Exploring Conceptual Space in Language Games Using Hedonic Functions

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Abstract

The ambiguity of natural language can be an important source of creative concepts. In compositional languages, a many-to-many network of associations exists linking concepts by the polysemy and synonymy of utterances. This network allows utterances to represent the combination of concepts, forming new and potentially interesting compound meanings. At the same time, new experiences of external and internal contexts provide abundant materials for the evolution of language. This paper focuses on exploring the role of compositional language for social creativity through the simulation of language games running on multi-agent systems using a hedonic function to evaluate the interest of utterances as design requirements and the resulting design works.

Introduction

A single word may be associated with multiple meanings while one meaning can be represented by multiple words. Such ambiguity of polysemy and synonymy can be a source of creative inspiration, allowing the exploration of conceptual spaces by traversing the many-to-many mappings between words and meanings. Many-to-many mappings between utterances not only construct connections between seemingly unrelated concepts, but also provide more opportunities to recombine sub-utterances to new utterances representing novel meanings.

The function of the ambiguity of language for social creativity can be explored through the use of language games combined with multi-agent simulation. In the *guessing game* (Steels, 1995), a speaker-agent describes an object using an *utterance* to a listener-agent who attempts to identify the *topic* of the utterance based on its experience of previous utterances and the current context. By repeating the guessing game for many generations, a simple language, grounded in use, may evolve (Steels, 1995).

In the *generation game* (Saunders and Grace, 2008), agents that were previously speakers or listeners in a guessing game, explore a conceptual space using communication between client-agent and designer-agents. A requirement is expressed as an utterance by a client-agent and may be related with various meanings by multiple designer-agents that have different experiences of similar utterances. The creativity of communication primarily depends on client-agent generating an “interesting” requirement and selecting “interesting” design works produced by designer-agents in response. The evaluation of interest can be modelled using a hedonic function, e.g., the Wundt Curve (see Figure 1), where similar but different perceptual experiences are preferred (Saunders, 2009).

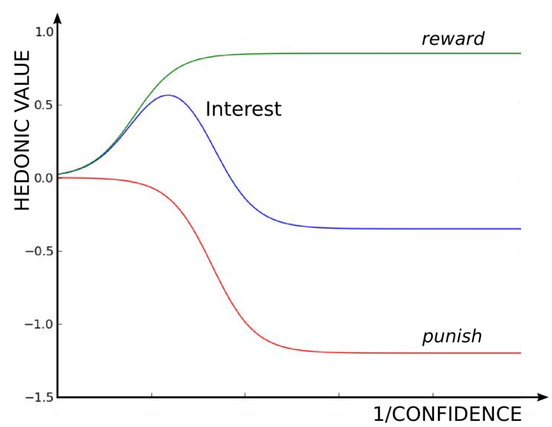

Figure 1. The Wundt Curve, a hedonic function for evaluating interest based on agents' confidence

Methods

The language games used in the simulations described in this paper produce utterances as a result of a compositional language. Compositional languages, as opposed to holistic languages, permit utterances to be composed using multiple words. Composition can be utilized to generate new utterances denoting valuable concepts. For example, given the previous utterances RED SQUARE, RED TRIANGLE and BLUE TRIANGLE, new utterances such as BLUE SQUARE may be generated by recombining the evolved sub-utterances BLUE and SQUARE.

The agents in the simulation use Adaptive Resonance Theory (ART) networks to categorize utterances and concepts. ART networks are both stable and dynamic, they can not only retain existing categories but also add new categories for unfamiliar inputs which exceed the threshold of recognition of ART system (Saunders, 2002).

Experiment

The experiment focuses on exploring the combination of existing utterances generating new utterances representing interesting meanings through the communication between agents who play the roles of speaker and listener in guessing game as well as client and designer in generation game.

Experiment Settings

1. Initial settings

The first set of experiments were initialized with 50 samples randomly selected from 121 objects, which were generated by combining 11 colors and 11 shapes. Each of the shapes is represented by a list, e.g., [0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0]. The population of agents is 6. The language game uses one combination rule combining two features including color and shape; and each feature is represented by one letter as its name. So the length of utterance is limited to 2. For example, {color:0.2, shape:0.3}'s utterance may be "ha".

2. Guessing game settings

In the guessing game, 8 topics are selected randomly from the samples available for each exchange between speaker and listener, selected among 6 agents randomly. When the success rate (see Equation (1)) is above 60%, the guessing game is finished and generation game is started.

$$rate_{success} = times_{success} / (times_{success} + times_{failure}) \qquad \mathbf{(1)}$$

3. Generation game settings

In the generation game, four types of procedures with or without evaluation of the interest of requirements (utterances) or works using The Wundt Curve (Figure 1) are implemented. Each design cycle is repeated 1000 times. Every time, the last agent always plays the role of client while others play the role of designers.

Experiment Procedures

Procedure 1. Guessing game

The following guessing game is implemented repeatedly till success rate reaches 60%.

1. The speaker selects one topic randomly from randomly generated context.
2. The speaker generates an utterance representing the selected topic and tells listener.
3. The listener guesses the topic by exploring its existing associations between utterances and the ART categories. If an appropriate association cannot be found, a new association between the utterance and the topic in current context is generated. Then listener tells the speaker its guess.
4. If successful, both speaker and listener increase the weight of their association between the topic's ART category and the utterance and increase the frequency of each related instance or generate a new association connecting the selected topic with the utterance. Otherwise, if guessing failed, the listener decreases the weight of the related association and generates a new association between the topic's ART category and the utterance, then increases the weight of the newly generated association and generates a new association connecting the correct topic and the utterance.

After completing the guessing game, the agents (Group A) are cloned three times to get three new groups of agents (Group B, Group C and Group D) to implement different procedures for the generation game.

Procedure 2. Generation game without evaluation of interest

The generation game is implemented for 1000 generations by Group A without evaluating the interest of requirements and works.

1. Each designer-agent generates a set of design works (topic) by searching existing associations or generating a new association connecting related an ART category with client-agent's requirement (utterance).
2. A client-agent generates an utterance by combining two randomly selected names of each feature's ART category (prototype) without evaluation.
3. The client-agent selects the most similar design works compared with its requirement-associated topic. But if the most similar works did not belong to the same ART category of client-agent's associated topic, game fails; and all designer-agents decrease the weights of their own selected associations. Otherwise, client-agent finds its own relevant association or generates a new association connecting its own ART category of the selected design works and the utterance, then increases the weight of the association and increases the frequency of related instance or generates new instance connecting the works and the utterance. At the same time successful designer-agents increase the weight of related rule and increase the frequency of related instance or generate a new instance while other designer-agents decrease the weights of related associations.

Procedure 3. Generation game with evaluation of works interest

The generation game is implemented for 1000 generations by Group B. The procedure is the same as Procedure 2 except that the client-agent selects design works using the Wundt Curve. In the process of selecting design works, the distances between each design works' features and client-agent's original topic's features are first measured, then their hedonic value is evaluated. The design works with the highest interest are selected by client-agent. If all interests were negative, the generation game fails.

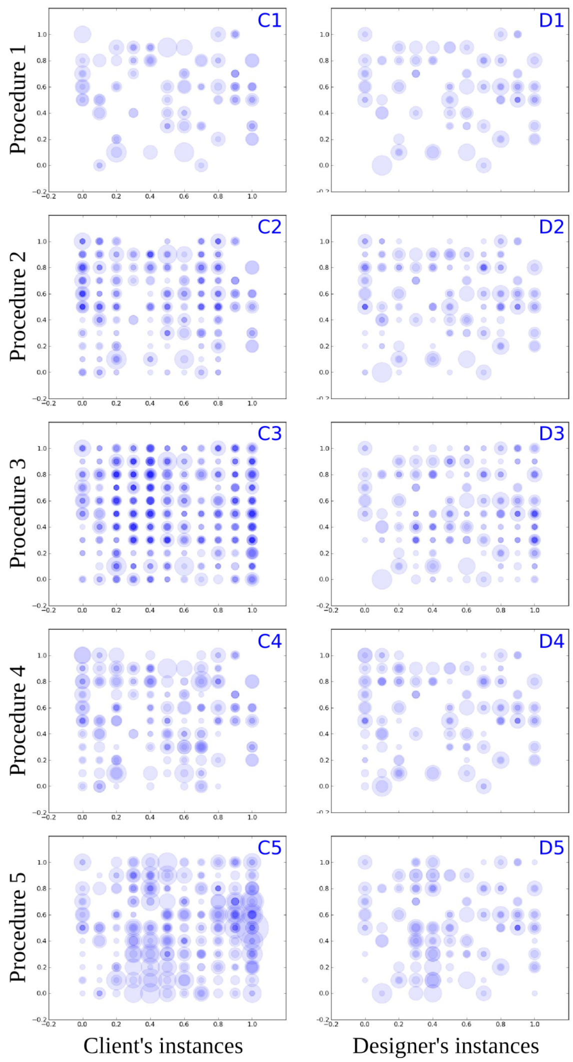

Figure 2. An example of the distributions of agents' instances

Procedure 4. Generation game with evaluation of requirements interest

The generation game is implemented for 1000 generations by Group C. Each time, the procedure is the same as Procedure 2 except that client-agent generates several requirements (utterances) and select the most interesting one. Firstly, the weight of each single utterance in every requirement is calculated by summing the frequencies of the utterance used in all instances. Then the interest values of these requirements are calculated by summing the interests of their own utterances. Finally, the requirement with the highest interest is selected.

Procedure 5. Generation game with evaluation of both requirements interest and works interest

The generation game is implemented for 1000 generations by Group D. In each generation game, the procedure is the same as Procedure 2 except for the generation of interesting requirements and the selection of interesting design works by client-agent. The process of generating interesting utterance is the same as Procedure 4. The process of selecting interesting design works is the same as Procedure 3.

Results

In Figure 2, the radius of each circle represents the frequency of an instance used by an agent. If a topic is associated with more than one utterance, several circles will be drawn at the same place resulting in a darker color.

The results of the experiments show that agents explored a greater number of new topics and generated more instances (the associations between topics and utterances) when the client-agent used the Wundt Curve only for selecting interesting design works, see Figure 2(C3). But the frequency differences between the instances are not distinctive compared with when client-agent utilized the Wundt Curve not only for selecting interesting works, but also for generating interesting requirements, see Figure 2(C5). This suggests that the client-agent preferred using a small set of interesting utterances frequently. Hence, the frequency-distribution of instances is nonuniform. This is similar as the signature of life with uneven frequency distribution comparing Figure 2(C5) with Figure 2(C3).

The number of designer-agent's instances are less than that of client-agent's instances, see Figure 2(C2–D5) except that generated in guessing game, see Figure 2(C1,D1) because only one designer-agent's works could be accepted by the client-agent in the most successful interactions while other designer-agents had no opportunities of updating their instances, but the client-agent can update its instances almost every successful time in generation game.

The average number of instances generated by client-agent and that by designer-agents in a generation game are shown in Figure 3. When only using the Wundt Curve to assess the interest of design works, the number of instances increased sharply especially for client-agent. However, when using the Wundt Curve to evaluate not only the interest of design works, but also that of utterances, the number of instances decreases even below that of instances generated without evaluation of interest except the average number of designer's instances generated in Procedure 5, which is slightly higher than that in Procedure 2 but still lower than that in Procedure 3.

The average max degree of the graph networks of instances generated by client-agent and designer-agents respectively are illustrated in Figure 4. As can be seen, the highest average max degree belongs to the instances generated using the Wundt Curve selecting both interesting requirements and interesting works. The average max degree related with the evaluation of only requirements are higher than that of only woks. Therefore, the evaluation of the interest of utterance may be more important than that of works.

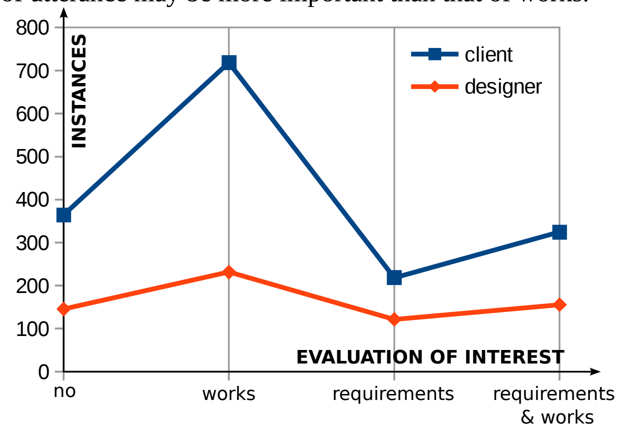

Figure 3. The average number of agents' instances generated with or without evaluation of interest in generation games

Discussion

Based on the results of the simulations, client requirements may be more important than designer's works because the final pattern of the distribution of utterances and design works are primarily determined by the client-agent rather than the designer-agents. "Interesting" requirements narrow the combination area of utterances initially generated via crossover of two randomly selected utterances, resulting into the selection of interesting artifacts.

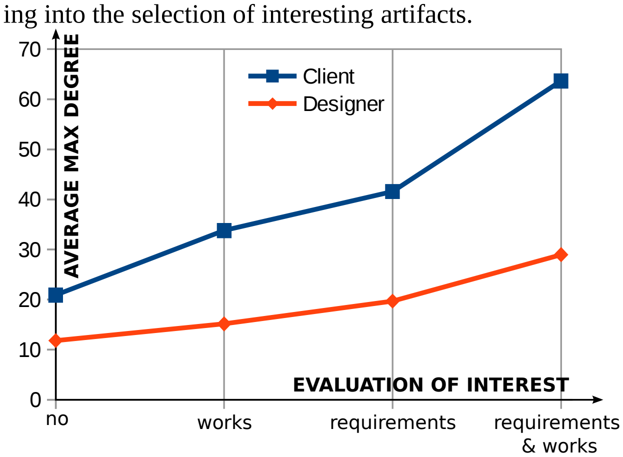

Figure 4. The average max degree of the graph networks of agents' instances generated with or without evaluation of interest in generation games

According to the illustrations of both Figure 3 and Figure 4, "less is more" is realized as less instances and more connections. In other words, many meanings may be associated with one utterance while the total number of utterances can be relatively small when using a hedonic function to select randomly combined utterances. Consequently, more connections may lead to discovering more new concepts.

Therefore, the procedures of language games described in this paper could be adopted in brainstorming by both clients and designers evolving original requirements and novel concepts. The combination of guessing game and generation game can also be utilized in artificial collaborative system to handle the evolution of compositional language for creative design.

Conclusions

The results of the simulations suggest the following conclusions:

1. Using a hedonic function to evaluate the interest of utterances affects the direction for exploring conceptual space.
2. The ambiguity of language especially caused by polysemy may play an important role in creative communication by using compositional language.
3. Client-demand driven design may be more important than content driven design in social creative systems.

Future work

Graph theory has been used in this paper for evaluating the degree of connections between utterances and meanings. Other graph-theoretic functions (Hagberg, Swart, and S Chult 2008) such as density, diameter related with the evaluation of social creativity will be explored.

Language games based on Fuzzy sets have been implemented in our most recent experiments. So, the simulations using Fuzzy sets to represent vague and ambiguous concepts will be studied in near future.

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