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Leveraging IEC and Others' Viewpoints Presentation to Foster Breeding of Creative IoT Gadgets

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Abstract: This paper proposes a MESH blocks based creative thinking support system equipped with others' viewpoints presentation feature. The recent hype around digital transformation (DX) fueled a growing sense of expectation for innovation, which requires flexible thinking and rich creativity. On the other hand, others' viewpoints are believed to hold clues for discovering new insights. Therefore, the present study aims at catalyzing creativity through adaptive presentation of context relevant viewpoints from others, as hints for idea breeding. Experimental evaluation results confirmed that the system was able to promote acquisition of new ideas which users did not have beforehand. In addition, we found that the system was able to generate MESH programs that subjects could not have come up with on their own.

Keywords: Creative thinking support system, Perspective-taking, STEAM education, IEC

1. Introduction

In recent years, digital transformation (DX) has been increasingly expected to change people's lives for the better. DX requires innovation, which demands originality based on sensitivity and intelligence, as well as creative thinking to generate many ideas. However, there is a limit to how many ideas one person can come up with instantly when prompted with a task. One solution for this problem is to help people generate ideas by acquiring others' viewpoints, which could raise awareness on different way of seeing and feeling things. The acquisition of others' viewpoints can be a clue to new insights and discoveries and is expected to be effective in supporting insight into ideas that are discarded due to differences in values (Ichikawa et al., 2008).

As one of the attempts to support people's creative thinking, idea support systems using computers (Orihara et al., 1993) have been proposed. One approach for supporting creative thinking with these systems is a so-called "interactive idea support", in which support is provided based on human evaluations (Sugiyama et al., 1991). The displayed contents and evaluation method are important for systems using this approach, and they need to be designed so that users' creativity can be fully exercised. Therefore, such approach requires the optimization of the display contents based on human sensibilities.

Interactive Evolutionary Computation (IEC) is one of the methods for creating products or artifacts that match human sensibilities through human-computer communication. IEC optimizes the system towards providing outputs that are consistent with the user's evaluation (Takagi, 2001). Research leveraging IEC-based idea generation has been conducted to achieve optimization based on user's sensitivity. As an example, an idea support system using Augmented Reality (AR) with an IEC driven optimization approach has been proposed (Furukawa et al., 2021). This system supports users' ideas through programmable IoT blocks called MESH blocks. The system displays virtual MESH programs, using AR to suggest the relevance of MESH programs and attached IoT sensors and objects. Finding relevance in things helps creating new value, hence using AR technology is considered to be effective in supporting ideation (Rosello et al.; 2016, Fuste et al., 2019).

In this study, we propose a MESH blocks based creative thinking support system which is equipped with AR technology and most importantly a context relevant others' viewpoints presentation feature. The proposed system supports new ideas creation through adaptive presentation of other users' perspectives (i.e., evaluation reasons), in addition to dynamic optimization of displayed MESH programs using interactive genetic algorithm.

2. Related Works

Creative thinking is a way of thinking that enables one to come up with new solutions from a state in which one does not have knowledge or necessary experience to solve the problem (Inaba et al., 2004). Thus, creative thinking consists of divergent thinking, which is the creation of numerous and varied ideas and flexible thinking without being bound by preconceived ideas, and convergent thinking, which is the selection of ideas that are useful for solving a problem from many and summarizing them in a deliverable fashion. That is, creative thinking is the act of seeking a better approach to a given task as a solution by viewing it from multiple perspectives and creating a variety of ideas based on flexible thinking.

Generally, acquiring others' perspectives is considered as the ability to understand how a matter is evaluated from others' standpoint, upon noticing differences between one's and others' viewpoints (Tanaka et al., 2013). For instance, in cognitive science, it has been suggested that projecting ideas of others with different viewpoints in problem solving can lead to serendipitous discoveries and creative solutions (Oehlmann, 2003; Morita, 2005). Kusunoki argue that it is necessary to create a framework for deepening one's own thinking from the viewpoint of conflicting others' ideas in cooperative learning (Kusunoki et al., 1999). In the same vein, Takeda suggests that others' viewpoints deepen creative thinking and contribute to the diversification of thinking (Takeda, 2020).

Thus, creative thinking through contact with others' viewpoints is suggested to be a trigger for making new discoveries and deepening one's own thinking.

Interactive Evolutionary Computation (IEC) is a generic term which refers to a group of optimization techniques or algorithms that uses subjective human evaluation instead of a numerical fitness function to perform search (Takagi, 2001). IEC can be seen as a computation paradigm that leverages human sensitivity to solve optimization problems where the fitness function cannot be assumed or appropriately represented in the form of a mathematical function. For instance, the use of IEC techniques has been successful in many areas, such as fashion design (Lee et al., 2001), music composition (Tokui et al., 2000), aid hearing aid fitting (Takagi et al., 2007), where optimization results should address users' preference.

In this study, we use an Interactive Genetic Algorithm (IGA), an IEC technique, which embeds human subjective evaluation into a traditional genetic algorithm. Because the user's subjectivity is reflected in the degree of solution optimization achieved by the algorithm, IGA is often used to solve problems that require sensory and intuitive human evaluation, making it ideal for the purpose of the present study.

3. Creative Thinking Support System

On the lights of the aforementioned studies, the present work aims at leveraging interactive evolutionary computation to achieve a creative thinking support system which presents relevant others' viewpoints as idea breeding hints that are optimal for users. Through the adaptive presentation of divergent perspectives or point of views from others during the idea generation process, the proposed system is expected to foster users' divergent thinking, thereby helping them come up with novel ideas that they could not have conceived on their own (i.e., convergent thinking). To this extent, we implemented an augmented reality (AR) based prototype system where users are instructed to design original MESH programs by combining visual coding and real word objects. In the next paragraphs, we provide a brief overview of the key components of the proposed system.

3.1 Creative Thinking Task

We designed a creative thinking task which enables users to follow their creativity and build gadgets using MESH blocks. MESH is a tool that allows users to realize various ideas by programming the combination of familiar objects and functions such as sensors and switches (MESH, 2021). The MESH blocks shown in Figure 1 can be easily programmed by drag-and-drop using MESH app on an iPad or Windows PC. Various conditions, including movement, brightness, and humidity, can be detected by each block. These can then be programmed in the MESH app and attached to any everyday object.

Figure 1. MESH Blocks and MESH app interface.

Figure 2. An Example of MESH Program.

In this study, physical IoT blocks such as motion sensors are called “MESH blocks”, while MESH blocks and other functions that are manipulated on the MESH app when programming are referred to as “MESH tags”. For example, in Figure 2, the MESH tags are combined and programmed on the MESH app to create a program that “waits for a few seconds when the motion sensor detects a person and then plays a sound”.

Moreover, in this study, MESH tags are classified into INPUT tags, LOGIC tags, and OUTPUT tags. INPUT tags are ones that function only as inputs to other tags, LOGIC tags are ones that function as logical operators such as “and”, “or”, and the remaining tags are classified as OUTPUT tags. Note that the use of such IoT devices is also intended to frame the present contribution in a STEAM Education context, which is an educational approach that connects problem-solving to real-world situations, thereby inspiring students’ inquiry and curiosity and promoting creativity and exploration.

3.2 Interaction Interface and Presentation of MESH Programs

To let users freely visualize and interact with objects in the AR based interaction environment, we used HoloLens2, a head mounted display developed by Microsoft (Hololens2, 2022). HoloLens2 embeds a hand tracking function which allows tracking movement of the 10 fingers of the wearer. Furthermore, HoloLens2 supports high-precision spatial recognition, allowing users to intuitively manipulate digital content by grasping it with their hands. Users can also move around in real space and use both hands freely while viewing digital information, since it is head-mounted and operates wirelessly.

To start with, based on the selected motion blocks and tags, the system generates some MESH programs that the user is required to evaluate. Then, the system optimizes the MESH programs based on the evaluation values entered by the user and generates the next generation of candidate solutions. Note that in order to achieve generation and optimization of candidate solutions, IGA, a type of evolutionary computation, is used, as explained in section 2.2. Note that since there is only one MESH block of each type, if the same MESH tag appears more than once in the generated program, it is randomly replaced with another MESH tag.

Next, individuals similar to the generated solution candidates are extracted from the database and presented to the user. The database stores MESH programs highly evaluated by other users, to which are attached the evaluation targets, as well as evaluation reasons. The evaluation targets are MESH blocks, tags, and objects that were the decisive factors for the evaluation, and the evaluation reasons are the rationale for highly evaluating a given MESH program. When extracting individuals from the database, the system extracts individuals that have not been presented to the user yet.

4. Pilot Study

4.1 Outlines

To the extent of investigating the meaningfulness of the proposed system, we carried out an experimental evaluation in which subjects were asked to refer to others’ perspectives (i.e., evaluations targets and reasons) while evaluating generated MESH programs. Participants were 12 male and female

Figure 3. Experiment Scene.

Figure 4. Evaluation Interface.

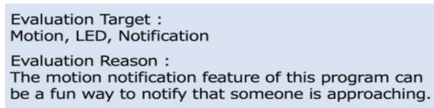


Figure 5. Example of Evaluation Reason.

students attending a Japanese university. A typical experiment scene is shown in Figure 3 and the evaluation interface is shown in Figure 4. Note that subjects are presented with others’ perspectives only after inputting a low or medium evaluation score towards the system generated MESH program. That is, if the subject evaluates the presented MESH program highly, the subject is not requested to refer to others’ perspectives. Figure 5 shows an example of evaluation reason left by another user.

Table 1 shows the questionnaire items used in the evaluation experiment. The questionnaire items were rated on a 5-point Likert scale going from agree / slightly agree / neither / slightly disagree to disagree. In addition, a free-writing section was also included so as to collect subjects’ opinions on the system.

Table 1. *Questionnaire Items.*

Number	Question
Q1	Were you able to find ideas that you didn’t have by referring to others’ viewpoints?
Q2	Do you think the proposed program broadened your thinking (i.e., divergent thinking)?
Q3	Did the system present you with programs that you might not be able to come up with on your own (i.e., convergent thinking)?

4.2 Results and Discussions

From the results of the questionnaire, we discuss whether the acquisition of others’ viewpoints using the proposed system contributed to the design of original IoT programs inspired from ideas that subjects did not have beforehand. The questionnaire results are shown in Figures 6-8.

Q1 asks whether the presentation of others’ perspectives during evaluation of various MESH programs, contributes to supporting subjects’ creative thinking. We found that 85% of the subjects answered “agree” or “slightly agree” to Q1, and the remaining 15% answered “slightly disagree”. This indicates that presenting others’ viewpoints supported subjects’ creative thinking.

Q2 and Q3 ask whether the MESH programs generated by the system contributed to prompt subjects’ divergent and convergent thinking. Here, 100% of the subjects answered, “strongly agree” or “agree” to Q2, and 92% answered “strongly agree” or “agree” to Q3, while 8% answered “neither agree nor disagree”. These results indicate that the proposed system was able to generate MESH programs that subjects would not have thought of, and that it might be an effective tool to encourage both divergent and convergent thinking.

Figure 9 shows the average evaluation scores of all subjects for the MESH programs generated by the system. The evaluation scores were mainly divided into high and low evaluations. The low evaluations were categorized into “positive change”, “no change”, and “negative change” based on the evaluation values before and after the reevaluation. A “positive change” is defined as an increase in the evaluation value after the reevaluation compared to the value before it. For example, a case a subject puts a rating of “3” and then changes it to “5” after reevaluation, is considered as a “positive change”.

“no change” indicates that the evaluation value after reevaluation is the same as before reevaluation, and “negative change” indicates a decrease from the value before reevaluation.

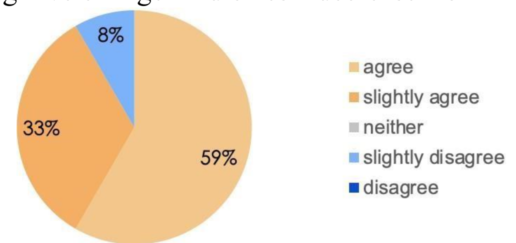


Figure 6. Q1 Questionnaire Results.

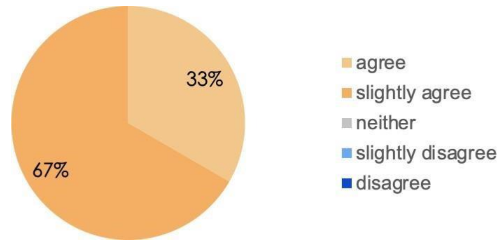
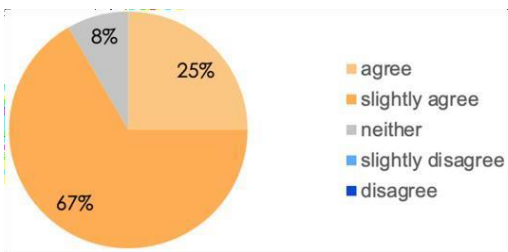


Figure 7. Q2 Questionnaire Results.



Q3 Questionnaire Results.

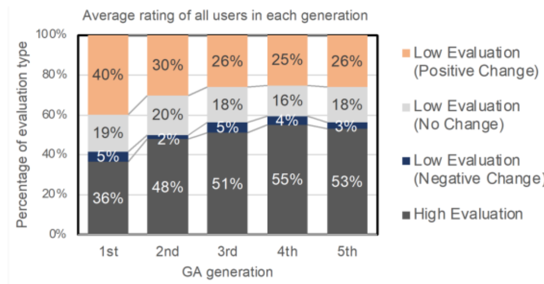


Figure 9. Evaluation Results of *Figure 8.* Generated MESH Programs.

In Figure 9, we can see that the number of high evaluations by the subjects increased from the 1st to the 4th generation, before decreasing around the 5th generation. This might be due to the presentation of MESH programs reflecting perspectives that are different from the subjects’ viewpoints. In addition, when subjects gave low evaluations to MESH programs, the percentages of subjects who changed their evaluation values before and after reevaluation were 70%, 62%, 63%, 64%, and 62%, respectively from the 1st generation to the 5th generation. Thus, in all the generations, more than 60% of the evaluation scores were updated. This can be seen as evidence that the creation and generation of MESH programs and the presentation of the reasons for others’ evaluation by the proposed system could be effective in prompting diverging thinking among subjects.

In sum, from the above results, we confirmed that the proposed system is able of generating MESH programs that subjects could not have come up with on their own (i.e., convergent thinking), by adaptively presenting subjects with others’ viewpoints, which might have contributed to broaden their thinking.

Moreover, in the free-writing, we received comments such as “I thought it would be more convenient if the proposed system could have a social media-like feature, making possible to instantly exchange reasons for the high evaluation to others”. On the other hand, some subjects also mentioned few issues such as: “As the generation evolved, the proposed system presented MESH programs similar to the ones I already evaluated” and “I didn’t change the evaluation value because the reasons for others’ evaluation that I referred to were not written in detail and seemed to be the same to my own idea”. From these feedbacks, we understand that the proposed system sometimes failed to present MESH programs that were not similar to the programs previously evaluated by the subjects. The lack of extensive accounting of the degree of difference between subjects’ own perspective and presented others’ perspectives might also be a shortcoming. Therefore, future works will be dedicated to address such issues.

5. Conclusion

Fostering creativity is not an easy undergo as it requires to prompt both divergent and convergent thinking. In this study, we proposed and implemented a creative thinking support system by embedding an others' viewpoints presentation feature in a MESH program optimization system. Then, we conducted an experimental evaluation to examine the effectiveness of the proposed system.

We found that presenting others' viewpoints can support the breeding of new ideas among the system' users and make them change their mind (divergent thinking) on the value of MESH programs they low-rated at first sight. In addition, we found that by interactively collecting users' preferences (evaluation scores), the system was able to optimize (convergent thinking) original MESH programs which users admitted they could not have come up with only by their own.

In future works, we plan to improve the performance of the system so that it can generate and present MESH programs that are not similar to those already evaluated by users, and present others' viewpoints that essentially differ from users' current perspectives.

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