Requirements of Task Modeling in Ambient Intelligent Environment

Asma Gharsellaoui,Yacine Bellik
AMI Group, LIMSI-CNRS, Paris-South University
Bât 508, Plateau du Moulon, B.P, 133,
91403 Orsay Cedex, France
asma.gharsellaoui@limsi.fr
yacine.bellik@limsi.fr

Christophe Jacquet
Department of Computer Science,
SUPELEC Systems Sciences,
3 rue Joliot-Curie
91192 Gif-sur-Yvette Cedex, France
Christophe.Jacquet@supelec.fr

***Abstract*— User tasks modeling has been the focus of many research works either for designing user interfaces suitable to given use cases or for identifying the current task of the user in order to assist him/her. The problem of user tasks modeling has been widely addressed within the context of GUIs (Graphical User Interfaces). In this paper we present an overview of several existing task models and we discuss the specificities of user tasks modeling in the context of Ambient Intelligent Environments which are mainly: place-related tasks, device-related tasks and the possible errors occurring while performing a task. Then w e discuss the limitations of the classical user tasks models and depict the requirements of a task model specific to an interaction with an ambient environment.**

Keywords-User Task modeling; Ambient intelligent environments; User-centered systems.

I. INTRODUCTION

Ambient Intelligent (AmI) environments strive to support everyday life of the user through their embedded intelligent objects [1]. The goal of such environments is to satisfy user needs based on his/her preferences. Users are the center of such systems and are becoming more and more accustomed to technology and require more complex interaction possibilities. A user interacts with the system through tasks which are actions the user is going to perform in order to achieve a certain goal. Research in the field of assistance and supervision of tasks in ambient environments are still at an early stage.

In this context our work focuses on the proper conduct of user tasks through an adapted modeling approach. The purpose of user task modeling is to paint a predictive picture of user's activity. This picture must be detailed enough to create usable systems. Section II details the basic concepts related to task modeling. Section III contains a discussion of existing task models and their limitations. Section IV presents the specificities of ambient tasks and is followed by a discussion on how existing models can or cannot deal with these specificities through a scenario example (Section V). Our main contribution lies in Sections VI and VII that respectively introduce a new taxonomy for tasks categorization in ambient environments, and identify requirements for task models adapted to ambient applications. Section VIII gives conclusions and directions for future work.

II. BASIC CONCEPTS

A. Task

According to the Shorter Oxford Dictionary, a task is "any piece of work that has to be done". Tasks can be seen as actions that have to be performed to reach a goal in a specific application domain. They can be either logical such as retrieving information about a contact or physical such as dialing a phone number [2]. These actions are intended to be performed by the user, but they do not necessarily correspond to the user behavior while manipulating the application.

B. Goal

A goal is an intention either to modify the state of an artifact or to maintain it [3]. For example, accessing a contact database to look up a phone number of a colleague is a goal which does not require the modification of the state of the application, whereas accessing a contact database to add a new contact requires the modification of the state of the application.

Tasks and goals are closely connected. Each task can be associated with one goal that is the goal achieved by performing the task while one goal can be achieved by performing one or multiple tasks. In some cases it is possible to choose among different tasks to achieve a certain goal [2].

C. Activity

A user activity is a set of actions that the user is really going to perform when interacting with the system to achieve a goal. The activity corresponds to the user behavior when interacting with the system depending on the context of use. It is unpredictable and obtained by observing the behavior of the user.

D. Task Model

When designing an interactive system, several phases are conducted. First of all the task analysis phase [4] takes place to identify the fundamental elements of a job and to examine required knowledge and skills [5]. When this phase is finished, relevant tasks are identified and the task modeling phase starts. The purpose of task modeling is to build a model which precisely describes the relationships among the various tasks already identified. A task model describes the predictive activities to be performed in order to reach user goals.

The basic principle of task modeling is to decompose each task until reaching basic tasks which cannot be further decomposed. In some cases basic tasks require one single physical action to be performed. The level of decomposition in task modeling depends on its purpose. Task models should be rich in information and flexible so as to capture all the main activities that should be performed to reach the desired goals and the different ways to accomplish them [6].

Task models can be useful for two main classes of people [2]:

-Designers: task models provide a structured approach to evaluate an existing system or as a starting point to design new applications from scratch before implementing them.

-End users: the developer takes into account the user's activities since the physical actions supported by the user interface can be mapped onto logical actions and the representations provided could support the possible tasks.

III. EXISTING TASK MODELS AND THEIR LIMITATIONS

A number of approaches to task modeling have been developed. In the following paragraphs, we present a short overview of the main ones.

HTA: Its main idea is to represent complex tasks through a hierarchical representation (tree-like structure) [7]. This process starts with the identification of goals [8] knowing that each goal has a status (i.e., latent or active) and conditions to be satisfied. Then the decomposition is repeated recursively until obtaining observable subtasks allocated either to the user or to the user interface [9]. Using this formalism we don't see clearly if we model a system action or a user one. This model doesn't offer a lot of operators. For example there is no specific symbol to model parallel actions; one can only choose to use non-ordered sequences.

GTA: It describes the tasks by focusing on four central concepts: agents, roles, work [7] and situation [10]. Agents often represent people, either individuals or in groups; in some cases there can be non-human actors, or systems that comprise collaboration between human agents and machines. GTA doesn't enable one to see if the task is allocated to the system, the user or both (case of an interactive task) since there is no single representation for each type. It enables one to express only few operators in a specific way, for example hierarchical structure is represented from left to right.

CTT: The Concur Task Tree is a concurrent notation having a structured representation (a tree-like form). There is a distinction between four groups of tasks with various representations: User tasks, Application tasks, Interaction tasks and Abstract tasks (tasks that need to be refined).It provides a large number of temporal relationships between the tasks [11]. It's one of the richest task models but it is a static model (once established it doesn't change, see Section V). In addition, it does not focus on the physical space where the task will occur, nor on the devices since it concerns a single system.

UAN: It is a textual notation where the interface is represented as a quasi-hierarchical structure of asynchronous tasks, the sequencing within each task being independent of the others. Each basic task is associated with one table. These tables have three columns indicating the user actions, the system feedback and the internal state modifications using some specific symbols [12]. A rich set of operators to describe temporal relationships among tasks is available. But this method leads to a large specification. And it is not possible to model actions out of the interaction with the interface.

TKS: This method is based on a Task Knowledge Structure, which is a conceptual representation of the knowledge a person has stored in her memory about a particular task [6]. It has a tree like form. TKS focuses on: Roles, Goal structure and Taxonomic structure. Using this formalism it is not possible to model various relations between tasks as there is no special notation for repetitive, optional, parallel actions. Another limitation of this method is that is not possible to model system actions.

DIANE+: DIANE+ formalism [13] is a tree-like model using three types of actions: interactive, automatic and manual [6]. Diane+ can represent all the constraints of the above specifications such as ordered sequences, unordered sequences, loops, required choices, free choices, parallelism, default operations, and so on [7]. It doesn't include any possibility to put additional information about the task concerning, for instance, location, required devices, etc.

TOOD: It consists of an object-oriented method for modeling tasks in the domain of processes control and complex interactive systems [7]. It is based on a hierarchical decomposition into tasks modeled using Petri Nets. This method consists of four steps: hierarchical decomposition of tasks, identification of descriptor objects and world objects, definition of elementary and control tasks and integration of concurrency [14]. This description covers task hierarchy and temporal ordering. Sometimes we have a succession of user actions and we can't model it using this formalism which obliges each action to be between two system transitions.

IV. SPECIFICITIES OF TASKS IN AMBIENT INTELLIGENT ENVIRONMENTS

A. Ambient Intelligence

The term Ambient Intelligence (AmI) was coined by Philips in 1998 then used by the European Commission in 2001 and has been adopted worldwide [16]. At the beginning, AmI was a vision of the future in which environments support the people inhabiting them. It has been introduced [15] as an intelligent, embedded, digital environment that is sensitive and responsive to the presence of people.

AmI has a wide range of application since applications in various domains were realized. According to [16] the main application areas are: AmI at home for domestic care of the elderly [17] or assisted living; AmI at Shops, shopping, recommender systems and business and also many applications in Museums, tourism, groups and institutions.

Unlike a workstation whose actions have an impact only on itself and its immediate environment, an ambient system can incorporate features that enable it to act more broadly on the physical environment (actuators) or to acquire information from its environment (sensors). In addition to the sensors and actuators, the system also incorporates devices enabling the interaction with the user [18]. Nowadays, sensors available in ambient systems may provide clues about the behavior of people (position, orientation, displacement...). This kind of information could then be exploited to ensure the proper conduct of tasks performed by the user and to offer assistance when needed.

B. Characteristics of tasks in AmI Environment

Device-dependent tasks

Ambient systems include many small devices in the surrounding space of the user. Fulfillment of a task may require resources from the environment in which it will take place. That's why we talk about device-related tasks.

If a task requires a specific device, we must find this equipment. In an AmI environment, the devices could be added or removed at each moment or could be used by another person. When the user needs a device, the system must invoke this particular device or an equivalent one. This requires devices' categorization according to the services it could offer to the user. For example, the screen laptop could be used as a projection screen for viewing a film if the TV is out of order or being used by another person. So for each device we will have a list of possible related tasks.

Place-dependent tasks

Some tasks may need some resources which may be not mobile but located somewhere in the physical space. The execution of the related tasks will be possible only in a certain range of the physical space. That's called place-related tasks. For example: Kitchen-related tasks are the tasks possible in the kitchen such as: make tea, wash dishes, and prepare dinner...

Tasks in AmI environments also share some characteristics with classical tasks, in particular:

Temporal relationships

Two (or more) tasks in an ambient environment could be associated through kinds of relationships. Parallel tasks should be executed at the same time. Sequential tasks need to be executed in order: the beginning of a task corresponds to the end of the previous one. In some cases we could have the choice to get into a state by executing a specific task or another that is equivalent. In other cases we may need to model a second task that suspends the execution of a first task and that will be executed again after the second task finishes.

Error-prone behavior

Since we model user actions in interaction with various intelligent embedded systems, it is possible that errors occur during the process (system errors or user manipulation errors). These errors must not be neglected during the modeling phase and alternative solutions should be provided.

V. DISCUSSION OF EXISTING TASK MODELS THROUGH AN EXAMPLE

A large number of task models have been developed, especially in the context of GUIs. In this section some of these models are discussed according to the characteristics of tasks in AmI environments through an example scenario.

A. Ambient scenario 1 "Renewing passport"

Elie was browsing traveling web pages. The system understands that she plans to go on a trip and reminds her that her passport is no longer valid. The system asks her if she wants help to renew her passport. Once she validates this option, the system starts giving her instructions.

The system connects to the "city hall" website (of the town where she lives) to get the different documents that should be provided when renewing a passport.

The system instructs her that she needs a certificate of birth. She asks for help since she forgets its place. The system mentions that it is in the shelf where she puts her papers. Elie finds it and presents it to the system scanner. The system scans the found certificate and notices that it is expired (it was provided since more than three months) and a new one must be extracted from the "town hall" where she was born. For this purpose, the system suggests Elie to send them an email. An email is automatically written including some information about her (first name, last name, date and place of birth …) asking for a new certificate of birth. Elie validates the email which is sent to the "town hall".

Now, the system indicates that she needs a new normalized photo. Elie goes in front of the camera. First she is in front of a white wall; the photo web service indicates that the photo is not valid since the background must be clear but not white. The second trial is in front of a black wall and the photo system rejected this picture too. The third one is accepted by the system and then printed. Elie takes the pictures and puts them on a tray where she collects all the needed items.

Then the system instructs her to buy a tax stamp from the web site of the general treasury. The system opens the website of the general treasury and Elie chooses the appropriate stamp indicated on the web site of the "city hall" then proceeds to the payment. She types her credit card number and prints the stamp received by email. She adds it to the tray containing all the other papers. She is not sure that she bought the correct stamp so she scans its barcode using the mobile tablet and the system tells her that it is indeed the asked one.

At this stage, she needs to find her old passport; she asked the system to help her to find it because she forgot where she put it. The system instructs her to look in the nightstand. She finds it, brings it and adds it to the tray.

Now that she has collected all the papers she must wait for the certificate of birth to have the file closed and to go to the "city hall" to deposit the renewing papers. However she decides to already get an appointment to deposit the documents.

The system dials the number of the “city hall” in order to make an appointment. When Elie talks on the phone, her calendar is displayed starting from the next week (as the certificate takes usually one week to be delivered) in order to see her free times to insure her availability for the chosen date.

B. Task models representation

In Section 3 we have talked about seven task models. We have tried to model the proposed scenario using some of them to highlight their limits.

Figures 1 and 2 show the modeling of this scenario using the HTA task model. As it could be seen from the model, we couldn’t model system tasks so we feel that a big part of the model is missing (TKS model exhibits the same limitation). For example we don’t see that the system proposes help. At first we see directly the user validating help request. We couldn’t model the parallel actions “talking on the phone” and “seeing the calendar”. We could not model the possible errors while taking photos directly but we represent them as a repetitive task.

Figure 3 shows a part from the renewing of the passport scenario model using the GTA task model. We can see that we could model system actions as well as user actions but we couldn’t differentiate between the two types since we use the same representation. At the starting of each subtasks we put the time relationship between them and we have various options for that (for example we have “seq” for sequential tasks, “and” for parallel executed tasks, etc…).

Using UAN, we cannot model actions out of the interaction with the interface so we couldn’t model the scenario since it includes many actions of an interaction with an ambient system not necessarily a GUI. We could just model for example the purchase of the stamp as it is realized on line.

Figure 4 shows a part of the scenario modeled using the CTT task model. We can see that this model enables to model user tasks, system tasks and interaction tasks with different representations but we need to differentiate between different sub-systems since the user is interacting with different sub-systems in order to achieve his/her goal. We also need sometimes to put constraints related to places for instance in our scenario the user must sit in front of the camera to be able to take the picture. This model is rich with its different time operators but once established it doesn’t evolve according to the context (when modeling ambient tasks, the task model must evolve in real time to ensure that it takes into account the modification in the environment). There is no special notation for errors occurring.

C. Discussion

Only few of the existing task models include a clear differentiation in the representation of the tasks between system tasks, user and interaction ones. For instance from the ones cited in the third section only CTT and DIANE+ explicitly introduce several categories, whereas the others represent all task types on the same way. None of the referred task models has a special notation for device-or-place-related tasks. This limitation is due to the fact that these task models deal only with tasks invoking only one system, so there was no need to model several systems or place-related systems. Some of the listed task models (for instance: GTA, CTT UAN...) have a large choice of time operators offering possibilities to express various time relationships between tasks. It’s also important to notice that not all the task models have a graphical presentation for example UAN doesn’t have a graphical representation but just a textual description of the different tasks.

Table I summarizes the main characteristics of existing task models. The column "Types" indicates if the model includes any differentiation between task categories. “Devices” and “Places” show if there is any possibility to express device-related and place-related tasks. “Time Operators” refers to the presence of time operators to express temporal relationships between tasks. The final column shows if there is any graphical representation of the model.

TABLE I. COMPARISON OF EXISTING TASK MODELS CHARACTERISTICS

	Types	**Devices**	**Places**	**Time Operators**	**Graphical Representation**
HTA				x	X
GTA					X
CTT	x			x	X
UAN				x	
TKS				x	X
DIANE+	x			x	X
TOOD					X

VI. PROPOSAL OF A TAXONOMY OF TASKS IN AMBIENT ENVIRONMENT

Tasks in AmI environments have some specific characteristics; let us try to depict them based on a second scenario.

A. Scenario 2

Elie goes to work at 8am, so she leaves home; the heater is turned off since nobody is at home. She comes home after 6pm so she planned a TV program recording at 5pm for her favorite film. The system starts also another recording of a cooking TV program since it knows that she likes that kind of program. When she leaves the office, the system puts the heater on, 30 minutes before she arrives (after taking into account the distance between the house and the office and depending on the traffic) as the house takes about 30 minutes at least for warming. When she comes back home, she calls her friend John and at the same time turns the TV on and asks for the second channel. Since the TV is in front of the window, the system decides to close up the window stores because the sun shines outside, disturbing watching TV.

TABLE II. TASK CATEGORIES THROUGH EXAMPLES

	automatic	implicit interactive	explicit interactive	User
Programmed	Recording TV programs programmed by the user	Put heater on when the user comes back home	Record TV program immediately after the user asks for that.	The user asks the system to remind him/her or them to do a certain task at a specific time.
Learned	Regular TV programs recording learned from user habits	Put heater on when the user comes back home because the user asked for that many times so the system learned this.	Modification of the intended/planned action after interactions with the user. The system learns how to respond to a new order.	The system notices that each time the user puts the conditioner on, he closes the windows. This task must be added to the task model to enable reminding the user to do it.
Deduced	Recording a given TV program since it is similar to what the user is used to watch.	Put on the heater when the user leaves the office (deduced in fonction of the traffic and the distance between home and the office).	When the user turns on the TV, the system closes the windows as it disturbes TV viewing.	The system has meta-rules saying that if the windows are opened the conditioner must be closed. If the user opens the windows and could not turn off the conditioner as the remote controller is disabled,the system asks the user to put off the conditioner manually.

B. *New tasks categorization*

Starting from the Scenario 2 and trying to imagine other possible situations, we propose a new categorization of tasks in ambient environments. Tasks are categorized with respect to 2 axes:

- **The way the task is launched**: Tasks can be automatic, explicit interactive, implicit interactive, or done by the user.

  1/*Automatic tasks:* the system does the task by itself without user intervention at this moment.

  2/*Interactive explicit:* the user action or situation is understood by the system as an entry condition or order to a certain task.

  3/*Interactive implicit:* the user directly instructs the system to do a certain task.

  4/*User:* the task is done by the user.

  For categories 2 and 3, there is an interaction between the system and the user which leads to the realization of the task.

- **The way the task is acquired**: Tasks can be programmed, learned or deduced, expressing the way the system gets knowledge of the task.

  1/*Programmed:* the user or the designer instructs the system to do a certain task.

  2/*Learned:* the repetitive invocations done by the user could be learned by the system and then anticipated and realized without user invocation. Here the system learns user habits or repetitive tasks and starts doing them without being ordered explicitly to do that.

  3/*Deduced:* The intelligence of the system includes some rules that allow some tasks to be initiated by the system to satisfy potential needs of the user, based on his/her profile.

We propose to categorize a task through the intersection of these two dimensions, depending on the way a certain task is launched and acquired. Table 2 explains each type through an example from the Scenario 2 or a variation of it.

VII. REQUIREMENT OF TASK MODELING IN AMBIENT INTELLIGENT ENVIRONMENT

From the previous scenarios, we can extract the following requirements for an ambient task model.

Place-related and device-related tasks

Concerning the constraints of place-related and device-related tasks, the task model should include the possibility of labeling tasks with spatial constraints and devices involved to achieve the task. However it is impractical to refer to a specific device in an AmI environment because in AmI environments devices and services may appear and disappear dynamically. So instead we should refer to a family or type of device.

The usage of an ontology for devices classification is necessary. One solution is to deal with services which could be realized by using different facilities from the surrounding environment and so the devices will be part of a category offering certain services. Once a task needing a given missing device starts, the system may propose to realize it with one of the available equivalent ones. For example if the user wants to call someone and at this moment the phone's battery is discharged, the system could opt for an equivalent solution which is to call on Skype using the user laptop, So these two solutions could be considered as equivalent since they enable the same goal in two definitely different ways to be achieved. Such devices classification was realized in previous research works; we can cite for example DogOnt, an ontology modeling for ambient intelligent environments [19].

Granularity or task decomposition

The granularity of task decomposition must be chosen. Since the basic principle of task models is to decompose a complex task into smaller subtasks until reaching a basic task which could not be further decomposed, the level of decomposition at which we stop decomposing a task in an ambient environment must be determined. We propose to stop the decomposition at the level where services are invoked.

User profile

Ambient intelligent environments may be proactive systems. They evolve according to the user profile in order to anticipate his/her expectations. So the model must integrate a part in which user habits and preferences are continuously stored.

Dynamic model

The proposed task model should be an evolving model in order to respond to the continuous changes of the context and to enable the representation of the learned and inferred tasks. In contrast to static classical task models, a task model adapted to AmI environments is dynamically changing with the new learned knowledge. It evolves once the system learns more about the user profile or new tasks. This task model should be able to model the reactive part of the tasks as well as the proactive one.

Error-prone behavior

Errors may occur during the interaction with the system so the model should have a special notation for either system or user errors and should be able to propose another alternative to overcome errors, for example by a system action or by proposing another alternative to the user. In ambient environments, error detection can go further since we have sensors enabling to detect any equipment's failure to overcome.

Task categorization

An ambient task model should refer to the new proposed task categorization by offering a means to label tasks according to their categories. The usage of this taxonomy will be helpful in many cases. For example when we have concurrent tasks to be performed using the same device we wish to prioritize them. Namely deduced tasks would have the least priority since they are only based on the system deduction whereas programmed ones should have greater priority.

Some of the existing task models offer facilities that should be offered by an ambient task model as well. For instance a model having a graphical structure is easy to use by both developers and end users because it highlights the main information and keeps out of sight complex information. A hierarchical structure could also be helpful to enable a clear identification of task steps and to reduce the complexity of the tasks that should be performed in order to reach a certain goal.

The model should also include a rich set of temporal operators to express any possible temporal relation between tasks.

VIII. Conclusion

Task modeling is an interdisciplinary research area which requires knowledge in computer and cognitive sciences and Human Computer Interaction (HCI). In cognitive sciences there is a big focus on how to characterize and identify relevant tasks. In computer science the focus is much more on finding notations suitable to represent tasks and their relationships more precisely. The last area involved is HCI since we try to study and to model a human in interaction with a system.

In this paper, we have made an overview of the existing task models and we have studied their limitations when used to model ambient scenarios.

Ambient tasks share some characteristics with classical tasks but they also have proper specificities. We have detailed the characteristics of tasks in AmI environment. Since the tasks may invoke specific devices in specific places, this has led us to specify device-related and place related-tasks.

We have proposed a new taxonomy of tasks adapted to ambient environments, based on two axes: the way tasks are launched and the way they are acquired. We have given precise examples for each possible category of this taxonomy.

From the previously detailed characteristics, we have deduced a set of requirements for a task model suited to tasks in an ambient environment. In summary such a model must:

- be an evolving model that takes into account changes that may occur in the surrounding environment,
- have services as the lowest level of task decomposition,
- give special labels to each task to specify if the realization needs special devices or must take place in a special area,
- propose a type for each category of tasks (from the proposed taxonomy),
- explicitly represent possible errors and solutions,
- offer a large set of temporal operators.

At this stage relevant characteristics of tasks in ambient environments are highlighted, new task categorization was defined and the requirements of a task model adapted to AmI environment are clearly identified. As a future work, we plan to develop this novel ambient task model that will enable an intelligent assistance to users in their daily activities. We also plan to have real scale experimentations in an equipped smart room at our Lab (LIMSI-CNRS) based on different scenarios.

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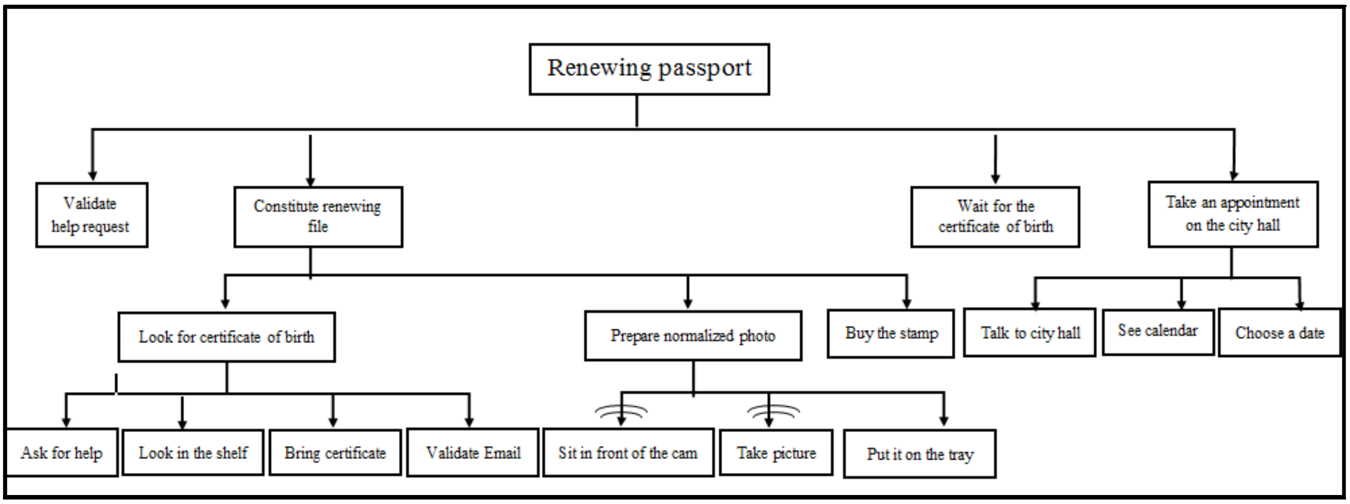

Figure 1. Renewing passport task represented with the HTA task model (part1).

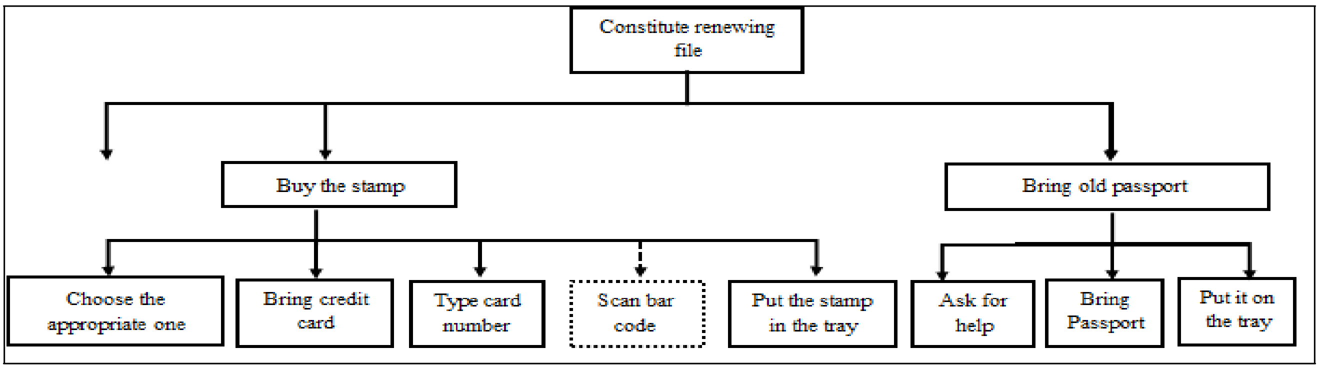

Figure 2. Renewing passport task represented with the HTA task model (part2).

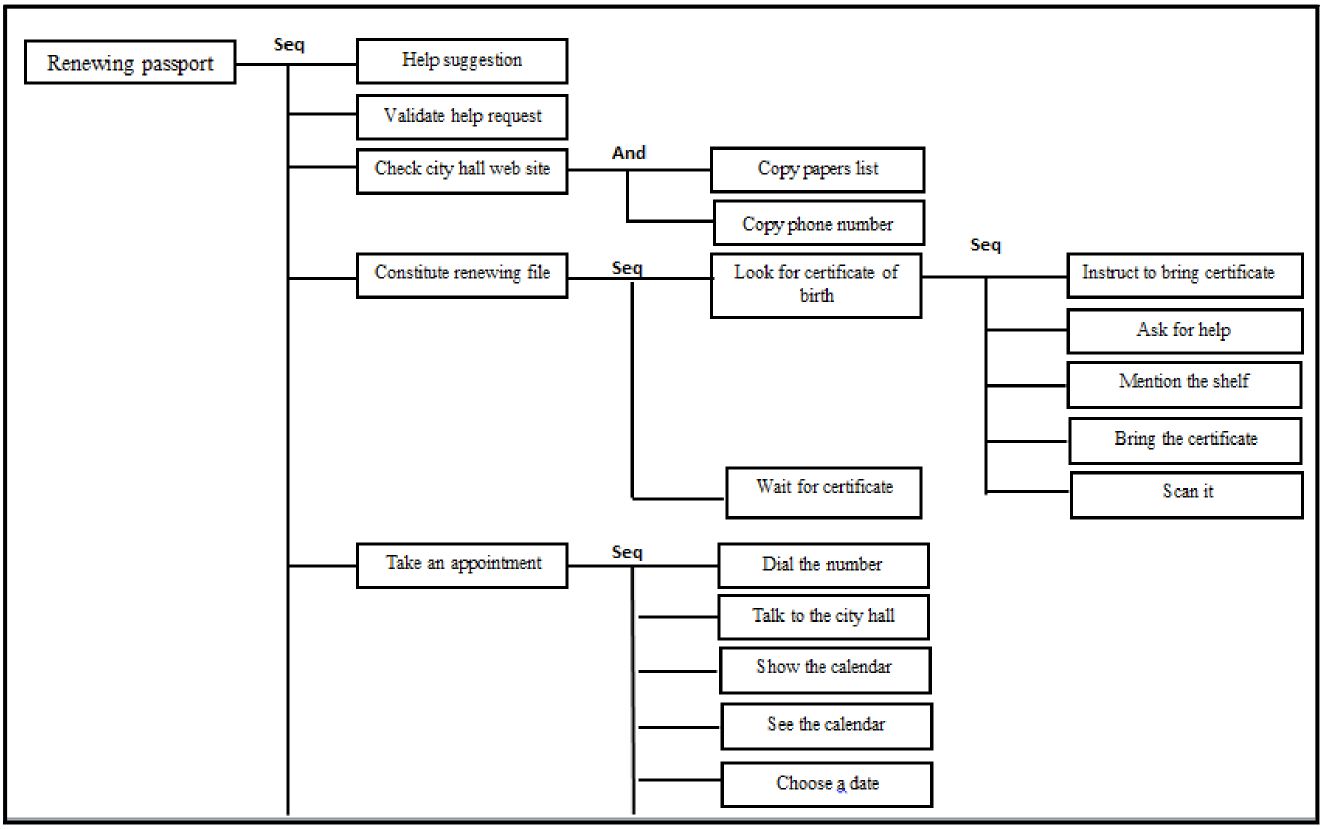

Figure 3. Part from renewing passport task represented with the GTA task model.

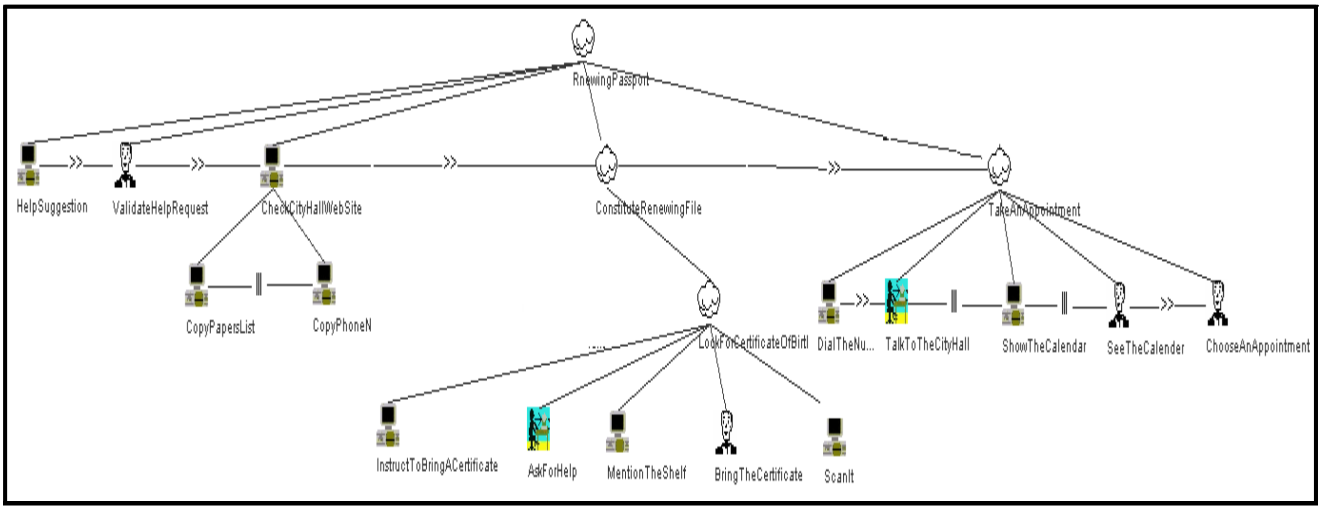

Figure 4. Part from renewing passport task represented with the CTT task model.