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Building a Conversational Agent based on the principles of Cognitive Pragmatics using Cognitive Architecture

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***Abstract*- Conversational agents can be used for customer support, help desk, technical support kind of services. It also helps in training the customer service executives. Speech recognition, natural language processing and cognitive architecture all play a vital role in building a conversational agent. Conversational agents which use computational linguistics techniques faces some technical challenges such accuracy and efficiency. (1) two basic challenges in building a conversational agent are understanding agents1's conversation and acquiring language processing capabilities to address agent2. These challenges can be addressed using speech recognition and nlp. These two techniques are used for answering only two questions such as 'what was told by agent1?' and 'how to frame sentences to answer it?' but apart from these questions, we require cognitive architecture to answer the question 'what to say?' the answer for this question depends on a number of aspects such as rational thinking, decision making, belief, etc.**

Keywords: Conversational Agents, Cognitive Architecture, Speech Recognition, Pragmatics, conversational psychology, BDI, Cognition.

INTRODUCTION

During the process of the Review of the literature, my guide introduced me to the 'Emotion Machine – Marvin Minsky' and BDI (Belief, Desire and Intention) approach which was his area of research. These two concepts interested me. During the course work, we chose speech recognition and wrote a review paper under the guidance of Prof.Balaji. The in-depth knowledge in both the areas made me arrive at a new idea of building a cognitive conversational agent.

RESEARCH WORK

Building A Conversational Agent :

Basic Components of Communication:

A conversational has to be built keeping in mind the above said techniques. The process of communication has three basic components namely Syntax, Semantics and Pragmatics. As a result of various researches, (Kelley, Jones, & Fein, 2004) the five components for the growth of linguistic proficiency are phonology, morphology, semantics, syntax and pragmatics. Phonology is the basic unit of sound, which is a subset of the sounds that humans are capable of producing. Morphology includes rules for using 'ed' and 's' as well as for using other prefixes and suffixes. Semantics refers to the meanings expressed in words, sentences and the smallest unit is known as morphemes. Syntax is the rules that specify how words are to be combined to form meaningful phrases and sentences. Pragmatics is the knowledge of language that might be used to communicate effectively e.g. The sociolinguistic knowledge. (2) Otherwise known as Cognitive pragmatics; it is the mental ability of human being which is used to communicate with each other.

Linguist Noam Chomsky has proposed that humans come equipped with a language acquisition device. LAD is an inborn linguistic processor that is activated by verbal input. According to Chomsky, the LAD contains a universal grammar, or knowledge of rules that are common to all languages which is referred to as the nativist approach. (3)

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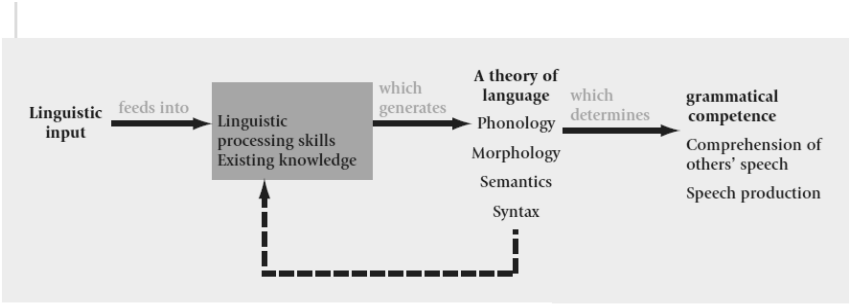

A model of language acquisition proposed by nativists.

Fig.1 A Model of language acquisition. (4)

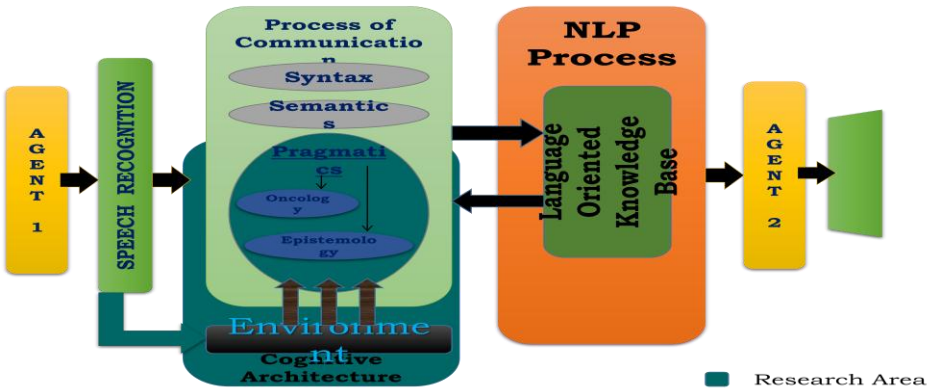

Fig 2. Conversational Agent Architecture

In the Learning Perspective, Imitation and reinforcement are said to play a role in early language development. The Interactionist perspective says that the language development results from a complex interplay among biological maturation, cognitive development, and an ever-changing linguistic environment that is heavily influenced by the child's attempts to communicate with her companions.

Cognitive Pragmatics:

It is a new area where knowledge is acquired from the environment and agent's belief. Cognitive pragmatics involves various mental states irrespective of the approaches be it philosophical or psychological. Currently researches on cognitive architecture focus on BDI (Belief, Desire and Intention). (5) This area is where my research will focus but with respect to communication between two perceptual agent.

Conversational psychology :

A study also suggests that 'Baby talk key to Conversational Agent' (6). Chat robots has evolved over the years from the simple conversational agent "Eliza". Professors from Osaka University has developed two models of robot named CommU and Sota which will act out programmed conversations. They say voice recognition was the most challenging part of developing a conversational agent. Robots struggle to respond due to the background noise. Thus conversational psychology is yet another area to be studied for the development of conversational agent.

Model of the Conversational Agent:

Keeping in mind the various factors that are involved in developing a Conversational Agent, I have designed a model of the Conversational Agent for communication between two perceptual agents.

My research emphasis is on the green area of 'Cognitive Pragmatics' which is developing a Conversational Agent based on Cognitive Architecture using the BDI approach.

Review of Literature:

Conversational Agents:

Conversational agents can be classified into Embodied Conversational Agents and Disembodied conversational Agents. The first conversational agent or a chat robot was disembodied. The disembodied agents are those which interact with humans through speech or text entered at a keyboard; whereas the embodied agents are those interact with humans or robots with an animated avatar (7). The challenge of embodied system is that they have to sense the human perception through facial expression, intonation, gaze direction etc. But in case of the disembodied agents the message is loud and clear and cannot be misunderstood.

Eliza – The First Chat Robot:

ELIZA was originally written by Michal Wallace and significantly enhanced by George Dunlop using Java Script. She is the oldest chat robot built in 1966. ELIZA emulates a Rogerian psychotherapist by only matching the keywords and substituting words with almost no intelligence. .(8)

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Apart from Eliza there are other chatbots like Eliza1, Eliza2, Dr. Romulon a Pandorabot, MathBot that does Math etc,. There is also a very interesting chatbot know as 'Chato' which also seems to be very intelligent. It uses

AIML(Artificial Intelligence Mark up Language) and PHP. Below is the chat I had with Chato. From Eliza to Chato we have definitely come a long way. (9)

Alicebot:

A.L.I.C.E. (Artificial Linguistic Internet Computer Entity) is an award-winning free natural language artificial intelligence chat robot. Its Alicebot engine uses AIML. One of its versions the Superbot was first released in the year 2005 consisting of over 120,000 patterns and responses. A mobile version is also available today for download. (10)

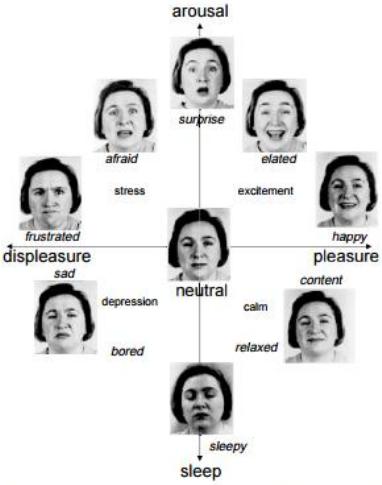
Rea:

Rea is a life-size animated humanoid robot that can understand the conversations of the human standing in front of it using computer vision techniques. It observes their speech and behaviour and responds with appropriate speech, animated hand gestures, body movements, and facial expressions. The architecture for this new "conversationally intelligent" agent is based on an analysis of conversational functions, allowing the system to exploit users' natural speech, gesture and head movement in the input to organize conversation, and to respond with automatically generated verbal and nonverbal behaviours of its own. REA is one of the embodied conversational agents and is very close to conversational agents built using cognitive architectures. (7)

Several versions of chatbox from CHATBOX1 to CHATBOX14 is available online as open source. But it uses database to store sentences and various searching techniques to process. (11)

Kismet and the sociable machines project:

The Sociable Machines Project develops an expressive anthropomorphic robot called Kismet that engages people in natural and expressive face-to-face interaction. KISMET is inspired by infant social development, psychology, ethology, and theory of evolution. Kismet uses visual and auditory channels to perceive and learn from human conversations. The expressions are mechanized using the theory of psychology that claims facial expressions have a systematic, coherent, and meaningful structure that can be mapped to affective dimensions. (12)



Russell's pleasure-arousal space for facial expression. Adapted from Russell (1997).

Fig 3. Rusell's facial expression

Some of the other researches carried out currently on conversational agents at MIT are: (13)

Other Conversational Agents:

- Affective Intelligent Driving Agent: AIDA is a robotic driver-vehicle interface that acts as a sociable partner and elicits facial expressions and strong non-verbal cues for engaging social interaction with the driver.
- DragonBot: Android Phone Robots for Long-Term HRI: DragonBot is a new platform built to support long-term interactions between children and robots. The robot runs entirely on an Android cell phone with an animated virtual face.
- Global Literacy Tablets: They are systems of early literacy apps, games, toys, and robots that will help children in learning using a mentoring algorithm that recommends an appropriate activity given a child's progress. This is the future of education.

Apart from building conversational agents, our focus is also on perception with respect to beliefs and goals of the conversing agent. Some of the researches in this area are;

- Mind-Theoretic Planning for Robots: MTP is a technique for robots to plan in social domains; here the system takes into account the initial beliefs and goals of people in the environment that are relevant to the task, and creates a prediction of how they will rationally act on their beliefs to achieve their goals.
- Robot Learning from Human-Generated Rewards: This research group develops robots that empower humans by interactively learning from

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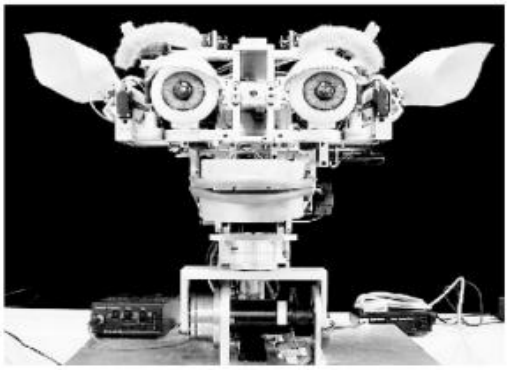

Kismet, sociable robot

Fig 4. Kismet Robot

- them. Interactive learning methods enable technically unskilled end-users to correct behaviour. This communication improves the robot's performance.

- Robotic Language Learning Companions: These systems help children in interactive language learning and focuses on social nonverbal behaviour.

Many such robots are currently being developed to act as companions both for children and elderly. Now our focus shifts from building a simple conversational agent to building conversational agents using cognitive architecture that supports learning through perception and belief and are also goal driven.

COGNITIVE ARCHITECTURE:

Cognitive architectures play a vital role in providing blueprints for building future intelligent systems that thinks and acts like humans. Cognitive architectures are built on the bases of the agent's beliefs, its goals and the knowledge it had acquired over the period. It acquires knowledge of the environment through perception and the knowledge about implications of the current situation through planning, reasoning. Cognitive architectures have a performance mechanism that utilize the acquired knowledge and the learning mechanisms that alter them. Other capabilities of a cognitive agent are decision making and problem solving. Thus an agent is build using a cognitive architecture and is said to be efficient if it can replace a human in a given environment. Communication is also an effective way for an agent to obtain knowledge is from another agent. Such agents are known as collaborative agents. Agents that uses cognitive architecture to converse with humans or other agents are cognitive conversational agents. Before discussing the criteria for building such agents, let us list out the available cognitive architectures.

- ACT-R: ACT-R stands for Adaptive Control of Thought Rational, or alternatively Atomic Components of Thought – Rational. In the Adaptive Character of Thought (ACT-R) theory, complex cognition arises from an interaction of procedural and declarative knowledge. Procedural knowledge is represented in units called production rules, and declarative knowledge is represented in units called chunks. The individual units are created by simple encodings of objects in the environment known as chunks or simple encodings of transformations in the environment known as production rules. ACT-R claims that in these large database comprising such knowledge and deployment of such knowledge underlie the human cognition. (13)
- SOAR (State Operator And Result): SOAR cognitive architecture is based on the computational theory of human cognition. SOAR was introduced by Allen Newell, John Laird and Paul Rosen bloom in 1980. SOAR is well organized to produce a general intelligence. SOAR is considered as a symbolic artificial intelligence mechanism for understanding and simulating human mind. SOAR cognitive model exhibits flexible and goal driven behaviour. The knowledge of the model is continuously enhanced by learning. SOAR cognitive architecture is an example of software as theorem for models of mind unification. In this theorem, cognitive capabilities like stimulus and response (perception); memory and learning; problem solving; and language capabilities are unified. Unification is an aim of the science to demonstrate cognitive capabilities. The major areas covered by unified theory of cognition are given below: perception, memory, problem solving, decision making, routine action, learning, language, motivations, emotion, motor behaviour, imaging, and dreaming. (13)
- CRIBB:(Children Reasoning about Intentions, Beliefs and Behaviour) was designed to investigate the belief-desire reasoning model in young children. CRIBB is given a proposition; a belief is inferred from it. The consistency of the belief is checked with the existing set of beliefs, and if no contradiction is found, then added to the belief set. Primary representations are the system's own beliefs about the situation and, behaviour of person and the others facts about a physical world. The secondary representations are the systems beliefs about mental states. This includes another person's perceptions, beliefs and intentions. This model states that a person's actions can be explained by his beliefs and desires, where beliefs can be derived from perceptions and previously held beliefs. CRIBB's theory of mind includes some commonsense schema that is essential for solving experimental tasks. (14)
- CogAff: CogAff is a generic cognitive architecture, and introduced by Sloman. The main aim of the cognition and affect architecture is to understand the different types of architectures based on human and nonhuman (minds) mental states, such as intelligent capabilities, moods, emotions, beliefs, thoughts, and desires. The Cognition and Affect project is concerned with understanding mechanisms of emotions, and to fit for cognitive models. Reactive layer includes a global alarm mechanism, which belongs to primary emotions. The deliberative layer supports for secondary emotions. Secondary emotions are semantically rich emotions. This layer is responsible for perception,

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planning, evaluation, allocation of resources, and decision making. This layer can learn the generalizations, and pass to the other layers. The meta management layer or reflective layer supervises, and controls the other layers of architecture, more efficiently. Sloman describes that; this layer can support and control the thoughts. (15)

- EM-ONE architecture originated from Marvin Minsky"s "emotion machine" architecture. EM-ONE architecture was proposed by Minsky and his student Singh in 2005. According to Singh, EM-ONE architecture is an example for its predecessors Minsky and Sloman, and hence he called Minsky-Sloman Architecture. Main goal of EM-ONE cognitive architecture is to support human-level intelligence in systems. According to Singh his architecture refers to the "structure and arrangement of commonsense knowledge and processes". EM-ONE architecture for commonsense computing, that is capable of reflective reasoning about situations involving physical, social, and mental dimensions. EM-ONE architecture involves complex interactions among the several "actors" along with physical, social, and mental dimensions. (16)
- CAMAL: (Computational Architectures for Motivation, Affect & Learning) architecture was proposed by Davis from the University of Hull. CAMAL cognitive architecture attempting to demonstrate some theoretical; and design issues associated with, linking perception and action through motivation and affect mechanism. CAMAL uses a logical model of reasoning based on Beliefs, Desires, Intentions that mirrors the motivation and learning. The BDI model intentions are adopted plans or strategies for achieving desires. The adoption of specific plans converts desires into achieved intended desires. (17)
- SMCA: (Society of Mind approach to Cognitive Architecture) makes use of a generic architecture, and developed in terms of generic cognitive and metacognitive agent types. Each agent is designed to fit one of the following categories: reflexive agents, reactive agents, deliberative (BDI models) agents, learning, metacontrol and metacognitive agents. (18)

There are only a very few cognitive architectures build for communication interms of conversation. Some of them are: (19)

- NARS (Non-Axiomatic Reasoning System): It is a reasoning system based on a language for knowledge representation, an experience-grounded semantics of the language, a set of inference rules, a memory structure, and a control mechanism, carrying out various highlevel cognitive tasks as different aspects of the same underlying process. The non-axiomatic logic is used for adaptation with insufficient knowledge and resources, operating on patterns that have the "truth-value" evaluated according to the system's "experience" with using these patterns. This approach allows for emergence of experience-grounded semantics, and inferences defined on judgments. While several working NARS prototypes of increasing complexity have been built they are solving only rather simple problems. (20)
- SNePS (Semantic Network Processing System) is a logic, frame and network-based knowledge representation, reasoning, and acting system that went through over three decades of development. It stores knowledge and beliefs of some agent in form of assertions (propositions) about various entities. Each knowledge representation has its own inference scheme, logic formula, frame slots and network path, integrated in SNIP, the SNePS Inference Package. When a belief revision system discovers contradiction some hypotheses that led to the contradiction have to be unasserted by the user and the system removes all those assertions that depend on it. The SNePS Rational Engine controls plans and sequences of actions using frames and believing/disbelieving propositions. The natural language processing system works with English morphological analyzer/synthesizer and generalized augmented transition network grammar interpreter. SNePS has been used for commonsense reasoning, natural language understanding and generation, contextual vocabulary acquisition, control of simulated cognitive agent that is able to chat with the users, question/answer system and other applications. Interesting inferences have been demonstrated, but the program has not yet been used in a large-scale real application, for example a chatterbot. (21)

Other Cognitive Architectures built for specific tasks are: (22)

- EPIC (*Executive Process Interactive Control*) is a cognitive architecture for building computational models that subsume many aspects of human performance.
- ICARUS project defines an integrated cognitive architecture for physical agents, with knowledge specified in the form of reactive skills, each denoting goal-relevant reactions to a class of problems.
- *EPA (Emergent Paradigm Architecture):* Emergent cognitive architectures are inspired by connectionist ideas.
- IBCA (*Integrated Biologically-based Cognitive Architecture*) is a large-scale emergent architecture that epitomizes the automatic and distributed notions of information processing in the brain
- Cortronics is a new emergent architecture that models the biological functions of the cerebral cortex and thalamus systems (jointly termed thalamocortex) in the human brain.
- NuPIC (*Numenta Platform for Intelligent Computing*) is an emergent architecture based on the Hierarchical Temporal Memory (HTM) technology
- NOMAD (Neurally Organized Mobile Adaptive Device) automata are based on "neural Darwinism" theory. Nomads, also known as Darwin automata,

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demonstrate the principles of emergent architectures for pattern recognition task in real time.

- CLARION (The *Connectionist Learning Adaptive Rule Induction ON-line*) is a hybrid architecture that incorporates a distinction between explicit (symbolic) and implicit (sub-symbolic) processes.
- LIDA (The *Learning Intelligent Distribution Agent*) is a conceptual and computational framework for intelligent, autonomous, "conscious" software agent that implements some ideas of the global workspace
- DUAL architecture has been inspired by Minsky's "Society of Mind" theory of computation, with a unified description of mental representation, memory structures, and processing mechanisms carried out by small interacting micro-agents.

Methodology:

The focus of my research will be building a architecture for cognitive conversational agent. Once the architecture is built, knowledge base will be created. Formulation of a structured conversational agent based on cognitive pragmatics will be created with the cognitive parameters as follows:

- cognition. It is a hybrid, multi-agent general-purpose architecture supporting dynamic emergent

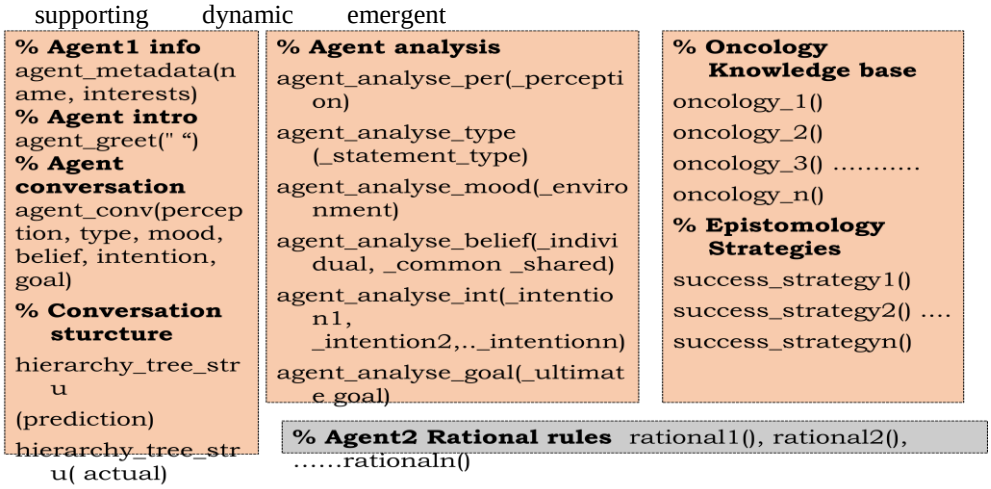

Fig 5. Conversational Speech Act

In the above algorithms, the type of conversation will be standardized based on the research termed as Computational Speech Act. (24)

STATEMENT	*Me, I'm in the legal department.*
BACKCHANNEL/ACKNOWLEDGE	*Uh-huh.*
OPINION	*I think it's great.*
ABANDONED OR TURN-EXIT	*So, -*
AGREEMENT/ACCEPT	*That's exactly it.*
APPRECIATION	*I can imagine.*
YES-NO-QUESTION	*Do you have to have any special training?*
NON-VERBAL	*[Laughter], [Throat_clearing]*
YES ANSWERS	*Yes.*
CONVENTIONAL-CLOSING	*Well, it's been nice talking to you.*
WH-QUESTION	*Well, how old are you?*
NO ANSWERS	*No.*
RESPONSE ACKNOWLEDGEMENT	*Oh, okay.*

Fig.6 Computational Speech Act

CONCLUSION:

Cognitive science research is highly interdisciplinary combining disciplines such as philosophy, psychology, Artificial intelligence, neuroscience, linguistics, and anthropology. Scientists in this field attempt to build computational models of human cognitive behaviour in order to combine and verify the findings of the different disciplines. Emotions are increasingly seen as an important component of cognitive systems of humans as well as humanoids. With advances in computational linguistics, well-engineered conversational agents have begun to play an increasingly important role in the enterprise. By taking advantage of highly effective parsing, semantic analysis, and dialog management technologies, conversational agents clearly communicate with users to provide timely information that helps them solve their problems.

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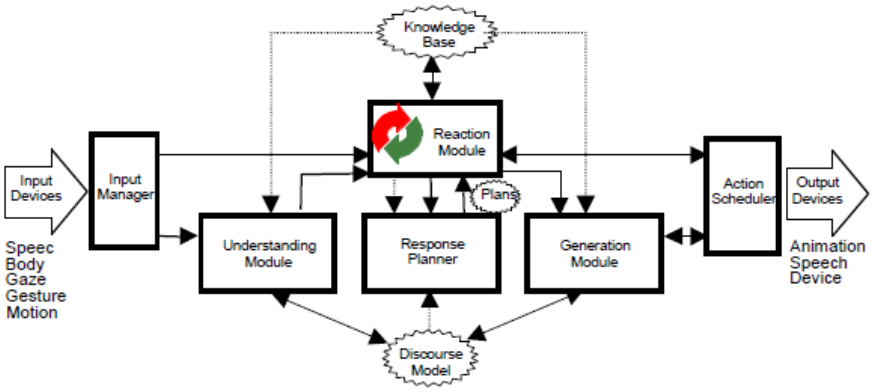

Fig. Conversational Agent. (23)

By making use of the agent's BDI-based reasoning, emotions must be incorporated into the conversational agents. Thus cognitive conversational agents are built, keeping in mind the mechanism to develop an effective conversational agent together with the cognitive concepts such as perception, decision making, reasoning, etc. New cognitive conversational agent architecture will be proposed with the above discussed cognitive architecture principles.

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