following proceses:

- Identification: Tracking of the user location at every instant of time by GPS localization. There should also be a constant monitoring of vehicular particulars like fuel consumption, speed, remaining journey duration and so on. In case any of his needs become pressing, the service should track restaurants, hotels and gas stations in the vicinity of the moving car.
- Anticipation and Decision: If any of his needs become high-priority, the service queries the Web to cater to that information need. For example, if the Angel anticipates from the user's habits that his lunchtime is approaching, it makes "food search" its priority. However, if more than one of his needs become pressing, then the decision becomes more complex. For example, if he is running out of gas and is hungry at the same time, the decision of which of the two deserves higher priority would primarily depend on how long the fuel may last.
- Recuperation and Filtering: The information pertaining to the anticipated user decision is retrieved from the internet. The information retrieved, filtered and eventually presented will keep the users' personal preferences in mind. For example, if he is fond of Chinese and not so much of Lebanese, the approaching restaurants serving his preferred cuisines will be ranked higher when presented to him. If he has to retire for the night, all the approaching hotels that fit his budget would be displayed to him.

Some of the main entities in this use case would include:

- User Information: Consists of the {User} entity that includes entities representing personal information like {Name, Personal Preferences, Car}.
  - Entity {Personal Perferences} can further be decomposed into entities like {Eating Pattern, Sleeping Pattern}.

  - Entity {Car} can further be decomposed into entities like {Current Fuel Quantity, Speedometer Reading}.

- Temporal Information: Includes entity {Time} that can be decomposed into {Travel duration, Estimated departure time, Estimated arrival time, Current time}.
- Activity Information: Consists of entity {Task}. The activity is performed by the user based on an arising need. Choices include {Refuel, Rest, Eat}.
- Spatial Information : Consists of entity {Location} that identifies location. It can further be decomposed into {Departure, Destination}.

Based on the above mentioned information requirements, proposed information rendering mechanism and architecture; the context aware service can be described as a situation-aware model. This model is able to use information gathered from observing entities playing roles to identify the overall situation and provide services accordingly [9].

2.7 Situation Models

The idea of situation models goes back to Scottish psychologist Kenneth Craik, who suggested that perception constructs 'small-scale models' of reality that are used to reason and anticipate events [6]. Situation models are thus the outputs of the human perceptual cycle [27]. A situation model interprets human activity and predicts the essential actions for the application to perform [7]. Some of these activties may be ad-hoc, while others may be structured. The current activity may also change depending on the current state of various contextual factors. The activity defines a subset of contextual elements, and can be observed in the form of scenarios that are composed of situations. The situation model can thus also be described as an interconnected network of situations where events trigger the transition from one situation to another. A situation can further be described as a set of relations of entities that interact by dawning roles. Entities are composed of a congregation of atomic level constructs called properties. A role selects an entity from a set of observed entities, the selection being done by means of a role function. No situation remains the same, and the current situation is most likely to change as well. Owing to this change, the entities playing roles will also change, and now the entity with the most appropriate property set will be assigned the role [9].

Alternatively, a situation model can also be described as a finite state machine of entities and relations that induces stability and reduces fluctuation. The selection of the entities and relations is done based on the services to be provided. These services to be provided are a system reaction to human activity performed.

Johnson Laird's "situation models" provide a simple and elegant framework for predicting and explaining human abilities for spatial reasoning, game playing strategies, understanding spoken narration, understanding text and literature, social interaction and controlling behavior. While these theories are primarily used to provide models of human cognitive abilities, they are easily implemented in programmable systems [28],[29].

In Johnson-Laird's Situation Models, a situation is defined as a configuration of relations over entities. Relations are formalized as N-ary predicates (truth functions with N arguments). Sets of relations and entities form a state space referred to as a network of situations, where each situation is a specific configuration of relations overentities. Each situation is associated with information about system behaviour such as:

1. A set of possible perceptual components for observing the entities and relations that define the situation,

2. Lists of system actions (or interaction modes) that are allowed or forbidden in that situation

3. Default values for entities and relations that may not be observable

4. A set of possible next situations.

Situation models provide context for smart systems and services and thus provide an enabling technology for context aware computing.

2.8 Situation Awareness

Mica R. Endsley, pioneer in ergonomics and human factors, postulated that information must be provided in a manner such that it can easily be assimilated, both cognitively and physically [13]. Situation awareness is thus knowing what is happening around you, that is, the information systems' capability to obtain the desired information under dynamic operational constraints. A formal definition states it as ”perception of elements within an environment within a volume of time and space, comprehension of their meaning and projection of their status in the near future”

In the model proposed by Endsley, sensors collect information from the user surroundings and internal system parameters and redirect a portion of it to the user interface. This information relayed to the screen aids the user in interpreting the situation, resulting in situation awareness.

The operators make a call on what to do based on the current state. Hence, decisions are formed by situation awareness and not the other way around. These decisions once made have a direct impact on performance. In a nutshell, the three (decision, situation awareness and performance) affect each other in a continual and cyclic fashion.

- Level 1: Perception : Forms the correct picture of the situation. The sensors collect a subset of information available with the systems' environment and internal system parameters. Some portion of this information is displayed to the operator on the GUI, based on which the operator proceeds with the following step.

- Level 2: Comprehension: Combining of information of various forms and ascertaining their utility in achieving the persons goals.

- Level 3: Projection: The ability to take the current set of events as input and determine future events. This anticipation helps in making the right decision in foresight.

- Temporal aspects: Play an important role in comprehension and projection. They allow operators to restrict themselves to the part of the situation that have an effect on the future goals of the operator. These aspects support the ideology that since the situation is always changing, the individual's situation awareness must also change accordingly.

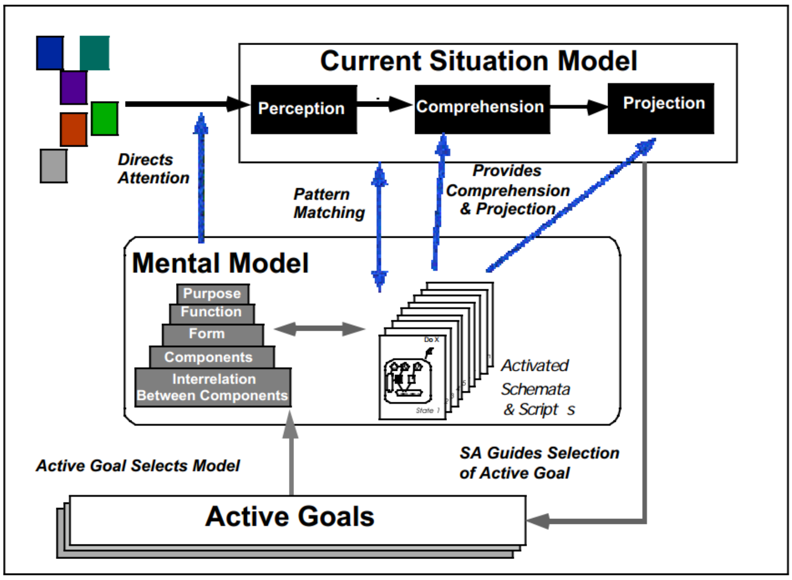

Figure 2.3: Endsley's model (picture from [13])

2.9 Factors Effecting Situation Awareness

2.9.1 Cognitive processes

Humans have a limited amount of working memory and attention span to work with [13]. The way in which people use their attention span influences which aspects of the situation end up being processed and inculcated into their situation awareness. The aspects of the situation that end up being processed are those which are deemed to be useful and worthy of being processed.

Short Term and Long Term Memory

Working memory is an activated subset of long-term memory, and information proceeds from the former to the latter directly. Situation awareness is said to be a product of acquired information, processes in working memory, and long-term memory stores.

Long term memory stores do not suffer from any of the limitations of working memory. These models help to direct the limited attention possessed by humans in an efficient fashion. Situation awareness can be called as the current state of the mental model.

Attention

Attention can be defined as the "focussed mental engagement on a particular item of information" [14]. It can also be stated as the process of raising an individuals' awareness for a particular piece of information. Some properties of attention include:

- It is goal driven.
- The person's walking speed, direction and orientation are best indicators of attention [42].

- Often it is assumed to be an implicit information found in the description of the entity with one or more objects in the environment [32].

Attention can be of two types:

- Voluntary attention: The conscious control of tasks.
- Involuntary attention: External stimuli that capture a persons attention.

When an item comes to an individuals' awareness, the individual will attend to the same and make a decision as to whether he should act on it or not. An input is received by the individual in the form of certain stimulus messages, followed by a perception phase to understand the meaning of the messages. Some of these messages are filtered early before the perception phase, making sure that the unattended stimuli are not processed. This whole process of stimulus reception, filtering and perception forms a part of the Single Channel Theory (SCT).

Attention is also influenced by interruptions. An interruption is a disruption in the normal course of activity or attention of an individual due to a sensory stimulus produced by an unexpected event [36]. The interruptions can be of three types:

- Internal interruptions: Caused by an individuals' own thought process
- External interruptions: Caused by the environment
- Mediated interruptions: Use of indirect information like the calendar to find opportune moments to trigger notifications.

The approach should be given an absolute necessity, to interrupt the user at a time that is most conducive and least annoying. Thus, an interrupt that occurs at a coarse breakpoint, such as the buffer period between the completion of one activity and the commencement of the other, is deemed useful. This leaves an impression that the interruption-producing mechanism respects the users' activity and waits for the most opportune time to push a notification.

Attention is a major factor of consideration of what data is worthy of being brought to human sensory notice. It is hence imperative to identify the most suitable mechanisms to display information, based on the users' current situation and attention state. The current attention state is determined from inputs collected at various levels of sensing. At the lowest level, it consists of information picked up by sensors. The information must be meticulously placed in the users' attentional space so as to provide least possible distraction [14].

2.9.2 Goals

Goals are one of the most important factors of situation awareness as [13]:

- They drive the selection of the mental model.
- The goal and chosen model direct attention to obtain required information.
- Goals and chosen models integrate and interpret information to achieve comprehension.

Goals direct the information selection and comprehension in the form of a top-down process.

2.9.3 Expectations

People have expectations about what they expect or prefer to hear in a given environment [13]. These expectations influence their attention direction, and hence the information collected and perceived as well. These expectations are driven by the current mental model as well as previous expectations and can be useful in filtering the available information to the useful part of it.

2.9.4 Automaticity

With gained experience, the action-selection process can be made automatic and sequenced [13]. Automaticity can hence aid the process of SA by reducing demands on limited attention resources. The flip side however is the fact that any new information outside the set sequence may end up being neglected, which is fatal in case the information turns out to be pivotal.

2.9.5 Plans

Suchmann defines a plan as a hierarchial process in the organism that can control the order in which a sequence of operations is to be performed [45]. When the subject is executing a plan, the literal sense can be misguiding. In truth it is the plan that is controlling the subjects' activity. A plan is eventually broken down into a set of instructions that serve as an input to the program that controls the action, such that the action is now a subsititution of the plan itself.

A plan is a prerequsite for an action. The planning model is described with a set of actions that is one means of solving a problem. These actions are further decribed by a set of prerequisites which identify subgoal states. These subgoals will be achieved by a series of subactions. The situation obstructs/advances a person's progress towards his eventual goal. In totality, the user analyzes a sequence of actions and forms a hypothesis about the plans that could be the reason for the performed actions.

A person's plan is rarely solitary in execution. A single agent directed towards a goal and responding to an environment surfeit with conditions is unheard of. In a real time situation, a plan is influenced by the actions of other actors in the given environment as well. The influence can be seen in the case of interaction, where it becomes a necessity to recognize others' actions with respect to the plan at hand.

Some important postulates about action include:

- The same action can be achieved in a number of different ways, each of which are dependent on the circumstances that come into play during the plan execution.
- The outcome of an action can neither be predicted from knowledge gained from the users' previous actions, nor be understood from the analysis of the result.
- An action is also governed by intent, though an intent very rarely implies the action that proceeds it. This is because that plans are plagued to be vague, that is, they are not equipped with the ability to describe the course of action that will occur. The planning model treats the intent as an anticipation of action and analyzes the outcomes in the case of the individual intents, treating that reasoning as a model for the action itself.
- Plans are models or sketches for actions. The structure of the plan engulfs the constituent parts of actions, goals, preconditions and consequences. The usefulness of a plan requires

that the subject forms a relationship between the plan and set of situated actions that must be taken at that point in time. It is often the case that future states of discourse become clear after performing a current action, and a desirable state of affairs produced at the end of the current action that reassures the subject that the current action was incremental towards achieving the goal.

Conclusively, the objective of a planning model is to characterize actions in terms of their preconditions and effects, and eventually formulate rules to map actions with underlying plans. The amount of planning involved is dependent on the subject's prior knowledge of the environment and its conditions. This prior knowledge can be termed as background knowledge.

2.9.6 Background knowledge

Labelled as ”common sense” in lay terms, Suchman refers to it as a domain of knowledge that is infinitely large and are ”there” in the mind of the subject [45]. In other words, it may be interpreted as the mental state of the user. This knowledge is responsible for the eventual action performed. It is a realm that does not fit into any domain of specialized knowledge, and is implicit and relevant at the same time. It can be identified as a situation where it is unnecessary to explain yourself, yet the point is seen to have gotten across. The problem with classifying knowledge that is inherently implicit is the fact that till date, it has not been possible to construct rules that can comprehensively account for this knowledge without referring to deeper ad-hoc procedures that have not been completely understood either.

2.10 A Closer Look At Some Outlined Aspects

Keeping the objectives of context aware systems in mind, certain aspects such as task identification and recuperation of base and inferred knowledge, call for a deeper analysis.

2.10.1 Human Activity Recognition

Activities performed by the user in daily life range from simple ones like fetching milk to more complex ones like cooking, that are identified by the use of various sensors found in ubiquitious devices [18]. The ability to accurate activity recognition remains as one of the major bottlenecks in the quest for situation modelling. There are namely three approaches to activity recognition: data-driven, knowledge-based and hybrid approach.

- Data-driven Approach: Uses supervised learning approaches like Hidden Markov Models, Conditional Random Fields and Dynamic Bayesian Networks. Despite having the advantage of accurate recognition of simple activities, these approaches falter in the case of complex high-level activities. One such approach by Buettner et al. uses RFID based sensors to acquire information and object traces, then uses a HMM to recognize human activity.

- Knowledge-driven: This approach makes use of Description Logics (First Order Logic with formal semantics) or ontological modelling and is capable of recognition of complex activities [2]. However, these approaches suffer from a lack of support for probabilistic reasoning that makes them incapable of handling contextual data with a high degree of uncertainity.

- Hybrid: The best of both worlds, it combines the data-driven and knowledge-driven approaches in a loosely coupled fashion. Due to the individual limitations of both the approaches, this is not seen as a comprehensive approach either.

- Log-linear Description Logic It is a family of probabilistic logics, that is, a combination of probabilistic log-linear models and description logics [34]. Probabilistic Logic is the formalism that combines the concepts of uncertainity and deductive logic to form a union that is stronger than both of its parts. Log linear DLs allow the modelling of both probabilistic and deterministic dependencies between DL axioms, extending uncertain axioms with weights [18]. Since it combines log-linear models and description logics, it supports both modelling and reasoning. Reasoning can be performed using a log-linear DL reasoner like Elog.

2.10.2 Reasoning

Reasoning forms one of the founding pillars of cognitive science. Laird describes cognitive science as a vertical of science that came into existence to address the shortcomings of experimental psychology and artificial intelligence [26]. Psychology looks to make its theories fact-based; while the objective of artificial intelligence is to make its theories coherent. Cognitive science looks at a seamless integration of the two, that is, theories should both be coherent and fact-based.

Laird postulated that reasoning is the focal point of the intellectual ability of humans [27]. It consists of premises that may be statements and perceptions/beliefs that produce a valid conclusion. He believed that the mind creates syntactic representations of assertions and proceeds to apply rules of propositional logic to them. Modern day reasoners construct mental models of premises that represent the situation, and infer conclusions from the models.

Mental Models

Laird postulated that an individuals' thinking depends on his goal, knowledge and beliefs [27]. Perception of a situation creates miniature models of reality that are used for anticipation and reasoning. Mental models are a product of this perception step and represent spatial relations, events, inferences, processes and operations of systems. Mental models are defined by the following characteristics:

- Represent relations among 3D or abstract entities, and represents the different ways in which a possibility may occur.

- Represent only what is true according to the premises.

- Inhabit the long-term memory in the form of knowledge.

- Form the backdrop for deductive reasoning, that is, if a conclusion holds in all models of the premises, it is valid. However if it holds in none of the models, it is impossible in all the premises.

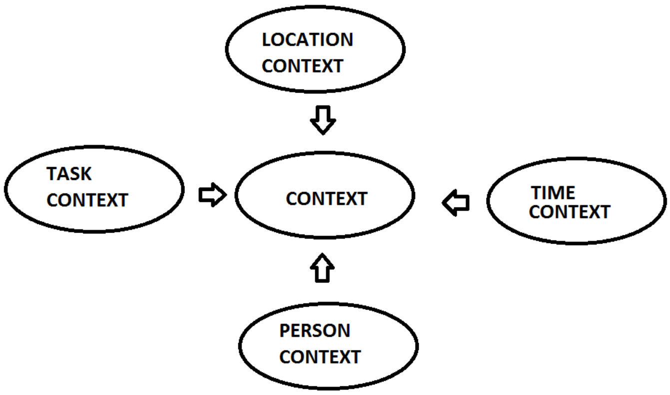

Figure 2.4: Context as identified by four foundational contexts

- The lesser the number of models and the fewer the entities, the lesser is the processing load on an already small working memory, the more simplified is the inference process.
- The reasoning process that draws from the model is also influenced by attributes of the individual, namely knowledge and beliefs. For example, in case an individual encounters a conclusion that is falsifies his belief, he will try harder to negate the conclusion.

Conclusively, the ability to draw inferences rests solely on the ability to construct and manipulate mental models.

2.11 Proposed Model

Wang et al. describe location, user, activity and computational entity as the most fundamental contexts to obtain information pertaining to a specific situation in mobile computing [48]. Dey proposed location, activity, indentity and time as fundamental contexts [11]. Each of these contextual definitions appear to be the most mimimalistic yet comprehensive that are capable of fully describing a situation. They allow the modelling of a set of entities, and provide reasonable gap to add concepts specific to certain domains of application.

Using these frameworks as a starting point, our proposed situation model is built on the following four contexts as building blocks, as seen in figure 2.4:

- Location: Can have a functional or a geometric definition, each of which find use in specific applications. The functional definition decomposes the physical space into a network of places, each of that has a scope of existence. For example, in the case of a scenario where the user is browsing library shelves in search for a particular book to issue, the aisles can be represented in the form of places, such that the user moving from one aisle to another in search of a book, is fundamentally proceeding from one place to another. In a similar example for the case of an office, each room can be presumed to be a place; and the corridor connecting the office can be seen as the intersection of the places or in other words, a transition from one place to another.

  The geometric definition of location simply decomposes the physical space on the basis of geometric coordinates, for example latitude and longitude.

- Time: The proposed model is essentially agenda-driven, which implies that all user activities have a stipulated time of commencement and completion. Dey et al. also highlight the importance of time in the case when the user has an agenda that is surfeit with activities, each having a stipulated duration [11].

- Person: The individual characteristics and preferences of the user constitute this context. This includes his personal details (name, email) and preferences (social situation, behavioral patterns, habits).

- Task: Activities performed by the user as well as the system. Some of the user activities may be routine, while others may be intermittently performed. While the user task is driven by agenda and habits, the system task is driven by the user task itself. The system task is essentially an action performed by the model that is in accordance to the task it anticipates the user will perform.

A model built on this foundation can easily be extended in a hierarchical fashion to accomodate various user activities. For any new activity to be modelled, this means extending the present context with new entities and relations in a top-down fashion. For example, in the case of a driving assistant scenario, the context "Person" can be extended to a sub-class for the entity "Car" that is further decomposed into car attributes like fuel guage reading, speed and range. Similarly in the case of trying to model an office scenario, the context "Person" can be extended with a context "Employee" as a sub-class, with employee-specific details like ID number, office number, salary and so on. Hence the leaves of such a tree created by extending it for every possible user activity will consist of entities that are connected by relations.

Summing up, the proposed situation model has the following characteristics:

- Characterized by person, item, task and location contexts.

- Extended in an object-oriented fashion by including the entities and relations concerning the user activity in question as sub-classes of these fundamental contexts.

- Driven by agenda, that is, activities are either routine or intermittent but definitely scheduled.

2.12 Design choices for model

The goal of the designed model is two-fold [48]:

- Modelling: Decompose complex user activities into simpler ones and describe them in a semantic fashion.

- Reasoning: Employ reasoning mechanisms in the form of inference engines allows reasoning about data and inferring knowledge from existing knowledge. Logical reasoning over context makes it possible to check the consistency of base and implied context information. Furthermore, it paves way for context sharing and semantic interoperability between heterogeneous systems. Probabilistic reasoning on the other hand has its fair share of advantages as well. It is possible to have different ways to decide about which activity to perform.

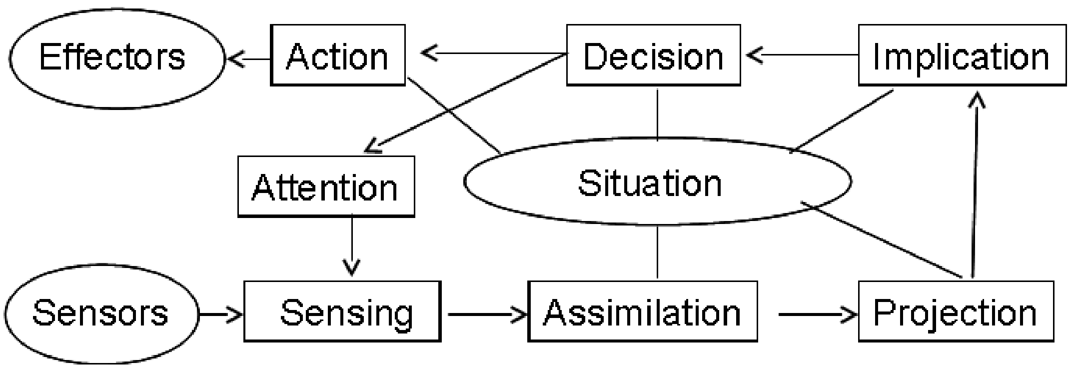

Figure 2.5: Proposed model

Reasoning over low-level explicit context allows to derive high-level implicit context in a bottom-up fashion. The upper ontology is a high-level ontology that encapsulates the entities mentioned above. The lower ontology is a specific ontology that defines the core entities in a particular sub-domain. High level contextual information cannot be obtained from sensor information, it can only be reasoned from low-level context which is further obtained from sensor input. Sensor input provides information on the relevant low-level context, that is used to deduce conceptual high-level context.

The use of an ontology to model a context is done as it allows agents and services to share common concepts about context during the course of interaction with one another. Also, it facilitates the reuse of knowledge that accelerates the process of building an ontology.

2.13 Proposed Model Architecture

The proposed situation model takes cues from the model proposed by Endsley, that is driven by the stages of perception (low-level sensory input from various environmental sensors), comprehension (assimilation of collected information to align with user goals) and finally projection (anticipate future course of action based on current event set). The proposed model advocates the following stages from information gathering to enaction, as can be seen in figure 2.5 :

- Sensing: Sensing is defined as the acquisition of information from low level sensors. In the case of mobile devices, these sensors could range from sensors that aid in geolocalization to motion, direction or object tracking. Continuous sensing ensures that system services are able to adapt to the user activities.

- Assimilation: Assimilation is the process of integrating and interpreting sensed information into the situation model. This information updates the entities, properties and relations in the model, eventually reconstructing the situation. The network of situations is thus created in a bottom-up fashion and used to characterize the context. This reconstruction is used to identify the situation and eventually the context of the user, that allows the model to be able to adapt its future course of actions and services to the user.

- Projection: The situation interpreted in the previous step is used as the starting point for anticipating future needs and actions of the user. These user actions will in turn drive the actions of the system. The future actions are driven by the current situation, as well as the users' intentions . These intentions are aligned with the final goal to achieve. The system actions are mostly close to the user actions, and sometimes are identical to them as well. In simple terms, this block of the model looks to answer the question "what's next?" in terms of predicting possible future courses of action of the system.

- Implication: The outcomes of the anticipated actions performed in the previous step are accounted for in this block of the model. The anticipated actions determine the future situations of the context. In a broad sense, it is the "then" clause of an if-then statement, where the "if" clause refers to the speculated action.

- Decision: The model chooses an action among the set of actions that have been speculated in the previous stage. The action chosen by the system is the one that is the most appropriate one amongst all the options available. The decision made by the model can be based on probabilitic reasoning or decision logics. This phase is the most volatile owing to the fact that the choices to be made between actions are not always straightforward, they may vary from scenario to scenario. In certain cases there may be uncertainity associated with outcomes, in which case the action with the highest probaility or the least uncertainity is chosen.

- Action:. The action stage supplements the users' estimated choice of action with information available from the web and presents it to him. This fetched information is then fed to the situation model that performs some primitive processing and filtering based on the situation. It is then passed on to the effectors that use various media to relay the information to the user. The objective is to present the user with the information in a non-obtrusive and non-diverting fashion.

- Attention: The attention phase selects what information to perceive from the environment, discarding other immaterial aspects. It then proceeds to retrieve that information from the web from the most appropriate source. In other words, this phase decides what information is required by the user and the optimal source which must be tapped for that information.

2.14 Conclusion

Devices are becoming sensitive to user activity and context. Also, the surge of Big Data means that there is an overwhelming amount of data and information at the disposal of the human sensory radar. However, a narrow attention span means that humans can only assimilate limited quantities of that information. The assimilated information would depend on the objective of the user, and the reasoning process he follows to attain that objective. Thus only activity-relevant information should deserve human attention. Also, there is a need for a service which can fuse both phenomena. Our proposed context-aware service would perceive information from the surroundings, perform activity recognition, predict future courses of action, retreive activity-relevant information from the internet, and present it to the user non-obtrusively.

— 3 —

Implementing the Model

The situation model that interprets human activity is composed of computational phases operating in a cyclic fashion. Each successive phase has a specific function and relies on the output of the previous phase to perform its function. Since each phase has a different function, their architectures and computational processes may vary as well. Thus, each phase implements a specific process which helps it perform its function appropriately. There are various recently-available semantic web tools that can allow in modelling the individual processes. In this chapter, we investigate the design alternatives for each of the phasal processes and introduce semantic web tools that can aid in implementing the phases.

3.1 Design Choices for Each Stage of the Model

The design deliberations for each computational phase, and final adopted choices are as below:

- Sensing: As stated earlier, the objective of this stage to be able to sense and draw input from the spatio-temporal surroundings of the user. This is done by the following sensors:
  - Position: GPS, Wi-Fi
  - Motion: Accelerometer, gyroscope
  - Direction: Compass
  - Proximity to device: Proximity sensor
  - Spatial object and activity recognition: Camera
- Assimilation, Projection, Implication, Decision and Action: The following approaches have been scrutinized in a bid to find the best suitable approach for each of these phases:
  - Forward Chaining: Forward chaining is an approach based on rules. Rules are conditional if-else statements which allow knowledge to be added only in case a set of conditions are true. They can also be referred to as condition-entailment statements. The forward chaining process matches condition to entailments [17]. All entailments (implied facts) are directly added to the data store. As a part of the same action, both the asserted facts and entailed statements are added to the data store. Forward chaining is an efficient approach which is optimized because the entailments are added alongside the assertions in the database. Hence, it is not

necessary to perform additional inference in case of retrieving data from the store. Forward chaining is appropriate when the data is static. However, it is an approach which increases storage size as well as the computational overhead associated with insertion and removal of facts from the database. The overhead is due to the difficulty of removing entailments from the store. Also, due to the complexity of the interrelations of explicit and implicit data in the database, it is difficult to ensure the complete removal of an entailment from the database.

– Backward Chaining: Backward chaining is the derivation of conditions of the goal set by backward application of logic till the conditions can be satisfied by the facts of the knowledge base. Facts once derived do not persist in the store. While it is efficient in terms of storage, it involves more computation to access the contents of the store, as the entailments must now be derived during the course of the access.
– Generate-and-Test: For the given problem space, generate a set of possible solutions in the form of paths from the start state to the goal state. The possible solutions are then tested to see if they correspond to the expected solution. If not, the other possible solutions are evaluated as well till the expected solution is found. This algorithm takes into consideration an exhaustive set of hypothesis in the problem space before arriving at the solution. One way to minimize effort is to apply a heuristic and eliminate paths which are unlikely to lead to a solution. Various forms of heuristic search may be deployed, namely: breadth-first search, depth-first search and hill climbing.
– Reinforcement Learning: The learning of mapping from situations to actions by trial and error [30]. The agent lands itself in a situation, which is a set of entities with relations among them. The agent then generates an action, which leads to the creation of another situation. The optimality of the system may suffer in case actions which are low in probability are chosen. The appropriateness of the action to that situation is determined by the assignment of a scalar reinforcement value. The higher the value, the more appropriate is the action. The intent is to identify the actions with the maximum value and filter out the ones with lesser values.
– Decision trees: A decision tree is a graphical representation of set of likely but complex decisions in tree format. It is an ideal tool for complex decisions, as complex decisions have a large number of intricate factors which must be accounted for. Also, the psychological frame of mind of the user influences the probability that a certain decision will be chosen out of a set of alternatives. The node of the tree used for decision making is called the decision node. The nodes which branch out from the decision nodes are the alternatives out of which only one can be chosen. The uncertain alternatives are represented by circles called chance nodes, each such node being associated with a probability of occurence. The expected value of each alternative is calculated by multiplying the value of each alternative with the probability of occurence of that alternative. The leaves of this tree are called outcomes, which represent the final outcome of choosing a path from the root node to the leaf node. The outcome which corresponds to the highest expected value is chosen as the most appropriate.
– Inductive and Deductive Reasoning: The premises in a deductive argument provide a strong support to the conclusion. Such an argument that provides a true conclusion

is said to be a sound argument. Since the premises of a deductive argument totally guarantee the conclusion, the argument is either entirely valid or invalid. Also since the basis of this logic is entirely based on the premises, the arguments are bound with the premises; that is, the conclusion cannot go beyond the premises. Consequently, these arguments are best associated to rules which are also condition-action constructs.

On the other hand, inductive logic deems a conclusion to be probable to a certain degree based on the strength of its premises. Unlike a deductive argument, an inductive one is not absolute but probable. The degree of support of the premises determines the probability of the conclusion. The stronger the support, the more probable is the hypothesis. This form of reasoning makes use of probabilistic or Bayesian logic.

3.2 Semantic Web and Ontology

In the term Semantic Web, the word "Semantic" means to provide meaning. The Semantic Web is an initiative by the World Wide Web (W3C) which looks to standardize the way in which data is represented and utilized on the web. The way data is organized in web pages at the moment is increasingly ad-hoc. This effort by the W3C represents data in web pages in a unified and structured format such that it is universally accessible.

The W3C defines the Semantic Web as "A common framework that allows data to be shared and reused across application, enterprise, and community boundaries." The intent of this framework is to organize data in web pages in a uniform format, that is, in the form of semantic data such that the format can be read and perceived by computers [3]. This data can be expressed in the form of an ontology.

An ontology uses a repository of terms to define concepts with relations between them [17], [10]. It can thus refer to a vocabulary, taxonomy or something else alltogether. Thus it is a rich, logic-based model for the description of a domain of interest. Ontologies can be used to express the meaning of vocabulary and taxonomy terms, the interactions between those terms, as well as their context of usage.

3.2.1 Semantics of Ontology

Semantics are strengthened by the inclusion of language and grammar constructs. Even though web pages are overflowing with data, the fact that the data is enclosed in specific and appropriate tags allows the document to be structured. The meaning of the specific data element can be guaged from the enclosing tag. Some of the language constructs include:

- Statement: A statement consists of elements which constitute a triple: subject, predicate and object. The subject and object are the entities described by the statement. The predicate describes the relation between the subject and the object.

- URI: Stands for Uniform Resource Identifier. It is a unique name which is assigned to each object in a triple, such that the name is unique across the internet. A URI may include a URL (Uniform Resource Locator) as well. An extension of the URI is the Internationalized Resource Identifier (IRI) which can be used interchangably with the URI.

An example of an IRI is:
$< http://www.semanticweb.org/mavefreak/ontologies/2014/3/untitled-ontology-17hasPlace >$
where the scheme describes the type of IRI, and the latter portions uniquely identify the resource.

- Language: Consists of a set of keywords utilized by statements. There are different ways of writing an ontology, which further depends on the type of application which needs to be suppported. The various writing formats are called ontology languages. Some of the languages include:

  – RDF (Resource Description Framework): Language which describes the model used by the Semantic Web. Statements of the model are represented in the form of a digraph, with the subjects and objects being represented by nodes and the predicates by edges. Nodes can further be of two types: literals or resources. Literals are numerical or string values which can only be the object of a statement. Resources on the other hand can be either subjects or objects. Each of the triple is represented in the form of an IRI.

  – RDFS: RDF Schema is designed to be an extension to RDF such that the relations between the subjects and objects can be described using a limited set of keywords in the RDFS vocabulary. It allows a hierarchy of concepts to be built. For example:
  Spike rdfs:subClassOf Mammal

    Here Spike is the subject and the statement describes that Spike is a mammal. The relation is highlighted by the keyword rdfs:subClassOf.

- OWL (Web Ontology Language): It is a language which is a level up from RDFS in terms of expressivity. It extends the existing vocabulary of RDFS with more elements, producing a more enriched vocabulary which can be used to build more expressive ontologies for the Web. OWL adds more restrictions to the structure and contents of RDF ontologies in order to make the processing of the documents computationally realizable. OWL uses RDF, RDFS, XML Schema and OWL namespaces. OWL2 extends the original OWL vocabulary but reuses the same namespace, hence is backward compatible with OWL. It is however not backward compatible with RDF, it can be thought of as having a syntax which is cast in the RDF syntax. It became a W3C recommendation in 2004 [41].

Each of the languages vary in their level of expressivity, with OWL-Full being the most expressive and RDFS the least.

Description logics (DLs) are a family of logics that are used to represent formalism in knowledge bases [18]. They are based on first-order logic. They combine a syntax for describing and exchanging ontologies. In practicality, they allow for the representation of facts and axioms (representing schema information).

At a structural level, an ontology consists of classes, instances, events, relations and axioms. A brief write-up of these semantic elements is as follows [17] :

- Ontology Header: Describes the ontology by means of labels, comments, import statements and so on.

- Classes: Set of entities which share a common characteristic. Classes can be represented in a hierarchial fashion. In OWL, the class 'Thing' is the root class from which all classes can be derived.
- Individuals: Members of a class which can be asserted directly or indirectly by reasoning.
- Properties: Predicates in statements which are used to express relations between individuals. These properties are of two types: object properties to link individuals, and data properties to link individuals with literals.

An ontology is represented by a set of individuals called classes. These classes are connected to each other by means of a set of relations. There are certain restrictions which are placed on the classes and the relations between them, these restrictions being named as axioms. Using the data provided, these axioms allow systems to infer more information as well.

3.2.2 Advent of OWL2

OWL1 was deemed to be insufficient in describing complex contexts due to the lack of operators to describe the complex relations between entities. Also, it does not contain any constructors capable of complex reasoning.

OWL2 is a successor of OWL1 in terms of the fact that it has several constructors which are used to model a variety of domains. It supports a property composition which is exploited for the support of rule-based reasoning. Some other characteristics include:

- Provides stronger support for expressive datatypes.
- Can recognize inconsistencies which arise due to error-laden data provided by sources.

3.2.3 SWRL

Semantic Rule Web Language (SWRL) is a Semantic Web language and is defined as the combination of semantics and logic [21]. It is an amalgation of OWL DL (SHOIN-D Description Logic) and OWL Lite sublanguages. The OWL axioms are extended to include Horn clause-like rules. Hence SWRL can broadly be defined as the extension of OWL axioms with rule axioms.

The rule axioms are represented in an antecedent-consequent format. This can also be called the body-head format. Both the body and the head are made of atoms.

$antecedent \rightarrow consequent$

where

$antecedent = a1 \wedge a2 \wedge a3..$

$consequent = a1 \wedge a2 \wedge a3..$

These atoms can be of the form D(x) and P(x,y). Here D is the description, P is the OWL property and (x,y) are variables, individuals or data values. The variables are universally quantified, their scope being limited to the judistriction of the rule. The antecedent is represented as a conjunction of the atoms. The theoritical interpretation of the rule is that if the conditions in the antecedent hold, then the conditions in the consequent hold as well.

For example, if C is the child of A, and A and B are married; the C is also the child of B:

$isChild(C,A) \wedge isMarried(A,B) \rightarrow isChild(C,B)$

3.3 Software Tools

3.3.1 Reasoners

The entities and relations that are modelled can be investigated further to reveal underlying truths which are not apparently visible. This is known as the process of inference on existing concepts. The benefit of using an ontology is the fact that it is possible to reason and infer over the existing data. The expressivity of ontological languages can be boosted by the power of reasoning by means of rules [37]. The job of deriving inferences is done by a reasoner, also known as an inference engine.

A reasoner or reasoning engine infers new information from a knowledge base [17]. Reasoners draw inferences from rules, triggers on RDF stores or decision trees [37]. Based on the different types of reasoning algorithns, there are several kinds of reasoners. Most reasoners are rule-based, which are used to express relations which cannot be modelled otherwise using OWL. These rules may be as simple as Horn clauses (logical formulas) or as expressive as First Order Logic (FOL) rules. In the general sense, reasoners create a new extended RDF model which contains triples which are already present in the base model to which the reasoner is applied, alongwith rules that are inferred from the base model by the reasoner. The new model would conform to the standards of the base model as well, which means that both the base and extended model can be queried in the same fashion.

3.3.2 Protege

Protege is a open source ontology creator and editor [20]. Created and maintained by Stanford University, it is the most comprehensive and commonly used tool for creating ontologies and reasoning with them. The east-to-use interface allows for the creation of the classes, individuals and properties (object/data) in a top-down fashion, also called the asserted hierarchy [47]. Protege supports reasoning on the ontology by means of various reasoners which are based on forward and backward chaining. Some of these reasoners include:

- Fact++
- Pellet
- Hermit

The hierarchy which is computed by reasoning on the existing ontology by the reasoner is called the inferred hierarchy. This inferred hierarchy will open in a window which is adjacent to the asserted hierarchy window. Any inconsistencies in the ontology design will be highlighted by the reasoner.

Protege also has various graphical editor plugins (OWLViz, OntoGraf) which provide a visual representation of the developed ontology.

Protege also includes the facility to create and execute rules. It consists of a window called the SWRLTab which is the development environment to work with SWRL rules. These rules can be fired by starting the reasoner which will infer knowledge from the ontology and display it in the form of the asserted hierarchy.

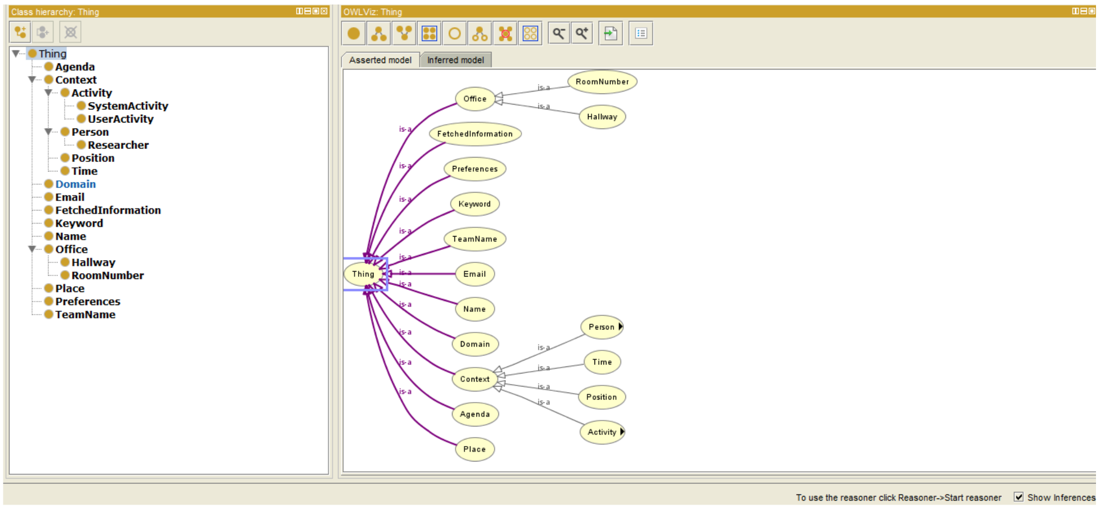

Figure 3.1: Protege

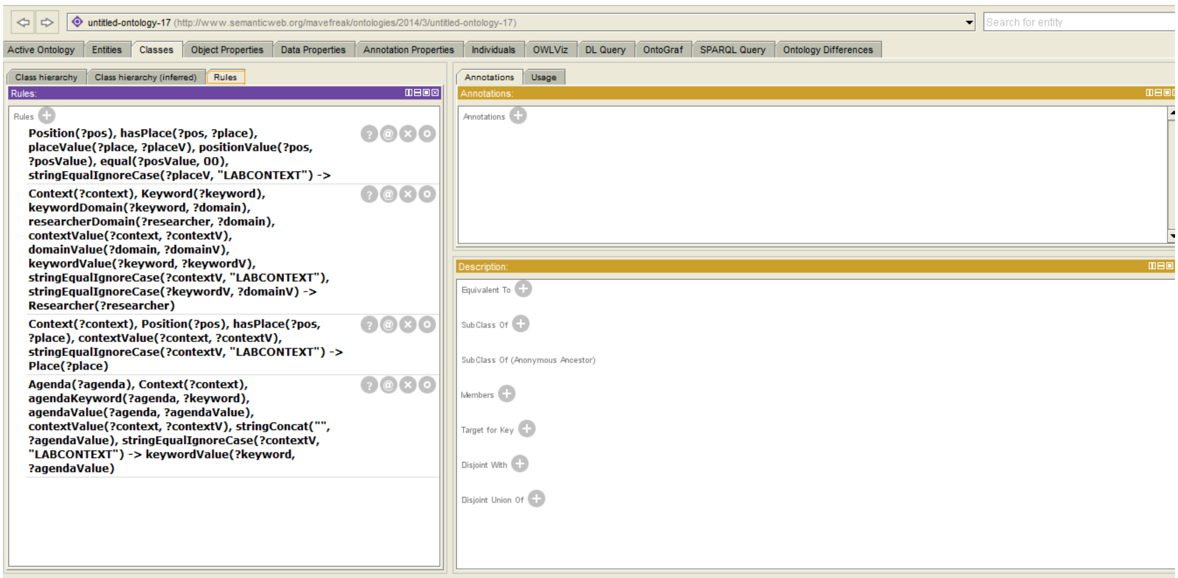

Figure 3.2: Rules

3.3.3 Androjena

Androjena is the Android implementation of Apache Jena, which is a Java based semantic web framework used to build world-class semantic applications.

Building any fundamental Semantic Web application involves [17]:

- Referencing the Semantic Web data by means of queries and building a knowledge base.
- Internal and external reasoning on knowledge base to produce inferred information.

The Jena framework translates the Semantic Web statements and predicates into object-oriented programming constructs. In simple terms, the Semantic Web is the powerhouse of data, while Jena is the processing hub which transforms the data into a commodity capable of driving the informational needs of the user. Jena uses the following Java classes to model the Semantic Web data:

- Resource: Similar to RDF resources and represents either subject, predicate or object.
- Statement: Triple containing subject, predicate and object. Is analogous to a Semantic Web triple.
- Graph: Low-level storage of Semantic Web data allowing minimal interaction possibilities with the data.
- Model: A level above the Graph, provides intricate interaction and reasoning possibilities with data.
- Query: Allows the model to be queried by means of SPARQL queries.
- Reasoner: Allows internal or external reasoning on the knowledge base.

3.4 Situation Model of a Use Case Scenario-the Driver's Assistant

The scenario of the driver's assistant can be used to illustrate and study the details of the situation model and computational processes. We recall the needs of the driver while driving to a distant location:

- Food
- Rest
- Fuel
- Weather
- Communications
- Dietary Needs: Meal times and meal preferences of the driver.

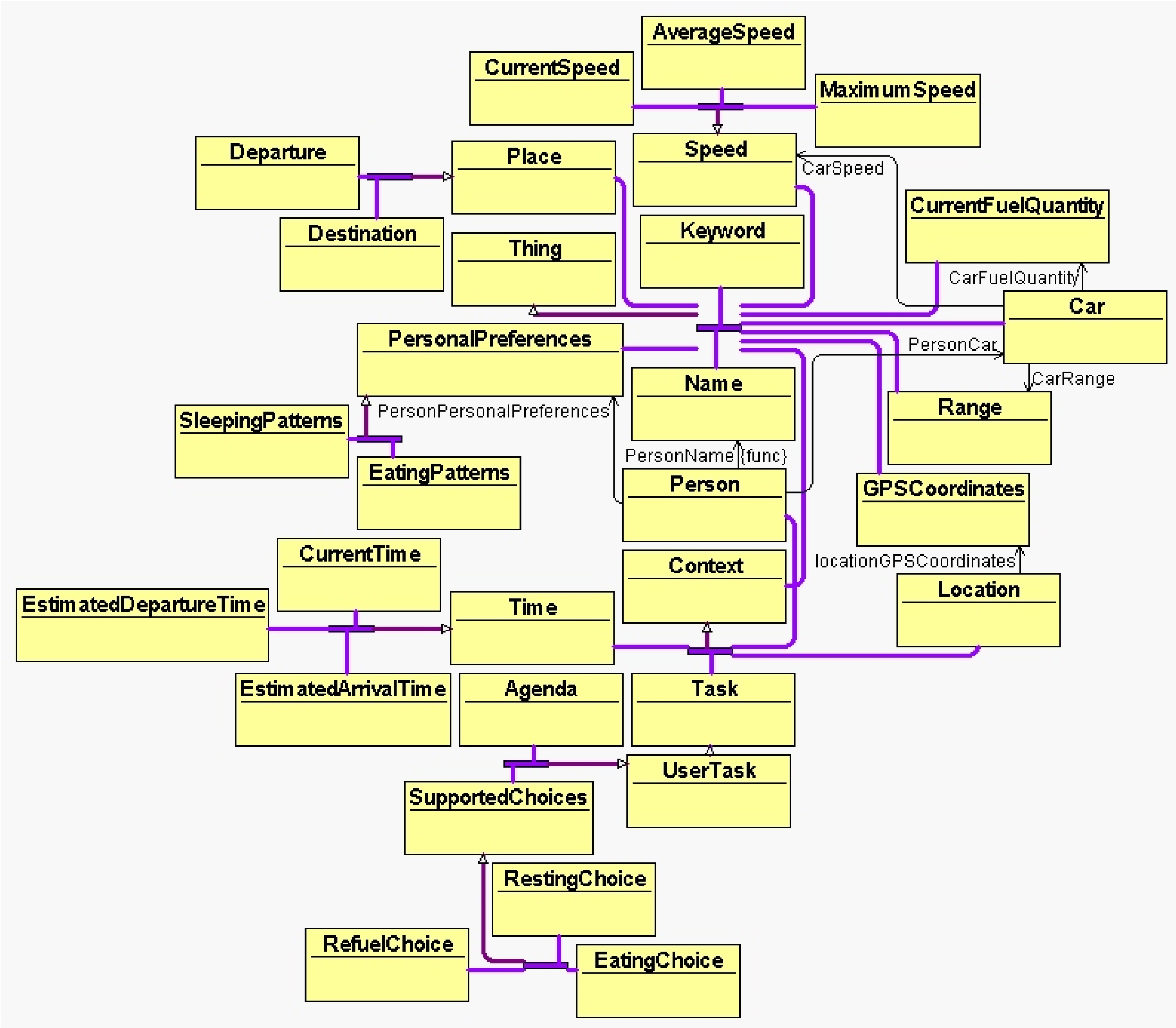

Figure 3.3: Driving Assistant Scenario

- Rest and Recreation: Keep in mind the sleeping schedule of the driver and how it works with the travel duration.
- Fuel: Consumption rate and availability of fuel during the course of the journey.

Our proposed model represents the driving context in the form of location, time, person and task context. Keeping the above mentioned needs and model representations in mind, the scenario can be depicted in the form of the ontology in figure 3.3.

We use the stages of the situation model to better describe the functioning of the Internet Angel in this scenario:

- Sensing: Sense GPS and car information. The variables on the left-hand side of each statement (destination, departure, speed, fuel consumption and so on) are updated with the information sensed by the functions on the right hand side:

```
?toDoList=readList();
?destination=getInfoFromGPS(DESTINATION);
?departure=getInfoFromGPS(DEPARTURE);
?range=getInfoFromGPS(RANGE);
?gas=getInfoFromGPS(GAS);
?speed=getInfoFromCar(CURRENT_SPEED);
?currentTime=acquireCurrentTime();
?arrivalTime=getInfoFromGPS(ARRIVAL_TIME);
```

- Assimilation: Load sensed information into model and identify context

```
Context(DRIVING_CONTEXT)^notEmpty(?toDoList)⇒ Agenda(?toDoList);
```

- Projection & Implication: Anticipate future courses of action based on pre-conditions.
  - If the current time is approaching the normal meal time of the user, the predicted user choice is to eat:

```
greaterThan(?currentTime, ?eatingTime-EATING_THRESHOLD)^
Context(DRIVING_CONTEXT)^equals(0,(?eatingTime-currentTime)%60)
⇒ EatingChoice(EATING);
```

  - If the current time is approaching the normal rest time of the user, or if the user has been driving for a period of time which exceeds the system threshold, the predicted user choice is to rest:

```
greaterThan((?arrivalTime,currentTime)^RESTING_THRESHOLD)^
Context(DRIVING_CONTEXT)
^lessThan(?sleepingTime,?arrivalTime)^greaterThan(?sleepingTime,?currentTime
⇒ RestingChoice(RESTING));
```

  - If the fuel quantity is insufficient to last the remaining distance of the journey, the predicted user choice is to re-fuel:

```
//course of action-GAS REFUEL
?remainingDistance=getInfoFromGPS(REMAINING_DISTANCE);
?requiredFuel=(?remainingDistance)/(?range);
```

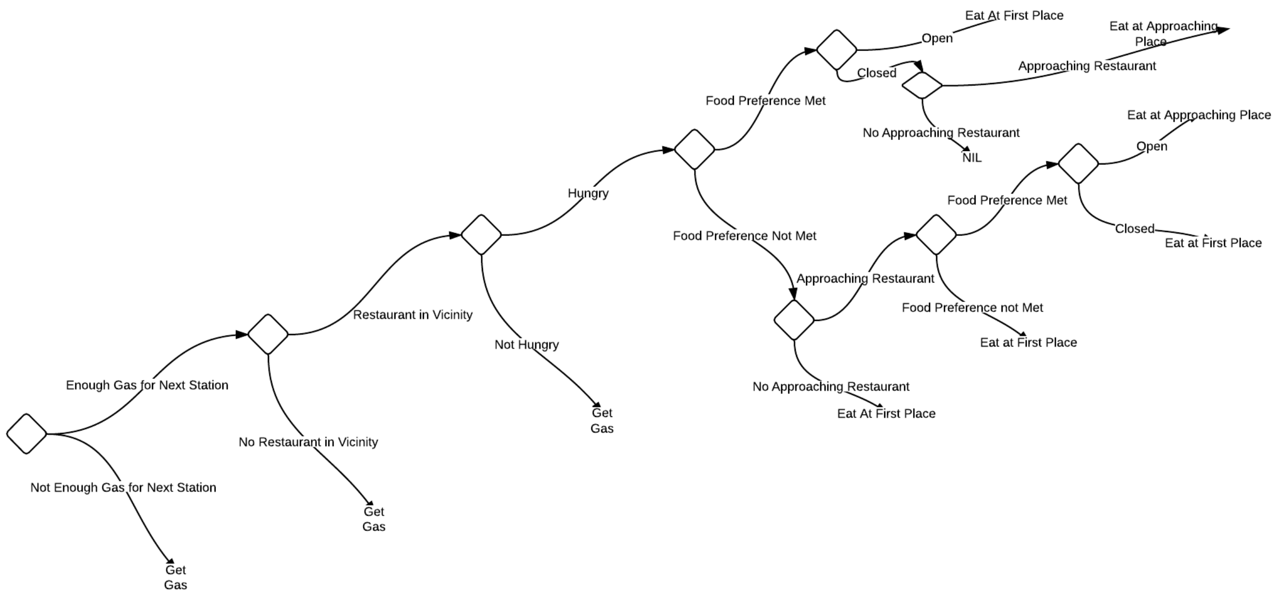

Figure 3.4: Decision Tree

?greaterThan(?requiredFuel,?gas)ˆContext(DRIVING_CONTEXT) $\Rightarrow$ RefuelChoice(REFUEL);

- Decision: Choose appropriate course of action from the decision tree procedure. This procedure is used when several options seem likely in the previous stage and it becomes necessary to choose one (see figure 3.4).

- Action: Proactively search for information based on anticipated user choice .

  – If the anticipated choice in the previous stage is eating, search for restaurants in the vicinity filtered on criteria obtained from decision tree (cuisine preference, closing hours).

  – In case it is gas refuel, search for upcoming gas stations.

  – If the choice is to rest, search for hotels which meet user preferences (budget constraints, luxury requirements).

- Attention: Focus attention on relevant phenomena in situation. However, this stage is a placeholder in this scenario, as the work of narrowing attention is handled in the previous stages of projection and implication.

3.5 Conclusion

Various approaches to model the computational processes of the Internet Angel have been considered. It is a design requirement that assertions and inferences be stored alongside in the knowledge base, such that they can be fetched in tandem when required and processed as per the information requirement. Keeping this requirement in mind, the forward chaining approach appears most convincing as assertions and entailments are stored together in the knowledge base. Conclusively, the forward chaining approach has been chosen as the computational process for all phases of the situation model except the decision phase. In the case of the decision phase, the model may have to deal with the likelihood of several outcomes and choose the most appropriate one. Decision trees have been chosen as the best alternative for the decision phase due to the simplicity of the approach and the fact that it provides a complete coverage of all the possible outcomes.

Various tools to implement computational processes have been evaluated. Amongst ontology editors, Protege was found to be the best because of sheer simplicity, support for reasoners and SWRL rules. Since the Internet Angel is proposed to be deployed as an android application, Androjena is considered the best choice as a semantic web framework for android devices.

— 4 —

Experiment

In the previous chapter, we presented the architecture of each of the computational phases of the model. This architecture should allow the model to perform all of the required functions: from activity recognition to non-obtrusive information display. The strength and appropriateness of the architecture, however, remains to be validated. This is done by implementing the model using the software tools previously discussed. The hypothesis, that the model enriches the user activity with situated information, must also be validated. This is done by designing an experiment centered around a human activity where the implemented model provides the user with situated information in a non-obtrusive fashion. The experiment uses certain qualitative and quantitative metrics as criteria and based on the collected results, validates the strength of the hypothesis.

4.1 Hypothesis

Our research hypothesis is that situated and non-obtrusive information, furnished from the web by a context-aware service, and presented to the user in a manner that respects the user's limited attention span, enables a user to be more proficient while performing the activity. We propose to evaluate this hypothesis with a pilot test, where the user is given a mobile device with a simple form of the context-aware service, and asked to perform a task that requires searching for a researcher with certain expertise.

4.1.1 Evaluation Metrics

The effect of the context-aware service on the users' ability to perform the task is measured by the following metrics:

- Acceptability: All the factors responsible for making an application usable and acceptable. Rate the extent of assent or dissent of the user with the product being tested.

- Usability: The degree to which a product can be used by users to achieve specific goals keeping the following in mind:

  – Effectiveness: The service aids the user achieve his desired objective, and the extent to which the user is aided. This metric is also referred to as task context. One useful way of evaluating is to ascertain whether the user completed the task or not.

- Efficiency: The objective is met with minimum time or minimum effort.
- Satisfaction: Feedback of the user on his level of content with the software at hand. This is done by asking the user for an account of the inconvenience caused by the distractions and obtrusions which have been placed in the application for the purpose of evaluation.

- Time: The time taken by the user to complete the task. The goal is to evaluate the usefulness of information based on how swiftly and effortlessly the user was able to perform the task and reach the goal.

4.1.2 Baseline and Variations

Some of the considered variants of the Internet Angel pilot application include:

- (User-Initiated or Self-Initiated)**Manual or Automatic mode:** Test whether the user prefers to be in control of the information-rendering mechanism, that is, what he sees and when he sees it, as opposed to a situation where information is displayed to him automatically without him making an intentional move.

- (Attention-seeking or Blending nature of information)**Obtrusive or Non-Obtrusive mode:** The manner of information presentation is as quintessential as the mode of information retrieval. We seek to test two modes of information display-one where the user's attention is diverted by the semantic information fetched, the diversion being provided by various means. The other is when the same information blends into the user's current perspective and does not divert his attention.

- (Quantity of Information)**Minimal or Maximal mode:** The quantity of information which is required by the user varies with the situation of the user. In some situations he could need a birds 'eye view of all the entities in the situation, while in others he may need precise and focussed information about a select subset of entities and relations. This experiment tests both ends of the quantity spectrum-one where the information is barely sufficient to meet user needs, and the other where the user is overwhelmed with information.

- (Best Case)**Adept and enriching information:** Precise, crisp and appropriate information which best aids the user to proceed to his goal.

4.1.3 Testing Scenario

The aim of the experiment is using the Internet Angel, to help a user find a researcher working in a particular domain in a research laboratory.

The experiment was conducted in the premises of the INRIA research center in Montbonnot. The building accomodates many teams, each of which work in separate domains. The teams are further composed of researchers, post-doctorates, Ph.D. students and engineers. While most members of the same team work in the same domain, their sub-domains might differ.

The experimental space chosen is a particular corridor of the INRIA building which accomodates teams of various research domains. Each corridor is dedicated to approximately two

Figure 4.1: Experimental set-up

teams, each team consisting of roughly 20-30 members. The members are allocated rooms on either side of the corridor, each room having between 2-4 team members. As the user walks through the corridor searching for the person who best matches his desired competence, his information needs change, depending on his position and current focus of attention. Keeping this notion in mind, three broad levels of information classification were defined:

- **Beginning of the corridor:** The starting point. The focus of attention at this point is the entire corridor in front of him. His primary information need at this time is a brief account of the teams in the corridor and their work domain.

- **Intersection of office doors:** At the intersection between office doors, the focus of attention of the user is all the offices in the vicinity.

- **At a particular office door:** The focus of attention of the user at this point is the office in front of him. His would desire to know about the researchers in that office, the information filtered with respect to the competence he is searching for.

The localization of the user was done using QR codes placed at strategic locations in the corridor. The scanning of the codes was done using a API called ZXing , an open source QR code recognition library developed by Google and coded in Java [25]. While the source code is available on Github, the library is also implemented as a full-fledged Android application, available on the Google Play store. The API integrates as a library with the application under development and provides functions which can directly be used. When the scanner is actually pointed at a QR code, the function will return the scanned QR code. This code can then be used by the application as desired.

The dynamics of the experiment required user localization to occur without his conscious knowledge, that is, in the background. Thus it was not possible to use the API in its original form, as the scanner is still visible on the screen. The scanner was required to run in the background. The source code of the API had to be changed in order to meet these requirements.

The final developed Android application had a QR code scanner running in the background. On scanning a QR code, the information read fires a set of rules and queries to the model and triggers an information retrieval cycle. This gathered information is then relayed back to the user interface for the user to read and understand it. This information perception leads to situation awareness for the user. The cycle is repeated with each successive scan of the QR code.

The nature of the task and the experimental conditions did not permit us to be able to test all possible flavors and criteria. Thus, we included some obtrusive factors in the application itself. For example, at each scan of the QR code, there is a sound notification and a flash of the screen before the information is displayed on it. The intent was to identify if the user would notice these elements during the course of the experiment and point them out in the survey. The variants tested include:

- **Optimal:** At the starting point, there is a brief account of the teams present in the hallway. Information about a researcher becomes more and more precise as the user proceeds from the starting point in the hallway towards a door.

- **Maximal:** At the starting point, there is a summary of all the researchers in the corridor ahead, alongwith their domains of work.

All the participants were asked to evaluate both the variants in separate tasks with different objectives in mind.

4.2 Computational Model and Algorithms

The stages of the model are implemented as follows:

- Sensing: Alternatives that were considered for localizing an individual include:
  - **GPS:** Provides accurate information of the longitude and latitude of the user. However, if the device is located indoors, the signals are heavily attenuated and delayed, making accurate tracking very difficult. Also, the dynamics of the task require the user to be constantly tracked, almost every second, as he moves across the corridor. As the frequency of the already attenuated GPS fixes is not high enough to track the user rapidly enough, it fails to meet the requirement.
  - **WiFi and Network:** The device obtains localization information by means of a network lookup from sources such as network towers and WiFi access points. This information, though obtained at high frequency, is essentially approximate. It is also inaccurate and coarse, making it difficult to fulfill the rudimentary needs of the task.
  - **QR Codes:** QR stands for Quick Response, which converges with the objective of its development: to create a code which can be detected and read rapidly [4]. QR codes were developed by Denso Corp. They are highly versatile and can read alphanumeric characters, binary, symbol and even control code. 7089 characters can be encoded in a single symbol. Some important characteristics include:

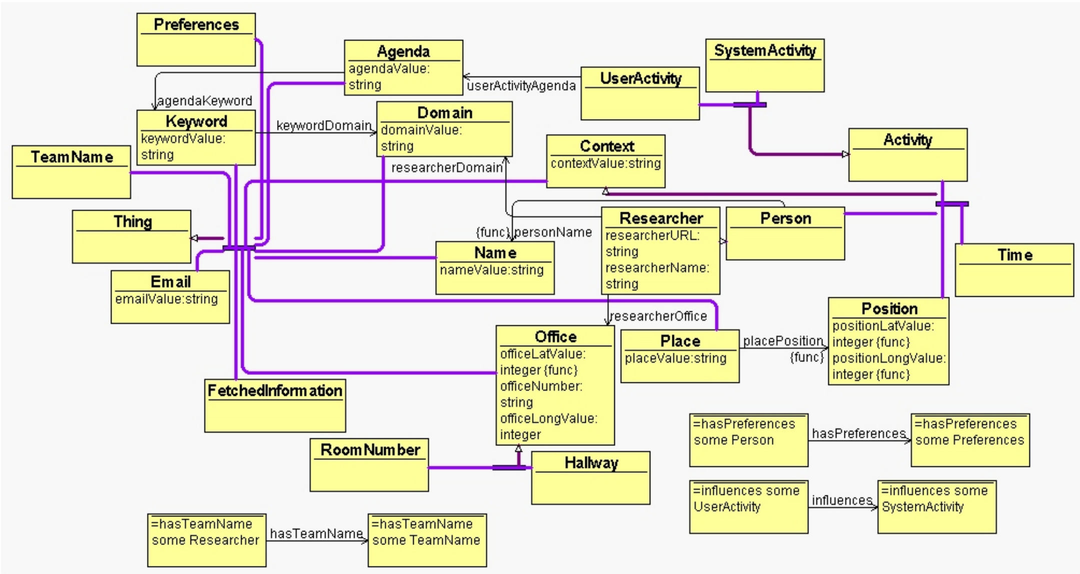

Figure 4.2: Researcher Ontology

* **Omnidirectional Reading:** The code can be read in any direction with high speed. This is achieved by position detection patterns located at three corners of the symbol, which negate any interference produced by the background.
* **Compact:** The information carried by a QR code is the same horizantally and vertically, occupying one-tenth of the space of a barcode.

The possibility of quick and accurate scanning makes it an ideal alternative to localize an individual in an indoor premise. This is done by embedding the location information of the individual into a QR code, and planting the QR code at strategic locations which signify points of interest.

- Assimilation, Projection, Implication, Decision, Action: These stages are implemented by firing rules to an ontology, collecting results and displaying them on the GUI. The ontology is developed using Protégé. The reasoning implementation has been done using forward-chaining rules written in SWRL using the SWRLTab option of Protégé. The entire framework has been integrated using the Androjena API.

The ontology is described by the diagram 4.2.

Some screenshots of the application in action can be seen in the figures 4.3, 4.4 and 4.5.

4.3 Requirement Elicitation-Focus Group Activity

It was important to understand user preferences for the application design. Consequently, we decided to conduct a focus group in order to gather feedback and opinions from potential users. This method was selected because a focus group is similar to a brainstorming session which allows participants to voice their opinion to thoughtfully predetermined questions. Concretely, it is a free-flowing discussion of a small group of strangers guided by a moderator. An assistant moderator plies in this group as well to take notes and record the discussion.

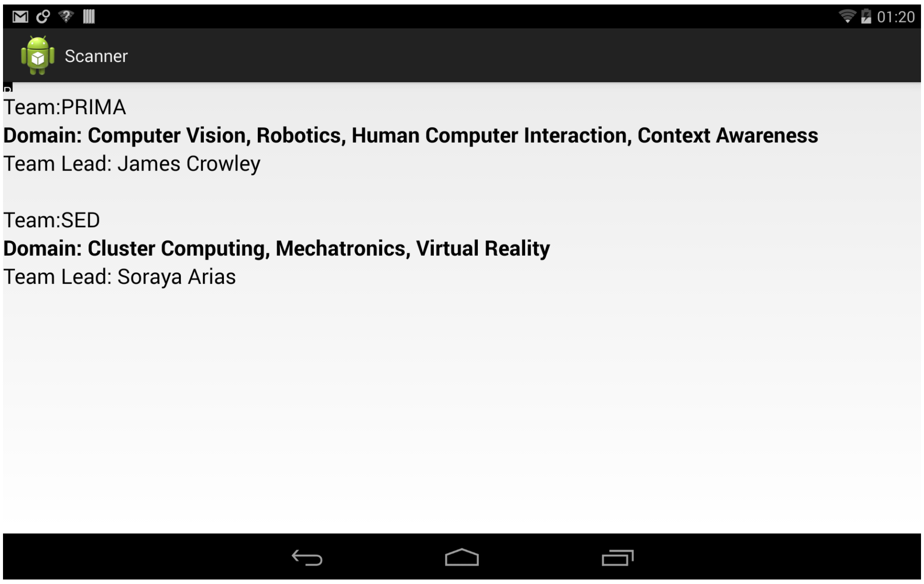

Figure 4.3: Application screen at starting point

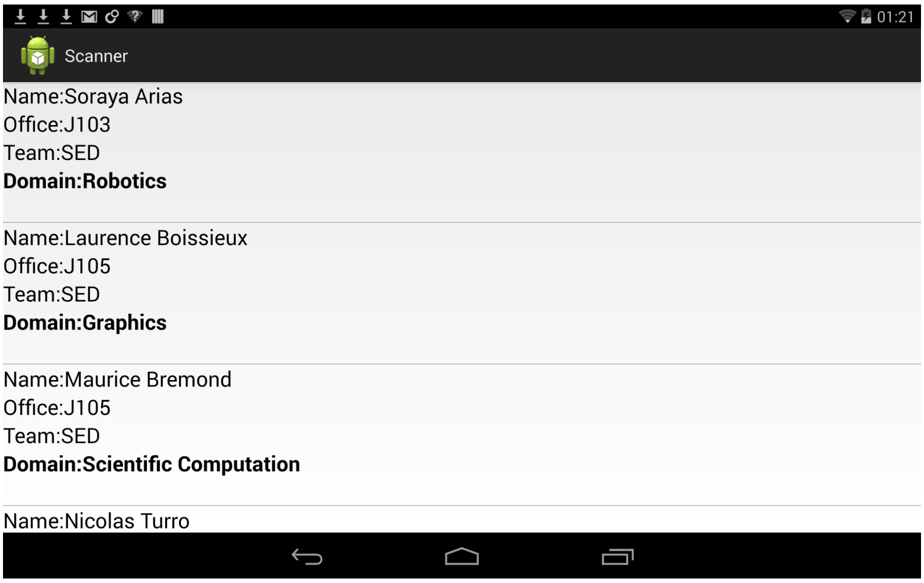

Figure 4.4: Application screen at door intersections

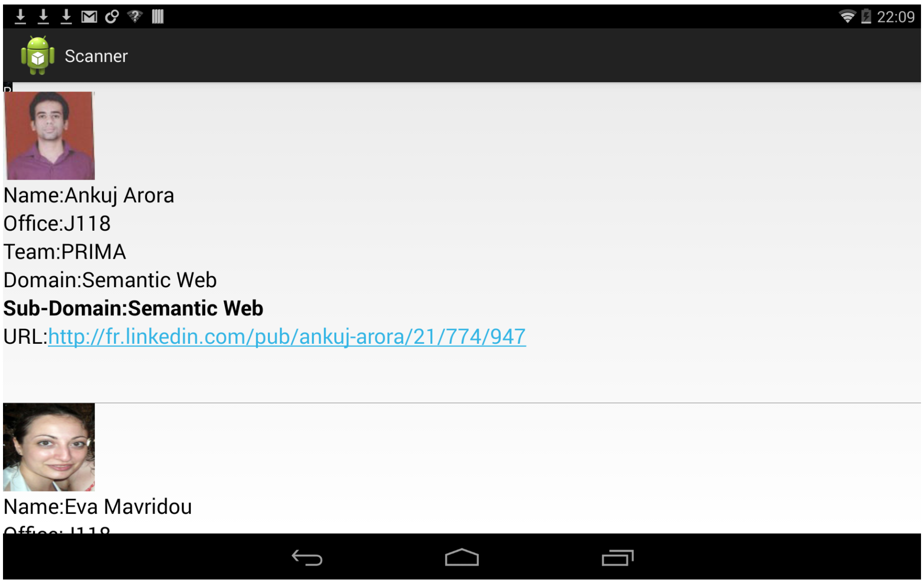

Figure 4.5: Application screen in front of door

Dear participants,

Thank you for your willingness to participate in our focus group. As discussed before, we would like to hear your ideas and opinions for drawing context-specific information from the Internet and displaying it in a presentable format. You will be in a small group with other participants and your responses to the questions will be kept anonymous. The date, time and place are listed below.

DATE May 27, 2014
TIME 16:00
PLACE Room A109

If you need any further information or will not be able to attend for any reason please send an email to ioanna.lampraki@inria.fr. Otherwise we look forward to seeing you.

Figure 4.6: Confirmation Email

After we defined the objective of this focus group, we had to decide the number of the participants and the ideal profiles we were looking for. We decided on a group of six people to ensure a rich conversation and one where none of the participants would be left out. We decided to have a mixed gender group of people around the same age. After identifying the participants, we had to invite people to voluntarily participate in this conversation. An email was then sent to each participant to inform them about the time and location of the focus group and to confirm interest and availability (refer figure 4.6)

In order to have better organization, the moderator had a prepared script to welcome participants, remind them of the purpose of the activity, and inform them about the ground rules (see figure 4.7). We requested for user consent for participation in the activity (see figure 4.8).

WELCOME
Thanks for agreeing to be part of the focus group. We appreciate your willingness to participate.

INTRODUCTIONS
Moderator; assistant moderator

PURPOSE OF FOCUS GROUPS
The reason we are having this focus group is to find out user's preferences about looking for information in a specific context.
We need your input and want you to share your honest and open thoughts with us.

GROUND RULES
1. WE WANT YOU TO DO THE TALKING.
   We would like everyone to participate.
   I may call on you if I haven't heard from you in a while.
2. THERE ARE NO RIGHT OR WRONG ANSWERS
   Every person's experiences and opinions are important.
   Speak up whether you agree or disagree.
   We want to hear a wide range of opinions.
3. WHAT IS SAID IN THIS ROOM STAYS HERE
   We want folks to feel comfortable sharing when sensitive issues come up.
4. WE WILL BE TAPE RECORDING THE GROUP
   We want to capture everything you have to say.
   We don't identify anyone by name in our report. You will remain anonymous

Figure 4.7: Focus Group Rules

Consent to Participate in Focus Group

You have been asked to participate in a focus group organized by Ankuj Arora and Ioanna Lampraki. The purpose of the group is to try and understand user's preferences for drawing context-specific information from the Internet and displaying it in a presentable format. The information learned in the focus group will be used to organize and perform the evaluation experiment for our proposed model that helps users at their routine activities.

You can choose whether or not to participate in the focus group and stop at any time. Although the focus group will be tape recorded, your responses will remain anonymous and no names will be mentioned in the report.

There are no right or wrong answers to the focus group questions. We want to hear many different viewpoints and would like to hear from everyone. We hope you can be honest even though your responses may not be in agreement with the rest of the group. In mutual respect, we ask that only one individual speak at a time in the group and that responses made by all participants be kept confidential.

I understand this information and agree to participate fully under the conditions stated above:

Date: ____________________ Signed: ________________________

Figure 4.8: Consent for Focus Group

The duration of the activity was about 45 minutes. The proposed questions were segregated into three categories: engagement questions, exploration questions and exit questions. The engagement questions are more of introductory questions to help the participants settle into the discussion. The core part of the discussion rests with the exploration questions. The discussion is wrapped up by exit questions, which are means by which people provide their final comments or general feedback about the session. The questions asked during the session can be seen in figure 4.9.

Engagement Questions

- What attracts your attention when you are looking for precise information presented on a textual format on a screen?

Exploration Questions

- Imagine that you are on a building looking for people with specific expertise. What would the tool look like?
- If you have information that does not fit on a single screen, what is your preferred mode of interaction.
- If your routine activities were to be supplemented with information fetched from the Internet, how would you prefer to see that information being displayed to you?
- Imagine that you are searching people with specific skills. What information is more useful for you?

Exit Question

- Is there anything else you would like to mention?

Figure 4.9: Questions for Focus Group

4.3.1 Focus Group Result Analysis

While the discussion was free-flowing and participants came out with diverse opinions, some of the prime convergent points are as follows:

- Participants are drawn towards any element of text which is out of the ordinary. This includes underlining, colored text and flashy graphics. The most useful is bold text, as it helps the user to summarize the information much more rapidly. This is however useful when it is not overdone.

- Participants are divided in the way they prefer to interact with their device in case the information does not fit a single screen. Some users prefer to tilt the tablet into landscape fashion and scroll down to continue reading. Others prefer that information be represented in a grid format, where they can click on a tile of the grid and get more detailed information specific to that tile. This would negate the need to scroll.

- With respect to the experimental task, most participants find it most important to see the domain and sub-domain of the researcher they are searching for. Some find it important that know how recently a researcher published an article in the domain the participant is searching for.

4.4 Evaluation and Results

The evaluation took into account the time taken by the user to reach the final destination. Factors such as acceptability and usability were accounted with a short satisfaction survey conducted with the participant at the end of the task. The following questions were asked in the survey:

1. What are the aspects that you found useful in the application?

Figure 4.10: Participant during course of experiment

2. What are the aspects that you found annoying or distracting in the application?

3. Do you think the information was structured in a fashion to help you reach your goal?

4. Are you satisfied with the manner in which information was presented on your screen?

5. Did you notice any difference between the two variants (optimal variant and maximal variant) you were asked to use?

6. Any additional points you would like to raise?

Based on the above mentioned methodology, the findings are summarized as below:

1. The average completion time of the task came out to be close to 3.58 seconds.

2. Most participants found the notification tone in the application obtrusive. However, they only bought it up when we explicitly asked them about the sound during the survey. Interestingly, no one noticed the flashing screen when the QR code is scanned. This was a surprising result, and countered our belief that the flashing screen would be extremely annoying. From both these observations, we see multiple possibilites. This could mean that the user requires a certain minimum level of obtrusiveness to be able to effect him and evoke a feeling of dissent. This could also mean that once a user has a particular goal in mind, he is able to subconsciously focus more attention towards the objective at hand, and lesser towards other deterrents. This is an unexpected find and requires a more in-depth analysis.

3. Most of the participants found the three level hierarchical structuring intutive and practical as they believed that it gradually led them to their goal. In most cases, participants were able to understand the information structuring in the QR codes and use it to their advantage.

4. Most participants did not notice the difference between the optimal and maximal cases. The reason they explained was that they were focused on the task and hand and were only looking for the domain and sub-domain to use for proceeding, and did not pay attention towards overall layout of information. We attribute this to the fact that since a corridor has a limited number of researchers, information of about 35-45 researchers on a single screen in the case of the maximal variant is not enough information to cause distraction. Also, fewer number of participants implies that we cannot converge upon a conclusion, and calls for a deeper analysis.

5. One participant had the opinion that a birds eye view of all the researchers in the wing should be provided at the beginning of the corridor itself. That listed information should, however, be restricted to only the researchers that work the domain being searched for. The entries of the list should be clickable in case the user needs more information pertaining to a specific researcher.

6. The layout of information was not acceptable to all participants. Many thought that information could have been represented in a better fashion. One had the opinion that when the user is at the door intersections, a grid layout of information is more useful, with each grid tile depicting information specific to a particular room.

7. Different people search for information with different perspective. For example, two users looking at the same webpage may not be searching for the same information. This means that both users perform the same task with different objectives. Thus, it is difficult for a service to model the needs of both users, even within the same context [31]. Keeping this in mind, we did not make it completely obvious to our participants that the task was meant to be done in the best possible time. Most participants went ahead and tried to proceed as quickly as possible, scanning information and proceeding in a direction they found most appropriate at the time. Some others chose to look at all the available information by scanning all the QR codes, and choose the most appropriate researcher in the end. This freedom of choice meant we could get a wider array of results to draw inference from.

This pilot experiment was designed to evaluate the strength of our hypothesis. Due to a lack of time, we have only been able to test the optimal and maximal variants. In the next experiment, we intend to learn from the shortfalls of the current experiment and conduct it in a more refined fashion, clearly defining the boundaries and objectives of the experiment. We intend to test the minimal, non-obtrusive, automatic as well as manual variants, alongwith their various combinations, in our future experiment.

4.5 Conclusion

Our research hypothesis that: situated and non-obtrusive information, furnished by a context-aware service, enables a user to be more proficient while performing a task, holds true. This is affirmed by the conducted pilot experiment. The presentation format is observed to be detrimental to the user proficiency while performing the task. We also conclude that the notion of what and how much the users find obtrusive has not been entirely understood, and needs deeper investigation.

— 5 —
Conclusion and Perspective

5.1 Summary

Mobile devices are pushing their physical dimensions and are becoming increasingly conscious of their spatio-temporal surroundings. This awareness of human activity and social context has led to the onset of services which serve the user with situated information. Due to recent advancements in Semantic Web technologies, this information is fairly easier to source, but is far from being precise and optimum. The users' limited attentional capacity means that he risks the missing the useful situated information which lies beneath this heap of irrelevant data.

The aim of this research project has been to develop a context aware "Internet Angel" that senses information about the user and user activity and proactively searches the internet for task-relevant information. The retrieved information is then presented to the user in non-obtrusive fashion, such that it respects and adheres to the users' limited attention span. It ensures that the user is entitled to only information worthy of his attention.

Our approach has been to model the user situation and activity by a situated and unobtrusive service called the "situation model". This model is driven by a series of computational processes which perform the following tasks in a cyclic fashion:

- Sensing
- Assimilation
- Projection
- Implication
- Decision
- Action
- Attention

We develop the computational processes by analyzing the operation of the processes in everyday routine tasks. Based on what the user is doing or searching, the model predicts his future information needs. It then retrieves the relevant information from the internet and presents it to the user.

From the scenario analysis, we converge to the idea that each of the reasoning processes can be realized using a forward chaining rule system. The model itself is developed in the form of an ontology, consisting of network of relations between concepts. Concepts in this case are entities, and the characterization of the situation of the entitiy is referred to as context [11]. With respect to situation modelling for human activity, context is defined from the following four illustrations : time, task, activity and person. Any situation can be modelled by extending these illustrations in an object-oriented fashion.

A pilot experiment was conducted to validate the model and affirm the hypothesis that situated information presented in a non-obtrusive fashion can facilitate user activity. The users were handed a tablet running the context-aware service and asked to search for a researcher working in a specific domain in a corridor of the INRIA facility. Results proved that situated unobtrusive information indeed helped the user in reaching the destination quicker.

5.2 Lessons Learnt

The conclusions drawn are as follows:

- A context-aware service can aid a user performing a routine activity with information from the internet, allowing him to perform better at the activity.

- Information presentation largely effects the users' ability to perform the task. Information presented to the user in a non-obtrusive manner is effective in aiding the user.

- Some results regarding what users find obtrusive were quite surprising. We conclude that the notion of what and how much information and presentation elements the user finds obtrusive is not completely clear. Deeper analysis is required to understand as to why something becomes annoying and disruptive.

- From the analyzed scenarios, we conclude that decision making is not only restricted to the decision phase. Most trivial choices are made in the projection-implication phase. Complex decisions, where there there is a possibility of multiple outcomes with partial probabilites, occur in the decision phase.

- From the scenarios, the "attention" phase of the model appears to be a placeholder, as the task of specific sensing already takes place in the assimilation, projection and implication phases.

5.3 Perspectives

This research project is aimed as a first attempt at the situation modelling of human activity. Some problems which remain to be addressed are as follows:

- Activity Recognition: Activity recognition is extremely fundamental because it drives the all the forthcoming stages of situated information retreival. Various probabilistic, logical and hybrid approaches have been proposed in the past and it is imperative to choose an accurate one.

- Acquisition of Model: Acquisition means automatically constructing the situation model for the first time. This can be done by employing knowledge engineering (machine learning) methods. The process of acquisition is a first build-up to the context model.

- Adaptation of Model: The adaptation process refers to the integration of user preferences into the model, and its constant adaptation to user behaviour and preferences. There are various supervised and unsupervised learning approaches which could be looked into.

- Decision Making: The decision tree approach used for decision making fits appropriately with the scenario considered. This does not imply that the same approach would be viable in case of other scenarios, some of which may be more complicated. Thus there is a need to consider other alternatives, such as probabilistic and logical approaches for decision making.

Glossary

aware Information about the spatio-temporal surroundings, user activities and needs. i, 1, 3–5, 7, 9, 12–16, 20, 25, 39, 49, 51, 52

context Information used to characterize the situation of an entity; which could be any person, place or object relevant to the interaction between the user and application, including the user and application themselves [12]. i, 1, 3–5, 7–16, 20, 23–25, 29, 35, 39, 49, 51–53

entities Predicate function of one or more observable variables [8]. 2

entity Predicate function of one or more observable variables [8]. 4, 8, 11, 12, 14, 15, 18, 22, 23

phenomena Any entity or event that is identifiable or observable. 2, 7, 25, 37

relation How objects are connected; an object's effect or relevance to another. 2, 4, 10–12, 15, 16, 21, 23, 24, 28–32, 40, 52

service set of actions or solutions that are put in place or are performed to provide a repeatable and consistent set of outcomes, deliverables, and performance for people, organizations, and systems that represent consumers or beneficiaries of such results [51]. 1

situation Specific configurations of entities, relations and roles with entities playing roles [9]. i, 2–5, 7–10, 12, 13, 15–25, 27, 28, 34, 35, 37, 40, 41, 51–53

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