Does Creativity Help Us Survive? A Possible Approach with Quantum-Driven Robots

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Abstract
How can we relate quantum computing, robotics, and music? This is a position paper where we try to connect these fields. We discuss one main question regarding computational creativity and we imagine an experimental setup to test our hypothesis. Artificial intelligence and autonomous machines can accomplish simple creative tasks such as reorganizing given material. Because creativity is a human (and not only) resource to survive, we wonder if also artificial agents, such as robots, might develop creativity at a higher level to ensure self-survival. Then, we design an experimental setup with three robots, playing and dancing. If music and movement flow is regular (with the beat difference below a certain threshold), the voltage given to robots is constant. Otherwise, if there are inconsistencies, it drops, activating robots' alert signal sensors, and triggering new musical activity. We use the paradigm of quantum computing to formalize our claims. This test might be performed *in situ* in a robotic lab.

Keywords
quantum computing, music, collaboration

1. Introduction

Can we model creativity? Even though we can analyze neuronal activity (brain) and decompose the thinking flow (mind), creativity, as well as consciousness, appears as an emerging and mysterious property. We can build up mathematical and computational models to make calculations and predictions, but these models are just mere tools: they are not meant to show what is going inside people's minds.

Here, we sketch an approach toward creativity, using robots as a simplified benchmark for human behavior. Because the need for survival might motivate the *need for being creative*, we investigate if it is possible to create an artificial model of creativity based on it.

The question of creativity in humans also comes with a feeling of aesthetic pleasure [1]. We can also wonder if this could even be modeled, and how. There are astonishing examples of creativity in non-human animals: we can think of gardener birds and fish creating circles and

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geometric shapes on the underwater sand [2]. We can also think of aesthetic reasons behind mate selection, not always correlated with a “good fit” in terms of natural selection [3]. It means that, according to this approach, individual choices “creatively” shape the evolution of species. Thus, both in the human and non-human animal world, beauty, creativity, and survival are strictly related. Creatures want to survive, both as individuals and as species; they become creative and feel a form of pleasure as a reward. Amongst the products of (human) creativity there are artifacts, including autonomous objects: the robots. How can we use these products of creativity to model the creative behavior itself? And, is there only *one* concept of creativity?

There is a distinction between different layers of creativity: humans can develop new paradigms and concepts, while a machine can just re-arrange existing material or explore pre-constructed spaces of concepts. Thus, the computer models of creativity [4] take into account the limitations of artificial agents [5]. Robotic creative application [6] have also been used to help teach creativity [7, 8, 9, 10]. Creative and pedagogical robotic applications include dance [11].

In our framework, we consider here, as a main computational tool, quantum computing [12, 13], a branch of computer science based on the paradigms of quantum mechanics, such as state superposition, destructive measure, and entanglement. There have been pioneering applications of quantum computing to robotics [14, 15, 16, 17]. Quantum computing has been also exploited to model the decisional system of robotic *swarms* [18, 19, 20]. A swarm of robots is constituted by multiple simple, interacting robots [21], collectively achieving a complex task. The behavior of a single, complex mind can in fact be approximated by a distributed intelligence of an artificial swarm [22], similarly to what happens with a natural-swarm intelligence [23]. Thus, we might be interested in swarm robotics, with their message exchange and local-global behavior, as a tool to approximate mental behavior. Global behavior is an emerging phenomenon: macro-properties are related to micro-interactions, but the global behavior is more complex than the simple sum of local behaviors.

Creativity is also an emerging behavior which requires the interaction of different abilities and, in the human mind, of both cerebral hemispheres [24]. The concept of ‘emergence’ has been connected with the complexity of quantum mechanics [25, 26]. The paradigms of quantum mechanics have also been used to create computational models of consciousness, helpful to make calculations [27, 28], and trying to formalize the *emergence* of consciousness [29]. Creativity and consciousness appear as being strictly related [30]. We restrict our attention to a particular manifestation of human consciousness, that is, musical creativity. Music is the domain of recent applications of quantum computing and robotic studies [31, 32, 33, 34, 35, 36], including quantum-based dancing robots [37].

In this article, we first formulate our research question and then design a possible future experiment. We propose a quantum approach to a creative design of an experiment with dancing and playing robots, and a decisional system based on external feedback, triggering the starting of their musical collaboration. For robots, the of survival need may correspond to the avoidance of being switched off. To achieve this goal, the robots have to maintain a certain degree of music interaction and flow.

2. Theoretical framing of our questions

Questions. Our question, more a syllogism, is: *because creativity is a fundamental resource for survival, and there is research regarding computational modeling of creativity, would it be possible to model creativity as a means of artificial-agent survival?* The second question, related to the first one, is: *Can we model the need to create?* It could be a corollary question of the use of creativity to survive. In the case of robots, we might want to create and test computational models of creativity, with quantum computing as a tool to make calculations. Of course, we also express our concern for our questions' implications—we, as humans, should nevertheless always be able to 'switch off' robots. Thus, we should limit their creativity resources.

Quantum formalism. We can quantize "success" as the 1 logic, and "failure" as 0. We allow the existence of intermediate degrees of success as a quantum state superposition of them. The perception of success and failure can drive artistic creation. According to the chosen scenario, the success can be achieving a result, represented by accomplishing a task, finding a target, completing a work already started according to precise criteria, or transforming it creatively.

Here, we call "reward" the perception of closeness to the target, be it a physical point or a more abstract goal. Creativity may intervene in the choice of the target and in the choice of the path. For the i-th robot, we will thus have:

$$|reward\rangle_i = \alpha_i|0\rangle + \beta_i|1\rangle, \;\; |\alpha_i|^2 + |\beta_i|^2 = 1. \tag{1}$$

Introducing discretized entities, superposition, and probability amplitudes is the first step toward a quantum formalism. Target can be seen as a goal, something to get accomplished. The object of creativity is the choice of target and the selection of path to reach it: $(T, p(\cdot, T))$. This formulation has a mathematical interest, with a point and a class of paths having that point as the endpoint. Points can be substituted by space probability amplitudes and paths by path integrals [38].

This simple formalization can remind one of schematic modeling of reward, with a target (*what* to reach) and a path (*how* to reach it). This problematics can be related to the quantum formalization of human-consciousness fundamental functions; in particular, the problem of the *choice of target* and *choice of path to reach it* reminds one of the free will [39], which is a rather philosophical problem. The quantum operator could be operationalized in an indirect way, relating the variation of activity of robots in response to their "need," that is, the voltage diminution, and thus the risk of being shut down. In the following section, we sketch the idea.

3. A possible experiment

In this Section, we design an experiment that could be run to substantiate our claims, assess their limits, and obtain some first quantitative results. Such an experiment could be performed in a robotic lab in the near future. We can suppose to model creativity through a logic gate with feedback. We have a qubit for each robot, and thus, a multiple-qubit system for a multiple-robot system. Here, the target is a certain flow to be maintained; the path is the collection of musical activity and gestures toward it. We propose a simplified and indirect approach to creativity measure through the level of artistic activity in response to the voltage diminution. We are actually more interested in finding the “need,” the motivation to create rather than focusing on the creativity itself.

The experiment should involve three robots. The first, Shimon, is a marimba player developed to investigate musicianship at Georgia Tech [40, 41]. The second is an NAO performing dance movements, investigated by the University of Palermo and the Italian National Research Council, CNR [42]. The third is a Pepper or just a couple of robotic hands slowly twisting the CubeHarmonic. The CubeHarmonic is a novel musical instrument based on the Rubik’s cube [43, 44]. See Figure 1 for a possible poster. The dancing NAO suggests rhythmic movements to the Shimon marimba player. The change of rhythmic pattern suggests a chord change to the CubeHarmonic player. The change of chords suggests a different pitch choice to the marimba player. Finally, the change of rhythm suggests a different selection of movements to the dancing NAO.

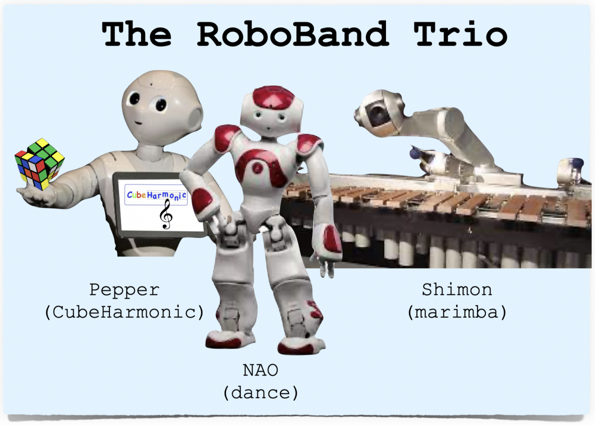

Figure 1: Poster with our imaginary robotic trio.

Robots’ synchronization can be measured as the frequency of chord change, pitch closeness of marimba and cube, time contiguity of dancing NAO, and rhythmic marimba beats. (Harmonic agreement of marimba and cube chords could be considered in a more advanced approach.) If synchronization amongst the three robots diminishes, the electric charge diminishes for one or all robots, raising internal signals of alert for robots. The affected robot should respond by raising its attention toward the other components of the trio, and modifying its activity until voltage gets back to safe levels. The target is thus: “keeping the robots awake,” through a well-working group musical activity.

All of that can be expressed through a quantum circuit, where $|1\rangle$ indicates an awaken robot with an incoming regular voltage (ON), and $|0\rangle$ would be the sleeping robot with a minimal tension level or no voltage at all—like a switched-off robot (OFF). The states between ON and OFF could be described through quantum superpositions. Thus, we can apply quantum computing resources to this experiment, representing each robot as a qubit, and its activity as a sequences of quantum gates. The measure would be a periodic assessment of the amount of musical activity and group synchronization. According to the result of such a measure, tension might dramatically diminish, raising alert signals, or be kept constant. See Figure 2 for a toy example of the proposed idea. At the end of the experiment, the robots will be switched off by the human user. In a human scenario, the feedback could be represented by audience involvement and applauses. What about the “reward” for the robots? In our simple machine-model, the robot is “happy” if it has enough voltage to not die. Thus, if the voltage is enough, the reward is high. When it is low, an alert starts, triggering the level of artistic activity. In response to the “creative” act, the reward gets higher again. In our qubit model of Figure 2, we indicate the reward qubits for each robot.

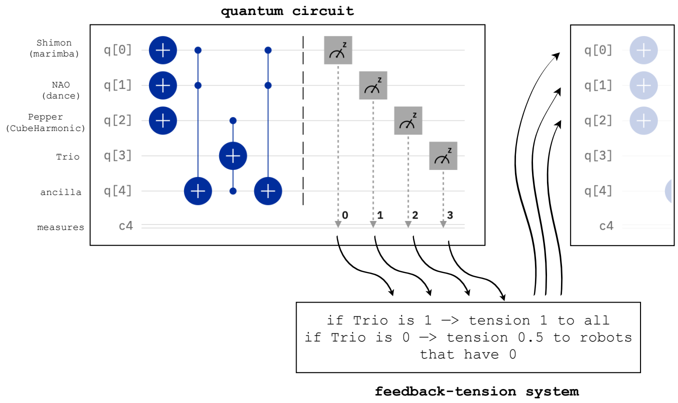

Figure 2: This is a naïve rendition of the proposed idea. If a robot maintains a certain level of rhythmic impulses, rate of chord change, rate of movements, then it has 1; else 0. The figure shows a situation where all the three robots have 1. There are periodic measurements of all robots. If they all have 1, then trio has 1, else zero (CCCNOT). This information is collected by the feedback system. According to the feedback output, robots receive a different amount of tension (normal 1, minimal 0), and they have to modify their behavior in response to lower tensions.

3.1. Discussion and Conclusions

In this article, we formulated a question regarding the need for being creative as a survival solution. We used the language of quantum computing and we designed a future experiment to test our hypothesis. In our article, we have used the word “quantum” while dealing with two different spaces: the formalism on one side, the possible role of quantum effects in the mind on the other side, and their connection with creativity. The first option is rather flexible: we build an artificial formalism to model objects and behaviors and run simple experiments to test and refine the model itself. The second option is more delicate because we do not actually know exactly how the human brain really works. This is also a conceptual problem because we use our brains to think of our brains. Even in the case of a refined and complete quantum model, we would consider it as merely *a model*, without the pretense of being the real underlying mechanism of our minds.

Here, we proposed an experiment with a behavioral adaptation in response to feedback. Creativity, in parallel with consciousness, is necessary to achieve an objective. Each target can be seen as a step toward survival. In nature, foraging behavior in ants is a sub-goal toward individual survival, which is, in turn, a step toward species survival. Thus, creativity intervenes in each passage of this process. The emergence of creativity in response to the survival need can be quantified not (only) by means of artistic activity intensification, but also with its improvements in terms of regularities of acoustic (simulated) phenomena, and increased coordination between musicians.

In conclusion, the considered robots are innocuous. Risks for human health could come from over-heating due to over-working. However, in general, all man-made machines should include systems to forcibly be switched off by humans for safety reasons. This is in agreement with Asimov's three laws of Robotics. Thus, limits to robotic creativity should be imposed. A future experiment will verify if such 'survival behaviors' are efficiently put in place. Such an experiment would confirm that creativity is an answer to a survival need, also for man-made agents.

This could constitute a first step toward a computational approach to complex and fascinating phenomena such as aesthetic pleasure in art-making.

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