ISSN 2278 - 3091

International Journal of Advanced Trends in Computer Science and Engineering (IJATCSE), Vol.2 , No.5, Pages : 51-54 (2013)
Special Issue of ICETCSE 2013 - Held during October 21, 2013,Mysore, India

Evolving a Common Language for Co-Operative Tasks

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Abstract*:* Language is used for co-existence and evolution. Human evolution truly increased its pace once humans were able to communicate with each other. The power of speech is what sets us apart from animals and make us truly intelligent, with these communication paradigms robots can communicate with themselves and with us more effectively. This will allow them to perform cooperative tasks in a way similar to humans; by planning and deciding what are the best actions required to complete the task. Computers require shared lexicon to communicate among themselves. This lexicon will interpret their view of the world.

Key words: language learning; intelligent robots; communication in robots; language games;

INTRODUCTION

Communication occurs when two agents (people, computers, animals etc.) use symbols (verbal or non-verbal) to explain to each other things that are happening in their environment. Languages are formed when a group of agents decide on particular symbols to be used to communicate. Languages evolve themselves through interactions between these agents

For effective communication agents need to be able to say words that have approximately the same meanings between communicating agents. Each communicating agent can produce certain symbols (like sounds a human can make). When these, agents combine these syllables together they make words. These words indicate things in the agent's environment. However these words might not mean the same thing to all the agents. For effective communication these symbols need to be grounded to mean the same thing. But as new things happen in the environment the symbols might mean different things or even be perceived differently by certain agents. This is known as the symbol grounding problem.[1] Attempts to solve the symbol grounding problem have usually been represented as Language Games. These language games involve communication between agents to allow them to learn new words and associate meanings to word. Proper communication, a feedback system etc. [2]
The proposed approach suggests a new form of language games, concerning language formation for cooperation. For robots to be able to perform cooperative tasks they need to be able to communicate with each other.

Most language games attempt to solve the symbol grounding problem through naming objects. We believe that robots might not only benefit from being able to talk about objects in their environment but also about the things they are doing.

If robots make a particular motion or want a particular motion made they might communicate this to another robot. This second robot has to be able to understand the first robot's command and take appropriate action. Working together the robots can communicate and cooperate effectively.

The languages hence formed will not be complex or extremely evolutionary however they will provide a tight framework within which the robots can work together for cooperative tasks.

RELATED WORK

L.Steels in 1995 invested a guessing game in which two robots try to achieve shared attention and guess features of objects. They build a shared vocabulary by trying to talk about objects once each other is focused on the same object. An example of this is implemented in The Talking Heads Experiment. [5] Talking Heads was an experiment both in computer vision and cognitive programming. They were attempting to study the evolution of a shared lexicon. The robots evolved their vocabulary by observing a scene and communicating what they saw to each other.

The lingodroids [6] develop their own language and perform spatial memory mapping using a shared lexicon. They are put in a particular area and develop a name for the area through sharing words. Every time they find themselves in a new space they invent a word for it. This allows them to map the space around them using this new shared lexicon. Thus cooperation was obtained via the shared lexicon.

In a naming game (K.Stadler et. al 2012) [7] agents engage in local interactions where one of the agents who is the speaker, tries to draw the attention of other agents (listeners) to an object in the surroundings by uttering a word. The agent fails the game if he does not understand the word the speaker said. However they both update their lexicons for future naming games, gradually learning the language.

PROPOSED SYSTEM

The idea is to prove that agents are capable of performing better cooperative tasks when using a communicating language. The proposed approach is a language game to test the amount of cooperation they can possibly achieve. For the purposes of achieving proper communication the robots will have a limited set of possible actions. These atomic actions will be combined to give rise to more complex action sequences as the language evolves. Thus as the language evolves, the agents will be able to perform more complex tasks with fewer utterances.

The agent's vocabulary will be limited to the task at hand. The communication will be limited to describing actions that he/she wishes to perform. However the actions will be

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decided at runtime and the complexity of these actions will progressively increase. This will eventually allow the robots to plan for the entire task at hand before executing.

The proposed approach focuses on the communication of robots under specific conditions, and attempts to evolve a language which can aid their cooperation.

The Cooperation Game

In the proposed system a language game is build which provides a framework for learning and the co-evolution of a language. This game is a divided into rounds such that each round provides a specific purpose.

The basic game requires a task to be completed that requires actions from both agents. The agents have a limited set of actions they can perform. As these actions may not be identical in both agents a learning round is required so the agents can become familiar with the actions of its counterpart.

Learning Rounds

Learning Rounds are before the actual task. In a learning round one agent performs a series of actions. Each of these are the basic atomic actions that that agent can perform. The other agent then will know these motions in the future games.

After the learning round, the agents are made to play several test rounds to attempt to communicate efficiently. As they play they continue to learn, through co-evolution and reinforced learning.

CA				
	CA	NCA		

Fig 1: NCA Wins: Communication Not Achieved

	CA			
	CA	NCA		

Fig 2: CA Wins: Communication Successful

Game Rounds

Types of Agents:

Communicating Agents (CA) - Can Communicate and need to cooperate to win

Non-Communicating Agents (NCA) - Cannot communicate but can attack and can win on their own.

Conditions for Victory

1. If a CA and a NCA are on adjacent squares the NCA defeats the CA and the CA dies.
2. However, if two good robots are on squares adjacent to a NCA, the CAs win and the NCA dies.

Game Rules

The game is won when either all the CAs or all the NCAs are dead.

In order for them to win the CAs must communicate and decide when to attack in unison. Only when the CAs are sure another CA will attack then they should proceed. To know this they must be able to communicate effectively.

GENERAL ARCHITECTURE OF A SOLUTION

Words

Words consist of syllables. There are a predefined set of syllables that the bot can use. These syllables are combined together to find combinatorial words. These are the basic words which are defined for any action. [8]

Sentences

Sentences in the language have a rigid grammatical structure and are used to describe the situation. The sentence consists in the following structure.

<character> <expected-action>

<character>: Refers to the character being described in the sentence. This character may be a good or bad bot. It may even refer to the speaking bot itself.

<expected-action>: Refers to the action the bot wishes to be performed by the aforementioned character.

These sentences are kept with strict grammar to allow for more comprehension within the domain. Though there may be some merit to keeping a grammar fluid, we feel within the paradigm of any one task a strict grammar may lead to better communication.

Fig 3 shows there are two entities Speaker and Listener. Both have a set of task associated with it. Both can interact in a common world. The speaker communicates to the listener in the following way

1. The speaker perceives the world and chooses appropriate words as follows

The speaker wants a certain action to be completed. It looks up its lexicon for words that correspond to that particular action. There are 2 ways by which the speaker can decide on the word to choose.

a. Most Common Word: of all the words the agent knows for the intended action, it deterministically selects the one with the highest frequency, i.e. the one that the agent has most often seen being used for the topic by other speakers in previous interactions.

b. Most Efficient Word: by the principle of least effort [10] the speaker will speak the word with the least number of syllables.

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After the speaker speaks, it looks to the intended listener. If the listener does not perform the correct action it lowers the probability of that word being right. Otherwise it increases it.

2. Listening to what the speaker said the listener reacts as follows
When the listener hears a particular word, he looks up that word in his dictionary
If there is an action corresponding to that word with a sufficiently high probability then the agent executes that action. If no action has been decided the agent assumes an action based on the heuristic to complete the task. This is added to the lexicon with an extremely low probability. NOTE: This may not necessarily be the correct action. However over time the heuristic assures that the agent will assume the correct action.

3. Evolving Complexity of the language:
Once all action sequences are defined with a high enough probability the agents start creating words for new actions sequences (combinations of the previous actions). Eventually over time the language increases in complexity and the agents are able to perform extremely complex actions.

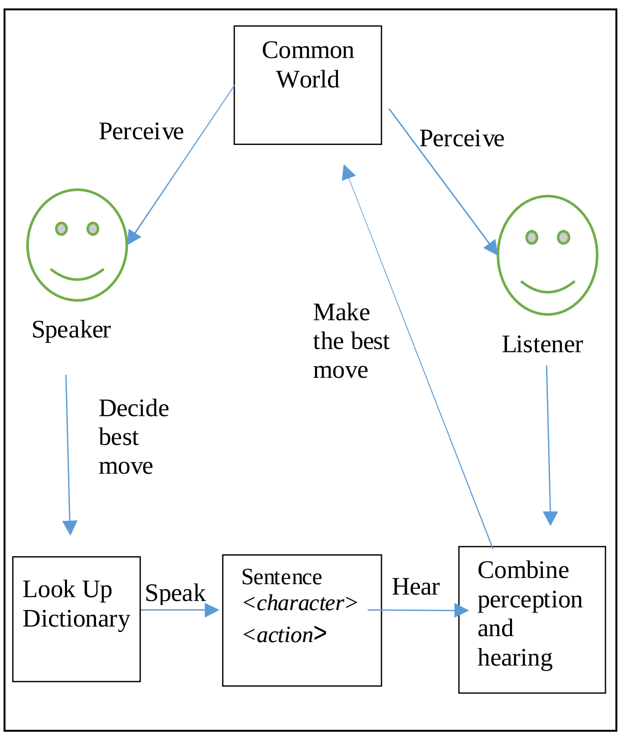

Fig 3: Flow diagram of the game semantics(proposed system)

RESULTS

A simulation was run in basic Java language of the language game described above and the results were tabulated.

No. Of Actions: The basic number of actions each bot in the game had

Threshold: The confidence at which all the words is considered to have been learnt

Learning Rate: The rate of change of confidence about words the agents are learning.

Iterations: The average number of iterations before which the agents gained confidence equivalent to the threshold for every action.

Table 1: Table of Results

No. Of Actions	Learning Rate	Threshold	Iterations
4	0.1	2	343
4	0.1	6	643
4	0.1	20	1785
4	0.1	50	4250
4	0.1	200	16617

RESULT ANALYSIS

From the small experiment performed and results analyzed as displayed in Table 1, it was seen that the agents do converge on a common language. It is also evident from Table 1, that with an increase in the threshold, there is a corresponding increase in the number of iterations. This signifies that the number of iterations completed is directly proportional to the confidence which the robots achieve in using the language.

LIMITATIONS

1. The set of actions are limited to the actions the robot can perceive. This deterministic approach to word building would fail in a world with innumerable actions.
2. The agents only have knowledge about each other and cannot talk about the world around them. To be able to truly communicate they need to also be able to talk about their world.

CONCLUSION

Tasks may not only be defined as a series of actions. Thus to be truly flexible and to be able to perform any task, the language needs to describe any task completely. To do so it would require further development of the syntax of the language.
Also this is a very simple concept and only applies to certain cooperative tasks. A substantial amount of work is required to expand it to a real world application. The idea of robot communication is in its infancy and the field needs to be fully developed before the robots can truly communicate in their own language.

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