Context Awareness in Human-Robot Interaction

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***Abstract*—This paper discusses the importance of context awareness in Human-Robot interaction. We address the different types of context awareness. We discusses the adaptation of common architectures in order to take into account with contextual information in Human-Robot interaction. The architecture will constitute the foundations for a generic context-based human-robot interaction framework.**

I. Introduction

Human–robot interaction is the study of interactions between humans and robots. Human–robot interaction is a field of study of human–computer interaction, natural language understanding, design, artificial intelligence, robotics, and social sciences. Context awareness is the ability of a system to collect information about its surroundings at any time and adapt behaviours consistently. For example: Whenever a person interacts with the robot, the robot interprets the information based on the data that it had procured previously. For instance, when a robot instructs the user to arrive at a place after 5 minutes, if in case, the user arrives after the above aforementioned time, the robot enquires the person about his/her late arrival, all because of the data it had collected previously. Another example: You are going to pick a case laying on the floor to the closest table. While going to get a handle on the container, you are informed that there are eggs inside. As a result of realizing that you adjust your developments so as to keep the eggs flawless, yet at the same time you get, convey and put the case on the table. Truth be told, so that you adjusted your activities dependent on the gained setting (important) data.

Why context is important? Context awareness provides a best solution to the user requests based on the obtained information about the environment or the context of operations (past incidents). The most common approaches to represent context data by explicit description about the surrounding conditions and those data must be executed in the presence of those surrounding conditions. Nowadays, there is tremendous development of context awareness related applications. The search engines collects the users data based on location, time and day and preference of the user to provide relevant information such as advertisements or recommended information. For instance, The sport channels in Brazil will display football results, Whereas in India probably will show cricket or tennis.

The motivation of the current work

1.Mobile Applications: Context awareness is a fundamental prerequisite for portable applications. A few analysts have offered various types of answers for adjusting smartphones for explicit applications.

2. Secure-Critical Systems: Context awareness attention to safety and secure-basic frameworks make them progressively versatile.

3. Pervasive Computing: Inescapable registering and universal applications should know about their condition so as to adjust (auto adaptation) to changing settings and give the right administrations. Programming situation.

II. Types of context awareness

There are various kinds of context awareness:-

A. Location

There is a developing range of location aware applications, specifically in GPS gadgets and smartphones. These programs can warn the person of the proximity of some point of interest, choose advertisements, or even choose applications associated with the place or position of the user.

B. Activity

An activity describes what is occurring in a given situation. A system that is activity aware will gather data regarding the activity that is presently being performed as well as from previously performed tasks. With this information, the system will conduct a numerous data analytic functions, and the obtained result will help us to identify the appropriate tasks needs to be performed and also helps to predict the future tasks.

The best example can be seen in the iTunes software. Every music purchase made by a client is stored in the client's account. Using this data, the system will suggest more songs based on the previous data or music listened by the user/client. This makes the client to buy new music collections in the future.

C. Identity

Identity refers to the information or data about the person or things such as user's face recognition, name and date of birth etc. For example, facial recognition software is used for the authentication purpose and identify the person interacting with the robot. For identity information to be implicitly collected, the user must directly interact with the software in order for the system to be made aware of the user.

A typical certain client's information gathering feature is a login discourse where the client must enter in their username and password. When this essential character data is procured the framework can get to optional data about the client likewise, for instance, a client's contact data, date of birth, association with others in the earth, and so on. Knowing the identity of a client is helpful device. It permits a framework to show redid data to the client just as utilizing this data to figure out what other framework occasions ought to be handled so as to satisfy the client's needs.

D. Time

When a user interacts with the robot. The robot has to remember the time and situation.

E. Sentiment

This describes the emotional state of a user in a particular situation. For example, based on the user personal data or previous context, a robot or system can detect the emotional state of the user.

F. Proximity

The ability of the system to detect nearby things. For example, Online shopping apps detect the product id and its descriptions.

G. Ambience

Includes the products and people that directly interact with the main user and the robot.

H. Physical context

Is the environment that consists of a set of products and people that indirectly interact with the main user and the robot.

I. Social context

Includes elements that do not explicitly interact with the main user, whereas such elements may influence the behavioral propensity of the user.

III. Interactive Robots

Fig 1 shows our future society with interactive robots. The robots developed by the companies will become part of the futuristic scene shown in Fig 1. The strongest reason is in the human innate ability to recognize humans and prefer human interaction. The human brain does not react emotionally to artificial objects, such as computers and mobile phones. However, it has many associations with the human face and can react positively to resemblances to the human likeness. Therefore, the most natural communications media for humans are humans. That is, humanoids and androids that have a very human-like appearance will be ideal media for humans. This is the reason why some companies have developed humanoid models, and why many people are interested in humanoids. However, it is not so easy to realize the robot world shown in Fig 1. We have to solve the following three issues:

a. Sensor network for tracking robots and people.

b. Development of humanoids that can work in the daily environment.

c. Development of functions for interactions with people.

Fig. 1 :Interactive robots working in our future society.

The robot cannot completely observe an environment with onboard sensors. The robot can have cameras and laser scanners and observe the local environment around itself. However, it is quite difficult to monitor the whole environment in real time with the sensors. On the other hand, the human functions in a more sophisticated way to monitor the environment with the limited sensors. Humans can guess and infer the events that happen in the environment based on experience. Therefore, even if the sensors have limitations, humans can widely monitor the environment. The robot cannot take the same strategy as humans since it does not have the sophisticated method to infer events that happen in the wider environment with the onboard sensors. The current technology of artificial intelligence is not enough to simulate the human brain function. The alternative way to monitor the wide environment is to use many sensors distributed in the environment. This is the idea of ubiquitous computing. We are already using various ubiquitous sensors in our current society. There are many surveillance cameras in banks, railway stations, and hospitals. Some of the cities are placing many cameras along streets for security purposes. By extending this sensor network, we can develop more sophisticated sensor networks for monitoring both human and robot activities.

The second issue is the development of humanoids. The most popular humanoid is ASIMO developed by Honda. The perfection level is very high, and it functions almost practical level. However, the biped mechanism is not perfectly safe. ASIMO cannot physically interact with young children. A more reliable and safe mechanism for moving is the mobile platform with two driving wheels used for Wakamaru.

Wakamaru has been developed based on Robovie, an innovation from Intelligent Robotics and Communication Laboratories in Advanced Telecommunications Research Institute International (ATR). The design concept of Robovie was to have safe and stable hardware for interactive communication using gestures (Fig 2). It has two driving wheels and two arms and a head. Each arm has four degrees of freedom with minimum torque motors for gestures. Therefore, children can easily and physically stop the arm movements to avoid any dangerous situations.

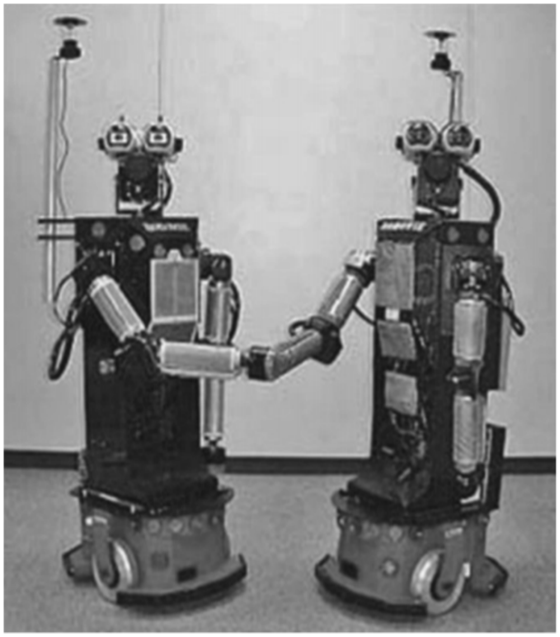

Fig. 2 : Robovie developed by ATR.

In addition to the minimum mechanical hardware, Robovie has various sensors. It has two high-speed pan-tilt cameras on the head and an omnidirectional camera on the top of the pole attached in the back. The high-speed pan-title cameras are good for watching people standing in front of the robot, but they are not sufficient for observing the surrounding of the robot. For such a purpose, the omnidirectional camera works very well. Robovie is always monitoring its surroundings and quickly pays attention with the high-speed pan-title cameras when it finds something of significance. Another important sensor is the tactile sensors that cover the whole body. Robovie also has several ultra-sonic sensors to monitor the surroundings. However, they are not enough. During interactions with people, they touch the body. In order to detect touching, we have developed tactile sensors by using conductive sheets.

The third issue is to develop functions for interacting with people. This is the most important issue for human–robot interaction.

IV. Psychological background in Context Awareness

The field of Human-Robot Interaction (HRI), and specifically, the field of social HRI profits by a wide scope of logical information. As a network, we perceive that the specialized fields of engineering, control hypothesis, and software engineering don't give fundamental apparatuses to the logical examination of the 'human' and 'communication' portions of HRI. Thus, scientists have taken motivation and ground quite a bit of our exploration in setting up results from the sociology – basically social brain research, subjective brain research, and human science.

As researchers in HRI wind up at the convergence of these numerous fields and intend to offer bits of knowledge to developers and architects, just as analysts. In this sense, our field exemplifies the essential thought of intellectual sciences: building spans across controls to increase new bits of knowledge on complex logical difficulties. All things considered, the socioeconomic of the scholastic working in HRI is slanted towards designing foundations ; one regularly turns into a scientist in HRI by first structure robots and afterward taking a gander at how the machines may cooperate with people. While a few of us do have to prepare in brain science, many don't. This isn't an issue as such: as prepared researchers and designers, can peruse and decipher the sociology writing, and replicate errands, conventions, and – maybe results. In any case, the ongoing replication emergency in brain research currently gives occasion to feel qualms about that reason.

Aarts et al. [2], in their fundamental examination, found that after endeavoring to repeat 100 brain science considers, just 39% of the replication studies could abstractly be appraised to have recreated the first outcome. As the aftereffects of 66% of 100 examinations couldn't be appropriately recreated, whatever the reasons may be (from production predisposition, to sociological changes in the populace. The concept of context is a closely related to reasoning and cognition in humans. Even though, context might be important for reasoning in other animals, it is common knowledge that context is of huge importance in human reasoning. Beside the more mechanical view on reasoning advocated by neuro-science, psychology and philosophy play important roles in understanding human cognition. It might not be obvious how computer science is related to knowledge about human cognition. However, many sub-fields in computer science are influenced by our knowledge about humans; and other animals.

As indicated by Ekbia and Maguitman, Dewey recognizes two principle classifications of setting: spatio and temporal context, together know as foundation setting; and particular intrigue. The spatio setting covers every single contemporary parameter. The temporal setting comprises of both intellectual and existential setting. The Intellectual setting is the thing that we would typically name as foundation information, for example, convention, mental propensities, and science. The existential setting is joined with the specific interest identified with the thought of circumstance. A circumstance is in this work saw as a confounded, cloud, and clashing thing, where a human reasoner endeavors to understand this through the 2 utilization of setting. This view, by Dewey, on human setting prompts the accompanying proposal by the practical methodology [3]:

- Setting, frequently, isn't expressly recognizable.
- There are no sharp limits among settings.
- The coherent parts of reasoning can't be disengaged from material contemplation's.

- Conduct and setting are mutually unmistakable.

Behaviours and appearances of robots have dramatically changed since the early 1990s, and they continue to change — new robots appearing on the market, other robots becoming obsolete. The design range of robot appearances is huge, ranging from mechanoid (mechanical-looking) to zoomorphic (animal-looking robots) to humanoid (human-like) machines as well as android robots at the extreme end of human-likeness. Similarly big is the design space of robot appearance, behaviour and their cognitive abilities. Most robots are unique designs, their hardware and often software may be incompatible with other robots or even previous versions of the same robot. Thus, robots are generally discrete, isolated systems, they have not evolved in the same way as natural species have evolved, they have not adapted during evolution to their environments. When biological species evolve, new generations are connected to the previous generations in non-trivial ways; in fact, one needs to know the evolutionary history of a species in order to fully appreciate its morphology, biology, behaviour and other features. Robots are designed by people, and are programmed by people. Even for robots that are learning, they have been programmed how and when to learn. Evolutionary approaches to robots' embodiment and control (Nolfi and Floreano, 2000; Harvey et al., 2005) and developmental approaches to the development of a robot's social and cognitive abilities (Lungarella et al., 2003; Asada et al., 2009; Cangelosi et al., 2010; Vernon et al., 2011; Nehaniv et al., 2013) may one day create a different situation, but at present, robots used in HRI are human-designed systems. This is very different from ethology, experimental psychology etc. which study biological systems. To give an example, in 1948 Edward C. Tolman wrote his famous article "Cognitive Maps in Rats and Men". Still today his work is among the key cited articles in research on navigation and cognitive maps in humans and other animals. Rats and people are still the same two species; they have since 1948 not transformed into completely different organisms, results gained in 1948 can still be compared with results obtained today. In contrast, the robots that were available in the early 1990s and today's robots do not share a common evolutionary history; they are just very different robotic 'species'.

Thus, what we mean by 'robot' today will be very different from what we mean by 'robot' in a hundreds of year time. The concept of robot is a moving target, we constantly reinvent what we consider to be 'robot'. Studying interactions with robots and gaining general insights into HRI applicable across different platforms is therefore a big challenge. Focusing only on the 'H' in HRI, 'user studies' , i.e. the human perspective, misses the important 'R', the robot component, the technological and robotics characteristics of the robot. Only a deep investigation of both aspects will eventually illuminate the illusive 'I', the interaction that emerges when we put people and interactive robots in a shared context. In my perspective, the key challenge and characterization of HRI can be phrased as follows:

"HRI is the science of studying people's behaviour and attitudes towards robots in relationship to the physical, technological and interactive features of the robots, with the goal to develop robots that facilitate the emergence of human-robot interactions that are at the same time efficient (according to the original requirements of their envisaged area of use), but are also acceptable to people, and meet the social and emotional needs of their individual users as well as respecting human values".

V. Response to Context

Social Robots can have critical implementation scenarios such as boosting the autonomy at various places such as the home by serving the primary needs of the old aged ones by catering to them spiritually and physiologically. Thus, enabling them to break free from the shackles of depression and loneliness.

The diverse set of activities pertaining to domiciliary care, such as housekeeping tasks like polishing, cleaning the windows, or sorting out the laundry that can soon build up as well as cooking meals, plating up, serving lunch, snacks, etc are recognized as the essential issues that involves physical interaction of the robot with the surroundings, which can be easily achieved with the help of social robots.

Models must be developed that cater to the needs of the elderly and should serve them accordingly. Therefore, models must have two important abilities, Firstly, the models must be designed to utilize its a prior knowledge which could be either in the hard-coded form or the one that is derived from experience. Secondly, the models must be competent enough to progress on their own over a period of time. The area of Human-Machine interaction still has not come up with the framework that effectively describes the learning and reasoning that stems from contextual data particularly in case of distributed systems that encompass the sharing of the information pertaining to a given context amongst its various components [6],[7].

Currently, the robotic systems that come into being offers the services in the field of public, domestic and professional domains are mostly comprised of being operational with respect to context a usage, data involved and the various pieces of equipment that are used. The current systems are restricted to adapt to the dynamic changes that are involved in sharing and learning from data pertaining to a given context, rather they are equipped to learn from the pre-defined as well as implicit set of contexts. The application can be fed with the contextual information manually by considering the final targets and goals of a given user. However, this approach fails miserably when a user expects the application to progress over time. With the environment changing like never before, the applications that are run primarily with a predefined set of contexts do not get adapted well to the newer scenarios. Hence, the fixed context model does serve the purpose.

Furthermore, the maintenance followed in the traditional common approaches results in a detrimental impact on the economic standards. For instance, the cost incurred would be quite high if an expert is expected to adjust the system every now and then. The limitation of this approach has led to research strides to bring about various intelligent, self-adaptable and self- learning systems.

VI. Approach

Computer-Supported Cooperative work(CSCW), which enables computer systems to collaborate and coordinate a set of activities among group of individuals [4]. Groupware brings about the interface that allows the interaction of various activities between the humans and the robots.

According to CSCW literature, Awareness information constitutes the information that individuals have about every other individual during a coordinated activity. It equips them to understand the activities and identities of every participant. Awareness information is also quite impactful for productive coordination and collaboration, since it mimics the subtle non-verbal cues that people acquire when they communicate face-to-face and when they are in the similar physical location. There are two notable differences between the HRI and CSCW applications.

Primarily, the participants in CSCW applications are humans only whereas in HRI, it could be either robots or humans constituting one or many in number. Secondly, although robots do coordinate and collaborate a real time task, it can't match up the cognitive ability possessed by that of the humans.The definition of awareness in explained in the Table 1.

The HRI awareness framework renders description of various combination that includes single and multiple humans and robots. The most elementary combination occurs when a single robot interacts with the single human (Base case) Base case: It defines the various assimilation that a human being ought to have pertaining to the status, activity, surroundings and location of the robot as well as the information that the robots possess with respect to the commands stated by the humans and understanding of their limitations to effectively to complete a task in hand. HRI awareness directly corresponds to the autonomy that a robot is expected to possess.Greater the autonomy, greater the awareness and vice-versa. Five clear and definite cases can be interpreted for the HRI awareness framework [5]. Firstly, Human-Robot, the awareness possessed by humans of the robot in discerning the different attributes such as the surrounding of the robot, status, activities, locations and identities.

Secondly, Robot-Human, the awareness that robot has of each human in terms of commands stated by the humans and of the possible adaptation and adjustment in case of conflicts, when commands are issued by multiple humans.

Thirdly, the Human-Human, the awareness that every human being has of another that primarily concerns the activities, identities and locations of their fellow human counterparts.

Fourthly, the Robot-Robot, the awareness each robot has of another which encompasses the knowledge of commands issued by humans as well as their quick adaptation amongst them in cases where a specific goal needs to be achieved that require greater collaboration and coordination.

Awareness term	Definition	Source
Awareness	An understanding of activities of others, which provides a context for vow own activities	Dourish and Bellotti[8]
Awareness	Given participants P1 and P2 who are collaborating via asynchronous collaborative application,awareness is the understanding that p, has of the identity,and activities of p2	Drury[9]
Concept Awareness	The participants understanding of how their task will be competed	Gutwin wt al.[10]
Conversational awareness	Who is communicating with whom	Vertegaal et al.[11]
Group structural awareness	Knowledge about such things as people's roles and responsibilities, their positions on an issue, their status, and group processes	Gutwin et al.[12]
Informational Awareness	The general sense of who is around and what others are up to	Gutwin et al.[12]
Peripheral awareness	Showing people's location in the global context	Gutwin et al.[13]
peripheral awareness	where people know roughly what others are doing	Baecker et.al. [14].
situation awareness	the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning,and the projection of their status in the near future	Endsley [15].
social awareness	the understanding that participants' have about the social connections within their group	Gutwin et al. [10]
social awareness	information about the presence and activities of people in a shared environment	Prinz [16]
(not named by authors;our term is spacial awareness)	the more an object is within your focus, the more aware you are of it;	Benford and Fahlen[17]

task awareness	the participants' understanding of how their tasks will be completed	Gutwin et al. [10]
task oriented awareness	awareness focused on activities to achieve a shared task	Prinz [16]
work space awareness	the up-to-the-minute knowledge of other participants' interactions with the shared work space	Gutwin et al. [10]
work space awareness	who is working on what	Vertegaal et al. [11]

Table 1. Definitions of Awareness in the CSCW Literature

And lastly, the awareness that a human possesses that encloses the complete understanding of various collective and concerted targets in accomplishing a real time task.

VII. Context-Based Human-Robot Interaction Framework

A. Preexisting Architecture

The Laboratory for analysis and architecture of systems developed a global architecture. This enables the integration of process with the different temporal properties and representations. The current existing architecture comprises four layers as shown in the Fig 3.

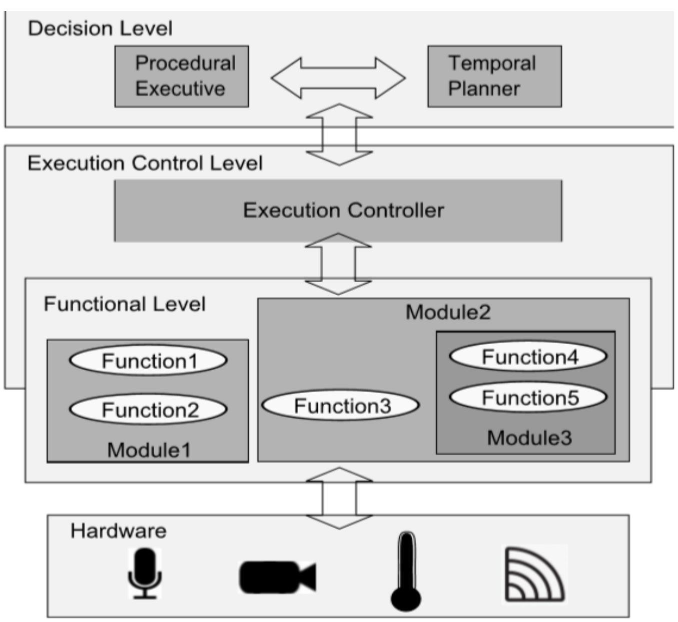

Fig. 3 : Generic architecture for robots.

- **Hardware Level**: It mainly comprises of various sensors and actuators that are a part of the robotic system.
- **Functional Level**: The various processing functions and control loops such as controlling the motion, processing of an image, avoidance of an obstacle, etc concerning the interaction of the robot are enclosed into one module known as the controllable communicating module. It comprises of the several primary built-in perception and action associated with the robot. The services pertaining to a given task are executed based on the instruction from the decision level.
- **Execution control Level**: It mainly deals with ensuring the smooth and accurate implementation of the services abiding by the safety standards and critical rules thus protecting the module from unpredicted and unplanned interactions leading to disastrous consequences.
- **Decisional Level**: It enables the robotic systems plan and orchestrates the task plan and its execution. It manages and looks after the entire functionality. It is also quite responsive to the events emerging from the functional level.

The organization of overall framework in layers and the functional layers in modules are certainly a positive impact in integration of modules and reusability. However, an architecture and a few apparatuses are "insufficient" to warrant a sound and safe conduct of the general framework.

Right now componentization strategy we propose will permit us to integrate a controller for the general execution of all the practical modules and will uphold by development the limitations and the guidelines between the different functional modules. Subsequently, a definitive objective of this work is to actualize both the current functional and execution control level with BIP.

B. Extended Architecture

It incorporates the contextual information with the overall system, controlling and supervising the workflow concerning to the robot-human interaction.

- **Controllers:** It incorporates the interfaces with the other components that are present in the architecture(Fig 4). It is also accountable for the different functionalities and orchestration that are included in the framework.
- **Recognition algorithms**: It consists of different varieties of algorithms that are used to be equal to the information being perceived with the information being stated to be contextual.
- **Context models**: It comprises of a large collection of a-priori context data models.

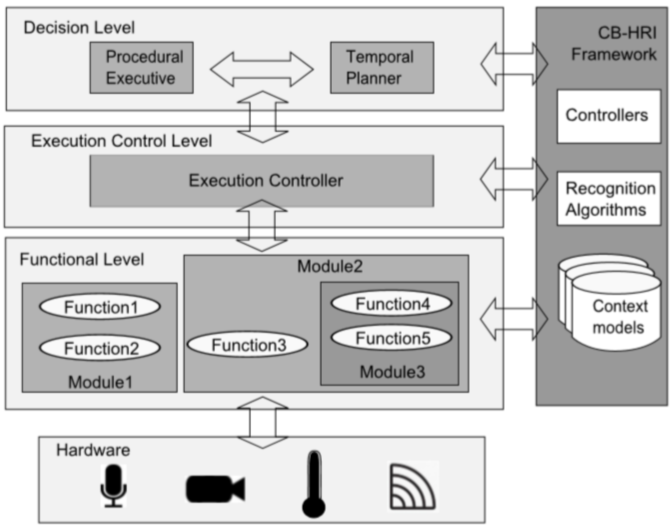

Fig. 4 : Context-based Human-Robot Interaction Framework extending preexisting architecture.

The proposed approach concerns in dealing with the various contextual information being consolidated between the diverse range of available algorithms and other existing resources that are expected to be executed effectively under a given set of conditions.

Consequently, The context-based Human-robot interaction architecture should be integrated with the modules dealing with perception, sensor data and actuation.

C. Context verification process

The context is described as the output of the transformation of raw sensor data into a useful data or information. Here, the context is based on the situation, and the resulting behaviour of the robot. The context is obtained through classification of sensor data based on the restriction or guidelines for the particular situation. This approach considers context awareness as a dynamic process that works in the background of the system, while interacting with a user.

This operation workflow is provided in the Fig 5. This helps system to activate adaptation behaviour in the execution loop (perception action) when there is a change in the context.

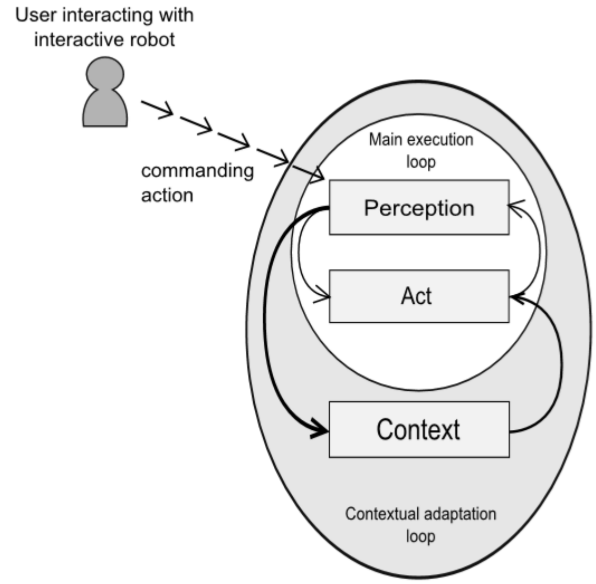

Fig. 5: Context verification process.

VIII. Conclusion and Future work

The paper addressed the importance of context awareness in the interaction process between human-robot. It considered the importance of psychology in the context awareness. The main of the context-based HRI framework is to provide solution to the problem of integrating contextual information during interaction process.

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