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# Universal Creativity Engine: Real-time Creation of Melody and Lyrics based on the Ant System

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**Abstract:** Creativity plays an important role in almost all human activities and has been investigated by many researchers in a wide variety of fields. However, it is difficult to design a methodology for generating highly creative artifacts mainly because previous researches tended to depend a little too much on human subjective evaluation. One idea to tackle with creativity is to leave out the value aspect from the definition of creativity for the moment at least. This paper proposes Universal Creativity Engine (UCE), a conceptual organization for reproducing the creative process in human brain on the basis of the idea. It is characterized by a real-time property, representation universality and creativity based on two types of deviation. This paper also describes the design of UCE-ANT, the initial prototype implementation of UCE, for creation of melody and Lyrics based on the Ant system.

**Keywords:** Creativity, Ant colony optimization, Artificial life

## 1 INTRODUCTION

Creativity plays an important role in almost all human activities, and therefore, has been investigated by many researchers in a wide variety of disciplines such as psychology, cognitive science, philosophy, artificial intelligence, and engineering. We usually assume that creativity has an inseparable connection with the concept of value. For example, Boden defined creativity as the ability to come up with ideas or artifacts that are 1) new, 2) surprising and 3) valuable [1]. Therefore, it is extremely difficult to provide an objective definition of creativity and a reliable method for its evaluation. In a sense, it is thus reasonable that previous researches tended to depend a little too much on human subjective evaluation. However, for automatic generation of highly creative artifacts, it is important to develop a methodology that does not depend on human evaluation.

One idea here for tackling with creativity might be to leave out the value aspect when considering creativity for the moment at least. Dorin et al. [2] presented a value-free account: Creativity is the introduction and use of a framework that has a relatively high probability of producing representations of patterns that can arise only with a smaller probability in previously existing frameworks. If we accept such a formal and systematic account, when a solution to a problem can be cast in terms of a computational representation to be found in some definable representation space, then the problem can be tackled by applying some search algorithm to that space.

We hypothesize that new frameworks in this context can continue to be created by the coupling of two types of deviations, and propose *Universal Creativity Engine* (*UCE*), a conceptual organization for continuously generating the creative property based on the hypothesis. It accepts data streams from real world, updates the internal model representation of the world, and at the same time, generates data streams on a real-time basis just like human brain. It has representation universality in the sense that it stores and updates the internal representations in abstract and unified forms, and can treat any discrete data sequences in principle.

This paper describes the concept of UCE, and then reports on the initial prototype implementation, *UCE-ANT*. It composes a song, in other words, creates melody and lyrics at the same time using the same process based on one of the simplest ant colony metaheuristics, Ant system [3].

## 2 CONCEPTUAL ORGANIZATION OF UNIVERSAL CREATIVITY ENGINE (UCE)

Creativity is defined by Dorin et al. as *the introduction and use of a framework that has a relatively high probability of producing representations of patterns that can arise only with a smaller probability in previously existing frameworks*. Here, *frameworks* are defined as stochastic generative procedures. Their idea is shown in Figure 1. In this figure, Distribution 1 and 2 represent the old and new frameworks, respectively. Both are probability distributions over a common design space (horizontal axis). It shows that the new framework produces representation patterns that can hardly be produced by the old framework. They consider that the use of Distribution 2 relative to the prior use of Distribution 1 to generate one of these points is therefore creative.

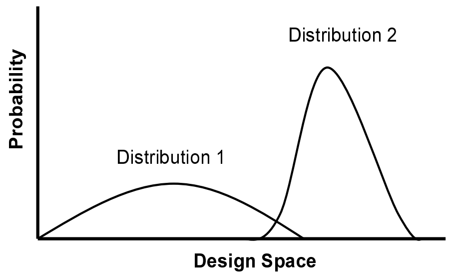


Fig. 1. The use of Distribution 2 relative to the prior use of Distribution 1 is creative.

We propose Universal Creativity Engine (UCE), a conceptual organization for reproducing the creative process in human brain (Fig. 1). UCE accepts data streams from real world, updates the internal model representation of the world, and at the same time, generates data-streams stochastically as the results of a creative process. The internal model is represented in a distributed manner, and the positive feedback loop is used to extract standard patterns inherent in the current data streams.

We considered the following requirements when designing UCE.

1. Real-time property
   UCE works on a real-time basis just like our brains. The world is changing every minute, and the existing frameworks captured in UCE should also change correspondingly to make the output streams creative. For example, timeline of Twitter can be used as an input data stream as described later.

2. Creativity based on two types of deviations
   We adopted the creativity concept proposed by Dorin, and embodied them in the following two types of deviation. Deviation from the frameworks that are updated by the input data streams from the world (I-deviation) and deviation from the frameworks of the output data streams themselves (O-deviation).

3. Representation Universality
   UCE stores and updates the internal model representations in abstract and unified forms, and can treat any discrete data sequences in principle. For example, melody and lyric are created using the same process based on two types of deviations in the prototype system.

## 3 PROTOTYPE IMPLEMENTATION (UCE-ANT)

We report on UCE-ANT, the initial prototype implementation of the UCE concept. It continues to compose a song: creates melody and lyrics at the same time representing the atmosphere of real world at the present moment, using the same process based on one of the simplest ant colony metaheuristics, Ant system [3][4].

UCE-ANT is composed of two layers: one for lyrics and the other for melody. Data streams (timeline) from Twitter and melody data from currently popular music scores are used as input for the melody and lyrics layers, respectively. Each layer has a directed network as an internal model of real world, in which each node represents a note or a word. Each link represents a connection from a node to the other with a pheromone value reflecting the strength of the connection. Two types of virtual ants: *Reflector* and *Performer* are moving from one node to another. The amount of the pheromone on link$_{ij}$ deposited by Reflector ants and Performer-ant$_n$ are described by $T_{ij}$ and $t^n_{ij}$, respectively.

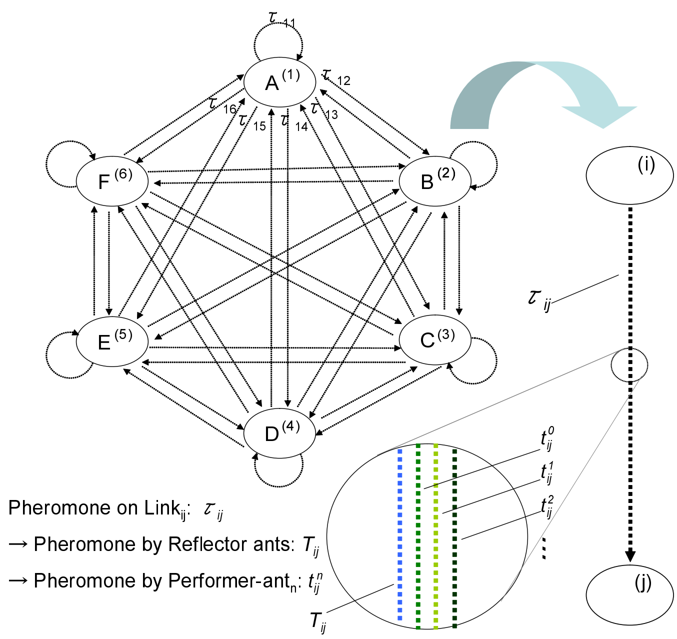


Fig. 3. Internal representation based on an ant colony metaheuristic.

While moving, they deposit pheromone on the links. The pheromone on the links evaporates slowly with time.

$$T_{ij} \leftarrow (1 - \rho_a) * T_{ij} \tag{1}$$

$$t^n_{ij} \leftarrow (1 - \rho_b) * t^n_{ij}, \tag{2}$$

where $\rho$ is a parameter called evaporation ($0 \leq \rho \leq 1$).

UCE-ANT works as follows.

1) World representation by Reflector ants

Each reflector ant moves according to its input data stream (note or word sequence), and deposits their identical

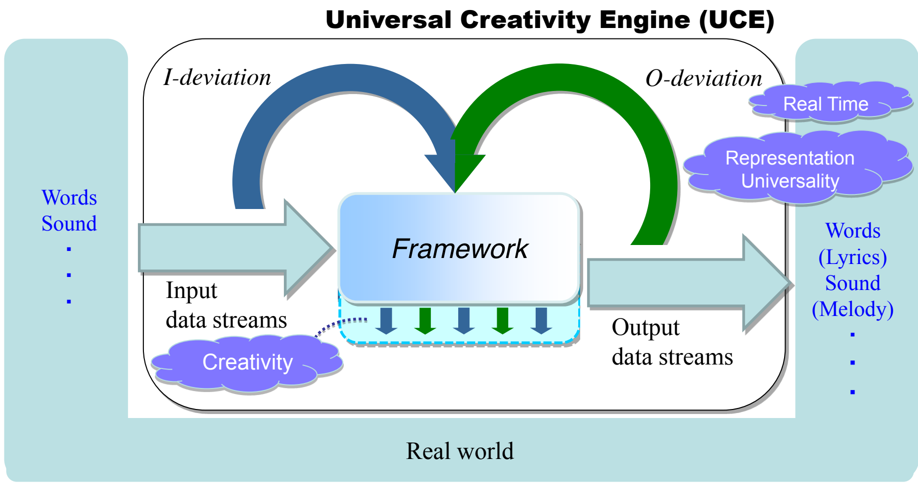


Fig. 2. Universal Creativity Engine (UCE).

pheromone on the link when moving. Each time a reflector ant moves from a node *i* to a node *j*, it deposits a pheromone quantity $T_{reflect}$ as follows:

$$T_{ij} \leftarrow T_{ij} + T_{reflect}. \tag{3}$$

The real world model is constructed and maintained actively as a pheromone distribution on the network on each layer through this process by Reflector ants and pheromone evaporation.

2) Exploration by Performer ants

Each Performer ant explores the network according to its pheromone distribution (deposited by itself and Reflector ants), creating melody or lyrics using an ant colony metaheuristic as follows.

When located at a node *i*, the probability for Performer-ant$_n$ to choose a node *j* is given by:

$$P_{ij}^n = \frac{T_{ij} + t_{ij}^n}{\sum_k (T_{ik} + t_{ik}^n)}(1 - \epsilon_n) + \epsilon_n, \tag{4}$$

where $\varepsilon_n$ is a random selection rate for performer-ant$_n$ ($0 \leq \varepsilon_n \leq 1$). Each Performer ant has its own random selection rate, which affects the creative property of its output data stream as described later.

When moving from a node *i* to a node *j*, it deposits a pheromone quantity $t_{perform}$:

$$t_{ij}^n \leftarrow t_{ij}^n + t_{perform}. \tag{5}$$

Every when they reach a new node, the corresponding note or word is selected. The node sequences, melody and lyrics, selected by performer ants on both layers are combined to play a tune continuously.

3) Creativity control

We hypothesize that new framework can continue to be created dependent on the coupling of I-deviation and O-deviation in UCE. Furthermore, we assume that creativity would be optimized by letting both deviations to be certain values (I-deviation$_{opt}$ and O-deviation$_{opt}$), although it might be difficult to know the values a priori. In UCE-ANT, I-deviation$_n$ of Performer-ant$_n$ corresponds to the difference between pheromone distributions of Reflector ants and the pheromone distribution detected by Performer-ant$_n$ (pheromone deposit by itself and Reflector ants). O-deviation$_n$ corresponds to the difference between the current distribution and the past distribution (*N* steps ago) of pheromone detected by Performer-ant$_n$.

We defined these measures simply as follows.

I-deviation for a Performer-ant$_n$, I-d$_n$, is given by

$$I\text{-}d_n = \sqrt{\sum_i \sum_j (P_{ij}^n - \frac{T_{ij}}{\sum_k T_{ik}})^2}. \tag{6}$$

O-deviation for a Performer-ant$_n$, O-d$_n$, is given by

$$O\text{-}d_n = \sqrt{\sum_i \sum_j (P_{ij}^n - \frac{\sum_k P_{ijk}^n}{N})^2}, \tag{7}$$

where $P_{ijk}^n$ is the past distribution (*k* steps ago) of pheromone detected by Performer-ant$_n$.

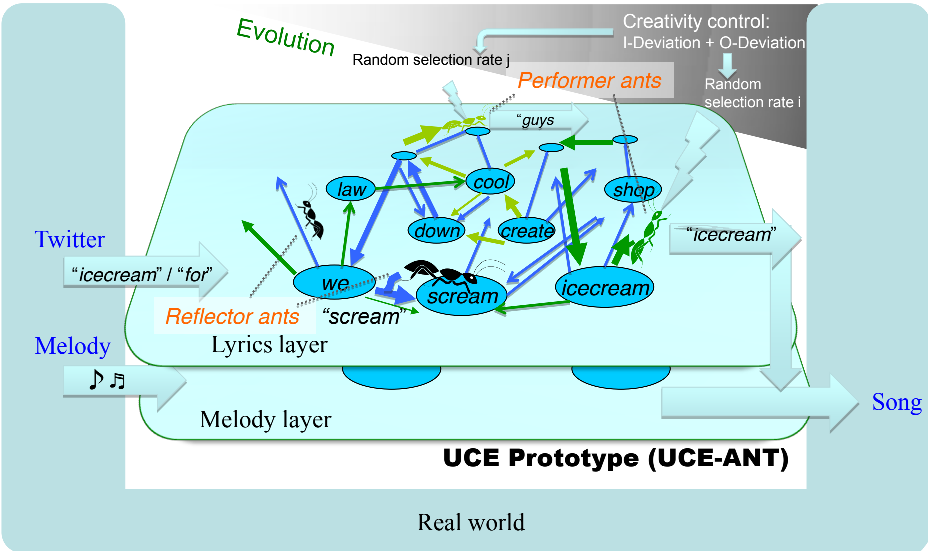


Fig. 4. Prototype Implementation of UCE (UCE-ANT).

Using these measures, Performer-ant$_n$ is evaluated as

$$E_n = \frac{1}{1 + |I\text{-}d_{opt} - I\text{-}d_n| + |O\text{-}d_{opt} - I\text{-}d_n|}, \qquad (8)$$

where I-d$_{opt}$ and O-d$_{opt}$ are the values that are supposed to maximize the creativity.

Each Performer ant has its own random selection rate, which controls both deviations, I-deviation and O-deviation. Evolutionary processes are used to evolve Performer ants with the optimal random selection rate that maximizes E$_n$.

We are currently conducting some preliminary experiments to examine the basic behavior of UCE-ANT. We found that in terms of the balance between intensification (exploitation of the previous solutions) and diversification (exploration of the search solutions), the former due to the positive feedback loop provided by the pheromone-based metaheuristic [5] works stronger than expected. Therefore, sufficiently large values of I- deviation$_{opt}$ and O-deviation$_{opt}$ are necessary to work against it. However, it is also the case that excessively large random rates make the melody or lyrics generated by the Performer ant unattractive.

## 4 CONCLUSION

This paper hypothesizes that the creative process is dependent on the coupling of two types of deviations, and proposes Universal Creativity Engine, a conceptual organization based on the hypothesis. This paper also described UCE-ANT, the first prototype implementation of UCE based on an ant colony metaheuristic. We examined basic behavior of it and found some characteristic of its dynamics arising from the balance between intensification and diversification, although UCE-ANT is still under development.

We gave simple definitions of two types of deviations for UCE-ANT. The future work includes investigating the effects when changing the definition of the deviations. It might be also interesting to generate motion of dancing and singing robots by adding a Motion layer in which each node represents an action of a joint.

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