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11 Dynamic agency: models for creative production and technology applications

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Abstract. Among the most promising modern approaches to creativity, a very important one makes use of non-standard problem solving techniques of artificial intelligence for addressing methodological descriptions of creativity. The purpose of this paper is to present creative dynamic agency as a novel partial description of creativity, which is based on a recent and powerful technique of artificial intelligence, developed by authors and called dynamic agency. The proposed approach is embedded in an epistemology on creativity which is envisaged in a more general epistemology of rationality, namely in the framework of the debate between weak and strong approaches to artificial intelligence. the position of the authors is that creativity cannot be fully modelled. However, with the adoption of creative dynamic agency, we can extend the size of rational elements and reduce the size of irrational elements (which still continue to be present) in both product and process of creativity.

Contents

A preliminary version of this paper has been presented by the authors at the International Congress on Discovery and Creativity held at the University of Gent, Gent, Belgium, on May 14-16, 1998.

11.1 Introduction

Some of the recent and promising advances in the study of creativity adopt complex problem solving methods of artificial intelligence for gaining a great potentiality in addressing a methodological, possibly partial, description of creativity. These new approaches are considered as standing in the middle between romantic approach (totally irrational) and classical approach (totally rational) to creativity.

Among the modern problem solving methodologies and techniques developed in artificial intelligence, the agency, namely a multiagent system composed of several intelligent cooperating entities, called agents, is one of the most important, promising and powerful.

The purpose of this paper is to present a novel partial description of creativity based on a particular type of agency, developed by authors [1] [3] and called *dynamic agency*. Our proposal, called *creative dynamic agency*, is a methodological description of the product and, partially, of the process of creativity. In particular, the product of a creative act is a creative dynamic agency, whereas the process of a creative act is the sequence of steps that constructs a creative dynamic agency.

We conceive the creative act as consisting in observing a set of phenomena and inventing a set of models of them. The proposed approach of creative dynamic agency represents the conception of a process producing, as result, a set of new models which are organized in a uniform way together with the old models. Moreover, the design of creative dynamic agency represents the process that, starting from a set of phenomena, ends to a uniformly organized knowledge.

The approach of creative dynamic agency considers the epistemology *on* creativity as embedded in a more general epistemology *of* rationality, namely in the debate between weak and strong approaches to artificial intelligence. In this way, we connect our new epistemological contribution to the two roles of artificial intelligence [15]: an engineering for constructing effective, powerful, and sophisticated machines, and a science for investigating and understanding phenomena of human intelligence. In fact, dynamic agency is both a powerful machine of artificial intelligence and an appropriate tool for the partial description of the intellectual phenomenon of creativity.

We claim that the creative intellectual activity is mostly irrational, thus it cannot be fully modelled. However, we propose a partial methodology which rationally defines some elements of creativity, whereas several other elements, whose nature is irrational, are left undefined. Thus, our approach aims to reduce the extension of what cannot be modelled in favor of what can be modelled. It is important to outline that creative dynamic agency is also suitable to describe creativity in the case in which one trusts that creative acts can be fully modelled, although this is not the epistemological thesis adopted by the authors.

Moreover, in order to clearly assess the conceptual role of this paper, we note that our contribution is the novel application of a technique of artificial intelligence, namely dynamic agency, to the partial explanation of creativity. The proposed approach is not an application of techniques of artificial intelligence aimed to the automatic production of discoveries performed by machines, as illustrated in the examples of machine discovery in [7].

The paper is structured as follows. In Section 11.2 we introduce the definition of some basic concepts such as phenomenon and model, moreover we delineate the epistemology on creativity as embedded in the debate between weak approach and strong approach to artificial intelligence. In Section 11.3 we illustrate dynamic agency as a technical methodology of artificial intelligence. In Section 11.4 we present the novel partial methodological description of creativity provided by creative dynamic agency. In particular, firstly, we introduce the description of the product of a creative act as a creative dynamic agency, secondly, we introduce the process of creativity as the sequence of steps which design and construct a creative dynamic agency and, finally, we examine some interesting properties of the proposed approach. In Section 11.5 we describe the connections and interdependencies between creative dynamic agency and artificial intelligence. In Section 11.6 we conclude the paper and we propose some future research directions.

11.2 Weak and strong approaches to artificial intelligence

In this Section we recall some concepts in order to set the framework in which our approach to creativity is inserted. In particular, in Subsection 11.2.1 we present our definitions of phenomenon, model, and abduction. In Subsection 11.2.2 we illustrate how the epistemology on creativity can be envisaged in the debate between weak and strong approaches to artificial intelligence.

11.2.1 Duality in creativity

In this Subsection we define what we mean as phenomenon, model, abduction, induction, deduction, adduction, afference and inference. In this way we set the framework in which our conception of creativity is embedded. We note that some of the proposed definitions are adopted in slightly different ways in current philosophy, namely we stress that some of our definitions are not conventional.

We consider [2] as *reality* the whole source of phenomena that humans can perceive. We can consider, in reality, the distinction of two parts, namely the *natural* and the *artificial*. The natural can be further divided into *man* and *world* (intended as the source of the phenomena which do not arise within man). Moreover the artificial can be identified with the notion of *machine* (see Fig.11.1).

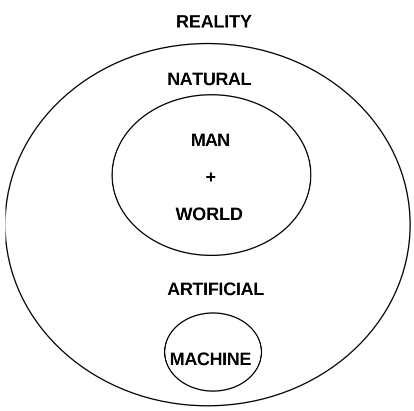

Figure 11.1 The division of the reality in the natural and the artificial.

The three entities, namely man, world, and machine, interact among each other. In particular, we focus the attention on the interaction between man and world. More precisely, we illustrate the process that brings man to know the world, and, in general, the whole reality, within the framework inspired by Galileo Galilei studies [14] and called *empirical inductive deductive paradigm* (see Fig.11.2).

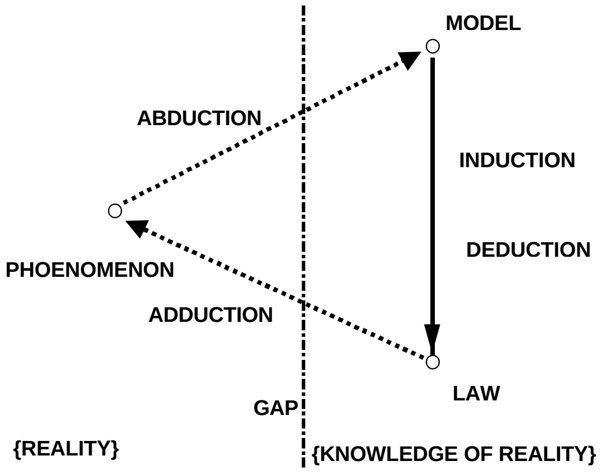

Figure 11.2 Galileo Galilei: empirical inductive deductive paradigm.

The empirical inductive deductive paradigm is a clear description of the difference between a *phenomenon* of reality and a *model* of a phenomenon of reality. In fact, starting from a phenomenon occurring in reality, its model is devised by man with a creative intellectual process called *abduction*. Thus, the abduction describes the passage from a phenomenon to its model. Therefore, we consider abduction as a bridge over a gap dividing two entities: *reality* and *knowledge of reality*. In the following of the paper, we consider the creative act as the invention of models of phenomena, namely as abduction.

Within knowledge of reality, man performs another intellectual process on the model in order to produce a *law*. The law is a new constructed element obtained from knowledge of reality. The intellectual process from model to law is called *induction* or *deduction*, depending whether it is a passage from lower to higher abstract knowledge or vice versa. We call *inference* either induction or deduction. Inference identifies a passage within the knowledge of reality.

The new knowledge of reality, described by law, can be utilized for predicting a new phenomenon of reality. The intellectual process from law to phenomenon is called *adduction*, and it represents the passage from knowledge of reality to reality.

The activities of abduction and adduction are called *afference*, whereas, as we mentioned above, the activities of induction and deduction are indicated as inference. The union of afference and inference, intended as two general intellectual processes, constitutes the global process of *intelligence*.

The whole empirical inductive deductive paradigm is subject to a meta-activity, called *critique*. Critique consists in revising and modifying the cycle of abduction, induction or deduction, and adduction into a new similar, but improved, cycle. The improvement is evolutionary, namely it permits a better knowledge of the reality that is exploited in an improved abduction, in a more effective induction or deduction, and in a more satisfactory adduction.

As previously stated, a model is to be intended, in the Galileo spirit, as a type of knowledge of a phenomenon of reality. A model of a phenomenon is, then, quite different from the phenomenon itself and cannot be identified with it [18].

A model is:

I. *finite*: only a finite content of knowledge is drawn from the phenomenon, intended as a potentially infinite source of information, and is inserted in the model;

II. *objective*: the model is so neat that everyone has the same understanding of the truth that is embedded in the model itself;
III. *experimentable*: the model can be used in order to predict the happening of a new phenomenon.

We think of a model as the result of a modelling activity which consists in adopting a given *formalism* and in shaping within it a given *form*.

A model has the following three properties:

I. a model is *perfect* within itself, because the built up form is precisely described since the adopted formalism (such as mathematics, logic, etc.) provides exact shape definitions;
II. a model is *imperfect* in knowing a phenomenon of reality, because the abduction is a creative process that expresses the knowledge embedded within the model, describing only some of the elements which contribute to the perception of the phenomenon; it is clear that the abduction cannot produce a model rich enough to describe the whole phenomenon;
III. a model is *perfectible*, since it can be indefinitely substituted with a better (in the sense of less imperfect) model. The new model is the result of a new abduction (namely, of a pulse of creativity) which takes into account additional elements of the real phenomenon. The process can be iterated in order to obtain a sequence of models, each one better than the previous one, but worse than the subsequent one. However, when the phenomenon to be modelled is very complex, various models of such phenomenon are not necessarily arranged into a hierarchical (monotonous) order, but into a heterarchical (non-monotonous) order (in this case the alternative models are called *paradigms*).

To summarize, we state that creativity is exploited in the passage from the reality (i.e., phenomena) to the knowledge of reality (i.e., models). Moreover, the problem of what is rational and what is irrational in creativity can be addressed from the point of view of what is rational and what is irrational in intelligence, namely the epistemology on creativity can be considered in the debate between weak and strong approaches to artificial intelligence. This argument is further detailed in the next Subsection.

11.2.2 Epistemology on creativity

The problem of whether human intelligence is partially or totally mechanizable leads to the problem of whether creativity is rationalizable, being our approach to creativity embedded in a more general epistemology of rationality. Therefore, we deem useful to consider this argument in the debate between strong and weak approaches to artificial intelligence: in fact, strong approach to artificial intelligence affirms that every part of the human intelligence, included creative acts, can be fully modelled, whereas weak approach to artificial intelligence, which is our approach, divides human intelligence into rational and irrational elements and considers only the rational ones as suitable to be fully modelled. From our point of view, the creative intellectual activity is mostly irrational, but in our approach we describe those elements of creativity which are rational, in order to reduce the extension of what cannot be modelled in favor of what can be modelled.

From the previous considerations it is clear that we need to investigate the concept and the definition of intelligence, starting from what Greek ancient philosophy has stated, in order to clarify the context of our discussion.

In ancient philosophy, intelligence is strictly connected with gnoseology, namely the problem of what knowledge is and how it can be reached. In Plato conception [20] there are two kinds of knowledge: *dòxa* which is composed of art (imagination) and belief (sensible world) and can be false, and *epistème*, namely knowledge referred to the world of *ideas*, considered as the only real world, which always brings to the knowledge of the truth. Hence, knowledge is a cognitive process from sensible world, considered as the imperfect one, to intelligible world, in which only it is possible the real knowledge, namely *epistème*. In Aristotle philosophy [6] we can find an analogous process from sensation to intellect, even if perfect forms of sensible things do not belong to a separate world, but are inserted in every object of the sensible world itself. The process starts from sensation which, being immediate, is always true, and founds the cognitive process, continues with inactive intellect (*tabula rasa*), and ends up in active intellect which moves our intellectual abilities from potentiality to activity. These schemas represent, with elements of generalization, the conception of knowledge in ancient philosophy.

We consider now the connection between knowledge and intelligence, intended as the man's capacity to reach a full knowledge of the truth. In the process previously described some different kinds of knowledge are presented: every kind of knowledge is connected to a different part of human soul, defined by the functions it carries out. These parts are *vegetative part*, *sensitive part*, and *intellective part* and correspond to different souls. In fact, the vegetative soul belongs to every living being of the world, included plants and flowers; the sensitive soul characterizes the whole animal world; and the intellective soul is an exclusive property of man, who, on the basis of it, can be differentiated from animals.

Considering this conception, we can say that different kinds of intelligence are in accordance to different activities: mechanical activities and rational activities; the former are connected to vegetative and sensitive parts of the soul, the latter are referred to intellective part, which characterizes the mankind. We can see, according to this subdivision between human abilities, the core of the question, referred as the *mind-body problem*, about which parts of human capacities can be satisfactorily modelled and, thus, imitated and reproduced. This represents the central issue of the actual debate between strong and weak approaches to artificial intelligence.

In modern philosophy the mind-body problem has been explicitly posed by Descartes (1596-1650) [11] [12], by thinking over the nature of mind and body. He considers two different kinds of human activities, the mechanical ones and the rational ones: only the first kind of activities can be fully modelled in order to be reproduced by an artificial entity, whereas the others cannot be imitated (modelled) since they reside in the soul, that part of man which derives from God and which we cannot know in an exhaustive and complete way. The interaction between body, which controls mechanical abilities, and mind, which performs intellectual activities, is regulated by a gland, called pineal gland and situated in the brain.

Starting from Descartes proposal, there have been many different approaches to the question related to which parts of the man can be modelled. The strongest approach to the question is proposed in the book "L'Homme Machine" by Lamettrie (1709-1751) [16]. In his book, he states that every man can be considered as a machine and can be fully reproduced, even in his intellectual capabilities.

We can summarize the problem and state our epistemological thesis on rationality in accordance to Bergson's classification [8] which considers *creative intelligence*, whose mental processes cannot be modelled, since they have irrational elements, and *fabricative intelligence*, consisting of acts which can be modelled. From this point of view we reconsider our previous definitions (see Subsection 11.2.1): abduction and adduction, which we call afference, belong to creative intelligence and cannot be fully modelled, induction and deduction, called inference, belong to fabricative intelligence and can be modelled.

In artificial intelligence the debate between rational and irrational human intellectual activities is an historical problem that is present from the origin of the discipline, and that is represented by strong and weak approaches to artificial intelligence. The two different approaches reappear considering the possibility of an epistemology on creativity, based on a more general epistemology of rationality. Our approach in describing creativity, based on creative dynamic agency, has many advantages and is suitable to describe creativity in the case of both weak and strong approaches to artificial intelligence.

In order to clarify some conceptual and functional aspects of our weak approach to artificial intelligence, it is useful to illustrate a framework, based on Galileo empirical inductive deductive paradigm, which represents the process of resolution of a problem (see Fig.11.3, which is a slight modification of Fig.11.2).

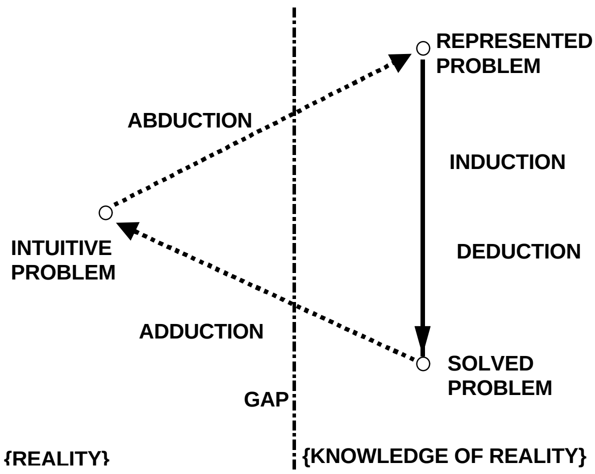

Figure 11.3 The problem resolution process of artificial intelligence.

In physics, there is a difference between a phenomenon of reality and a model of this phenomenon, which reproduces some characteristics of it. In artificial intelligence, *intuitive problem*, namely a requirement (an exigency) to solve a problem, corresponds to a phenomenon and *represented problem*, namely the product of the formalization process of the intuitive problem, corresponds to a model. In physics, the resolution process of a problem is ended by the law, which derives from a model of a phenomenon; in artificial intelligence, *solved problem* corresponds to a law.

We consider the roles of man and machine in the complex process of resolution of a problem: in physics every activity is carried out by man only; in artificial intelligence, as stated before, these activities are carried out by man or by machine. In fact, the passage from represented problem to solved problem is automatically carried on by machine, whereas the passages from intuitive problem to represented problem and from solved problem to intuitive problem are an exclusive activity of man, which cannot be modelled and reproduced by a machine, according to our weak approach.

We stress that intelligence is not fully mechanizable: just some abilities, referred to fabricative intelligence, are suitable to be modelled, whereas those referred to creative intelligence cannot be completely modelled, since they contain irrational elements. Our previous answer to this problem contains an epistemological hypothesis about creativity. We claim that the creative activity is mostly irrational and cannot be fully modelled.

However, we propose a partial methodology which defines, in a rational way, some elements of creativity and leaves as undefined several others, whose nature is irrational.

Moreover, some modern approaches give to the answer about which parts of the human intelligence can be modelled, that involves the debate between strong and weak approaches to artificial intelligence, the role of enlightening the epistemological framework for the comprehension of creativity.

11.3 Agencies and dynamic agencies

In this Section, we shortly recall the technical concepts of agency and dynamic agency, belonging to artificial intelligence. First, we illustrate three points of view from which agencies are envisaged. Then, we present a critical problem which arises in the construction of an agency and we introduce dynamic agencies which overcome the critical problem. Finally, some applications of dynamic agencies are described.

11.3.1 Agencies

The concept of *agency* has been introduced by Marvin Minsky under the metaphor of “The Society of Mind” [19]. The main issue addressed by Minsky is the deep understanding of the various phenomena of human intelligence which present a complex nature and provide a difficult task in their satisfactory representations within given models. To overcome this situation, Minsky proposes the concept of *agent* as an individual entity where a given way of modelling a phenomenon of intelligence is uniquely interpreted and embedded into the functional architecture of the agent itself. Thus, both the plurality of the phenomena to be dealt with and the variety of reasonable paradigms that can be adopted in modelling a given phenomenon suggest a scenario in which a high number of artificial individuals, namely the agents, coexist and collectively contribute to set up a rich, comprehensive and precise description of human intelligence. Minsky adopts to denote such system of agents, each one representing a paradigm of a given phenomenon, the term ‘agency’.

From the pioneering work of Minsky, the notion of agency has been further carried on in the field of Distributed Artificial Intelligence (DAI). In DAI, agency is a special *multiagent system*, which is composed of entities called agents. An agent is, in this context, an inferential problem solver, namely a system which is able to solve a problem exploiting its inferential abilities. Moreover, each agent enjoys several properties [24], such as autonomy (the agent controls its actions and its internal state), social ability (the agent interacts with other agents), reactivity (the agent perceives and responds to changes in its environment), and pro-activeness (the agent exhibits goal-directed behavior). For a survey of the field of DAI see [9] [10] [22].

In order to focus the attention on a novel approach to agency, developed by authors [1], it is useful to conceive an agency as a unitary machine. This interesting approach considers the agency as a type of machine which reifies the phenomena of intelligent cooperation among men.

We consider each machine as a reification of a model of a phenomenon [2]. In fact, each machine contains an embedded model of a phenomenon: the form of the model is the *architecture* of the machine, whereas the formalism is the set of *components* of the machine. In other words, we can state that a machine *emulates* the phenomenon whose model is embedded within the machine itself. We note that the term ‘emulation’ refers to the fact that a machine reproduces the external outcome of a phenomenon, without adopting the same internal process. On the contrary, the term 'simulation' is used to denote an entity which reproduces both the external outcome and the internal process of another entity.

Among the phenomena which have been modelled and reified into machines, we can distinguish three broad classes, which, in turn, address the following taxonomy of machines.

- *World machines*. World machines are machines which embed models of phenomena belonging to the world external to the human mind. Thus, world machines, called simply machines where no ambiguity arises, emulate phenomena of the world. Examples of world machines include motors, generators, compressors, etc.
- *Information machines*. Information machines are machines which embed models of some phenomena belonging to the intelligence of man and to the intelligent interaction between man and external world. In particular, information machines emulate the fabricative intellectual activities of man (see Section 11.2). Information machines are called also *metamachines* because they are reified models that act, as operators, on other models, called *information*, considered as operands. Among the operations that information machines can execute on models, we mention processing and interaction. Processing of models is performed by *computers* (machines of *informatics* or *computer science*). Interaction with world, by means of models, is performed, together with processing, by *robots* (machines of *robotics*).
- *Cooperation machines*. Cooperation machines are machines which embed models of phenomena belonging to the intelligent cooperation among men. Cooperation machines emulate a society of men. Thus, they are composed of several cooperating agents, each one roughly emulating the intelligence of a single man of the society. Consequently, each agent is a metamachine (usually, a computer or a robot). An agency is a particular cooperation machine which is composed of inferential cooperating agents.

In conclusion, we have illustrated three starting points from which the concept of agency has been reached: Minsky's explanation of the complexity of performances of human mind, the consideration of the multiagent systems in DAI, and the conception of machines that reify the phenomena of cooperation among men.

11.3.2 The Babel Tower Aporia

From the previous considerations, it is clear that an agency is composed of several cooperating agents. Each agent is a computer or a robot that roughly emulates a man composing, together with other men, a society which is, in turn, emulated by the whole agency.

A fundamental critical problem arises and stimulates interesting, important and modern research directions in the field of artificial intelligence [23]. The critical problem concerns a structural difficulty closely connected to the notion of agency and called *Babel Tower Aporia* [4]. The Babel Tower Aporia is encountered in the construction of an agency, when we consider that each agent has both to operate and to cooperate. On one side, it is useful to have specialized agents able to perform specialized operations. On the other side, it is necessary to have a uniform framework in which the agents can cooperate. Thus, the variety of problems that an agency can address pushes toward heterogeneity of the agents, whereas the information exchanging, that has to be performed within the same agency, pushes toward homogeneity of agents. Therefore, the Babel Tower Aporia consists in the problem of uniformly integrating the specialized agents in order to build an agency.

We have addressed the solution of the Babel Tower Aporia by proposing an architectural structure of each agent as arranged in a couple of semiagents [1] (see Fig.11.4).

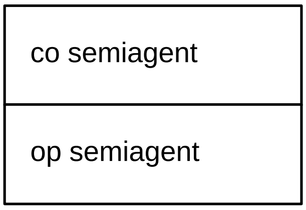

Figure 11.4 - An agent structured as a couple of semiagents.

The first semiagent, called *op semiagent* or *op*, performs specialized functions for providing a local problem solving ability, namely it provides operative functions. The second semiagent, called *co semiagent* or *co*, performs uniform functions for bringing the whole agent to be an active part in an unique and uniform global process of cooperation together with other agents, namely it performs cooperative functions.

Thus, the architecture of each agent of an agency involves the coexistence of the op, different in each agent of the agency, and of the co, uniform in every agent of the agency. The op semiagents perform functions, the co semiagents conjugate the functions together.

11.3.3 Dynamic agencies

We are now in the position to outline the process (Fig.11.5) that addresses the construction of an agency exploiting the new and powerful technique of mobile intelligent agents [13] in order to overcome the Babel Tower Aporia.

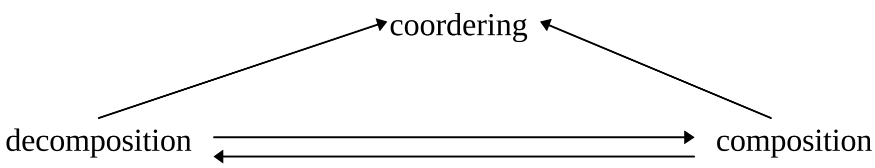

Figure 11.5 The design and construction process of an agency.

The first step in designing an agency is the *decomposition* of the problem (or of the class of problems) for which the agency is being constructed. In this phase, the problem is decomposed into a set of subproblems which are simpler than the original problem although they are not trivial. In fact, each subproblem requires, for its solution, some operative functions that individuate an *ideal op semiagent* which performs the requested functions and is, therefore, closely related to the subproblem. Thus, at the end of the decomposition, it is identified an *ideal agency* composed of ideal op semiagents; each ideal op semiagent addresses the solution of a subproblem obtained from the decomposition of the original problem whose solution is, thus, addressed by the ideal agency.

The second step in designing an agency is the *composition* of the *fixed agency*. In this phase, starting from the ideal agency resulting from the previous step, the designer covers the functions of the ideal op semiagents with the available *real op semiagents*. We can consider the available real op semiagents as organized in an *inventory* regarding to the functions they can perform; hence, the inventory stores the real op semiagents on the basis of their types, namely the set of functions they are able to perform. Therefore, the composition can be seen as the *recruitment* from the inventory of the real op semiagents that functionally cover the ideal op semiagents of the ideal agency [5]. More precisely, the set of functions of the selected real op semiagents has to be a superset of (i.e., to contain) the set of functions of the ideal op semiagent.

The decomposition and the composition are not completely independent steps: often the designer identifies an ideal agency that, for some reasons, cannot be covered by the real op semiagents in the inventory; so he has to return to the decomposition step and to try to find another decomposition in subproblems in order to identify another ideal agency to be covered. Thus, decomposition and composition are not performed in a static order but the designer performs them dynamically jumping from one to another and vice versa.

Once the recruited real op semiagents have been selected, they form the fixed agency. Thus, the fixed agency is composed of incomplete agents since each agent has only the real op semiagent and there is not a common and uniform framework of cooperation. The reason is that the real op semiagents in the inventory are computer and robots that have been designed and constructed by different companies which did not know how and in which applications the real op semiagents will be used. Thus, the fixed agency is not ready to solve a problem until the co semiagent will be inserted in every agent. However, the real op semiagents of the fixed agency are organized in a topology in which the connections among them can be exploited to communicate. But, as previously indicated, at this stage the real op semiagents are not able to utilize the communication channels since they lack the cooperation functionalities.

Among the various ways for inserting the co semiagent in each real op semiagent of a fixed agency, we have focused the attention on the one which emphasizes the role of the new technique of mobile code systems [13]. The third step is called *coordering*, and brings to an agency, called *dynamic agency*, in which each agent is complete in its operative and cooperative parts. The goal of the coordering step is to insert a co semiagent on each real op semiagent of a fixed agency.

A unique prototype of co semiagents (called *Mobile Intelligent Agent*, or *MIA*), that is implemented as a mobile code system, travels in the communication network among the real op semiagents (called, by contrast, *Fixed Intelligent Agents*, or *FIAs*). FIAs and MIA are considered as intelligent because they have inferential abilities. During its travel MIA, firstly, reaches, and replicates itself on each FIA and, secondly, evolves into a common and uniform cooperation process in order to build co semiagents. In this way, starting from heterogeneous FIAs (namely, real op semiagents that are computers or robots with specific abilities), inserted as nodes in a communication network, we automatically build an agency by spreading uniformity as the result of travel, replication, and evolution of the MIA. Each agent of a dynamic agency is thus composed of a specific FIA (real op semiagent) on which a uniform replica of the MIA has been installed and evolved (co semiagent).

The advantages provided by the dynamic agency approach are summarized in the flexibility of the process adopted to obtain a resulting agency tuned toward a given goal. Firstly, since the class of problems solved by a dynamic agency is related to the travelling MIA, the simple sending of a new MIA over an existing dynamic agency causes the modification of the application that is addressed by the dynamic agency. Secondly, it is easy to select the components (i.e., the agents) of a dynamic agency since the MIA can select the FIAs on which it replicates and evolves. Finally, the composition of a dynamic agency can be changed also during the process of solution of a problem without great effort, by allowing the MIA, which has generated the dynamic agency, to replicate and to evolve itself on new FIAs.

In conclusion, the coordering step provides the uniform integration of the various real op semiagents of the fixed agency in a common framework of cooperation by means of a unique bearer of homogeneity, namely the MIA.

11.3.4 Technological applications of dynamic agencies

We describe some applications of dynamic agencies to robotics tasks. This research is under development in the AIRLab (Artificial Intelligence and Robotics Laboratory) of the Politecnico di Milano Artificial Intelligence and Robotics Project. It involves two dynamic agencies, called MORO exploring agency and MORO cleaning agency, respectively. Both agencies are composed of a workstation (called MORO-0) and of two mobile robots (called MORO-1 and MORO-2, see Fig.11.6).

Figure 11.6 The two mobile robots MORO-1 (left) and MORO-2 (right).

The problem addressed by MORO exploring agency is to automatically build the geometrical map of an environment whose characteristics are initially unknown. Hence, the MORO exploring agency, by its operation, provides a model of the environment (intended as a phenomenon of reality). More precisely, the machine represents a model by performing the fabricative intellectual activity that involves the passage from general knowledge about exploring an environment (intended as a set of axioms, or rules, provided by man) to the new knowledge, produced by the machine, about the map of the environment (intended as a set of theorems derived from axioms).

The initial set of rules for exploring a generic environment is given by human to the initial set of FIAs (namely MORO-0, MORO-1, and MORO-2) from which the construction of the dynamic agency starts. Each FIA (except the workstation, which interacts with the user) is a robot that can both move in the environment (namely, it can navigate in the environment) and perceive, exploiting sensors (such as cameras), phenomena happening in the environment. (Note that Fig.11.6 depicts MORO-2 as equipped with an arm; however it is equipped by a camera during our experimental activity.) Moreover, the FIAs are integrated in a communication network, in particular in a radio Ethernet network. The travel, the replication, and the evolution of a particular MIA (exploiting the network) on the initial FIAs build a dynamic agency that has the capabilities of the FIAs for exploring a given environment. For example, let us suppose that the set of initial FIAs is composed of some FIAs able to build two-dimensional maps and of some FIAs able to build three-dimensional maps. Thus, if the purpose of a dynamic agency is to build a three-dimensional map of an environment, then the corresponding MIA selects only suitable FIAs, namely those able to build a three-dimensional map.

Once MIA has reached and has replicated itself on every FIA, the replicas of MIA evolve in order to complete the construction of the co semiagent of each agent of dynamic agency. After the completion of each agent, the dynamic agency addresses the solution of the assigned problem, in this case, the construction of the map.

In producing the map of an environment, each robotic agent of the MORO exploring agency iteratively performs the following sequence of operations.

- The agent takes a picture of the environment by its camera, analyzes it and extracts from it a set of low-level features (i.e., segments) of the perceived environment.
- The agent recognizes some mid-level features of the environment, called objects. In particular it looks for parallel and contiguous segments (which are merged in a single segment), for polygons (which represent walls, columns and other objects of the environment), and for concavity and convexity of objects. Each agent (actually, each FIA or op semiagent) can be specialized in recognizing particular mid-level features.
- The agent integrates the new perceived objects within its old map. This requires to identify which ones of the just perceived objects are really new and which ones have been already perceived and inserted in the map.
- The agent communicates the new knowledge it has discovered (i.e., new objects perceived in the environment) to other agent. Moreover the agent receives the knowledge (i.e., objects) discovered by other agent and inserts the received objects in its map performing a procedure similar to that of the previous step.
- The agent determines, possibly by negotiating with other agent, the next move (direction and distance) in the partially known environment. The next sequence starts from a new picture taking.

Thus, after each sequence, every agent (i.e., robot) has the complete knowledge of the global updated map. The agents exploit this knowledge in order to cooperatively find, for each one of them, the new move that is like to produce the maximum global increase of knowledge. For example, following this very general principle, the two agents never point in the same direction. Exceptions are when the direction presents interesting features, such as the possible presence of a new room, that has to be explored, or the presence of objects that are not completely modeled because of some difficulties in their perceptions (for scarce light, for redundant shadows, and so on).

In the case of exploring an unknown environment, we can fully appreciate the advantages provided by adopting a flexible and renewable machine, such as a dynamic agency. For example, if we consider that a dynamic agency is composed of robots (i.e., agents) of different physical sizes, we can exploit small agents in order to explore narrow environments, short agents in order to reach difficult portions of environments, and so on. Moreover, we can exploit the flexibility in composing a dynamic agency in order to dynamically include and exclude robots (i.e., agents) during the exploration of an environment. In this way, dynamic agency adapts itself to the environment of which it is constructing a map and provides, therefore, a very precise model of the environment. This second advantage, namely the on-line variability of the composition of a dynamic agency, is enabled by the adoption of co semiagents that are generated by a mobile agent. In fact, a MIA can, even when a dynamic agency is executing a task, reach, replicate, and evolve itself on different FIAs varying in this way the set of agents composing the dynamic agency. We note that the variation of the set of FIAs, over which the MIA replicates itself, corresponds to the variation of the set of operative functions that a dynamic agency can perform (we recall that FIAs, namely op semiagents, provide the operative abilities to an agent and, thus, to the dynamic agency).

The second dynamic agency, namely MORO cleaning agency, addresses the problem of automatically wiping an environment, acting as a support for man in performing fabricative activities. The MORO cleaning agency is enriched by the knowledge acquired by the MORO exploring agency. In fact, the map of the environment to clean is obtained by the latter and it is exploited by the former.

We note that the MORO cleaning agency is composed from the very same agents of the MORO exploring agency but, in this case, the mobile robots exploit their brooms in order to cover, by navigation, all the environment and to (consequently) wipe it. Thus, when the MORO exploring agency ends its task, a new MIA travels, reaches, and evolves on the agents in order to set up a new cooperation framework for the activity of MORO cleaning agency. This evidences, once again, the great flexibility of the dynamic agency methodology.

In cleaning the environment, each robotic agent performs the following sequence of operations.

- The agent negotiates with other agent the part of the environment (described by a geometrical map known by both agents as result of exploration) it has to clean.
- Once the agent has an assigned part of the environment, it produces a plan for covering all the assigned part.
- The agent navigates in the environment following the plan in order to clean its assigned part.

Moreover, there are some mechanisms for avoiding conflicts among agents (such as the attempt of contemporaneously reaching the same physical point) and for helping agents that experience difficulties in performing their tasks.

One of the advantages of adopting a dynamic agency for supporting man in fabricative activities, such as the cleaning of an environment, lie in the parallelism that it offers. Such parallelism can be exploited for tackling the efficient resolution of the problem and it is provided by the decomposition of the global problem in subproblems that are distributed over several agents. Moreover, the possibility of varying the composition of a dynamic agency allows to increase its generality by changing the type and the number of agents in order to have small agents for cleaning narrow environments, large agents for better addressing the cleaning of wide environments, and so on.

In the following Section we introduce a partial description of creativity based on the architecture and the process of designing and constructing dynamic agencies.

11.4 Creative dynamic agencies

In this Section we illustrate a novel partial description of the human creative intellectual process. We recall that we trust in the claim that creative acts are intellectual activities that cannot be fully modelled. However, we suggest a reduction of the scope of what cannot be modelled within these intellectual activities. Our novel approach to the description of the creative product is organized in two levels of abstraction. The more abstract one is called macro description, whereas the less abstract one is called micro description. After the explanation of these two levels, we outline the process that brings to the product of the creative act. At the end of the Section, we present some interesting properties of the proposed approach.

11.4.1 Macro description of creativity product

Our approach starts from the obvious consideration that the novelty, produced by a creative act, often substitutes old knowledge of reality with new knowledge of the same reality, even if sometimes the novelty introduces knowledge of previously unknown reality.

Therefore, our approach is based on two fundamental criteria. The first criterion considers each single creative act as an intellectual partial event which produces new knowledge of reality that partially innovates the previously reached knowledge of reality. The second criterion considers each single creative act as an intellectual distributed event devoted to produce, possibly in parallel, a set of distinct, although connected together, models of some interrelated phenomena.

These two criteria introduce the need of modelling, even if partially, the process of creativity, as an event producing partial and distributed results which require, as in the case of dynamic agencies, a distinct role played by operation (of each agent) and cooperation (among the agents of the agency).

Thus, we intend the creative act as the invention of some models of some phenomena. More precisely, assuming that concepts do not exist in isolation, the creative act starts from a set of integrated phenomena of reality and ends to a set of integrated models of the knowledge of reality (see Subsection 11.2.1).

Metaphorically, we consider the set of phenomena of reality as *patches* in a *field* (Fig.11.7), whereas we consider the set of models of knowledge of reality as *tiles* in a *mosaic* (Fig.11.8).

In this metaphorical representation we distinguish between a phenomenon (considered as a patch) and a set of phenomena (considered as a subfield, namely a set of patches): moreover we distinguish between a model of a phenomenon (considered as a tile) and a set of models of phenomena (considered as a submosaic, namely a set of tiles).

The set of phenomena initially considered is a set of related phenomena, possibly derived from the decomposition of a more complex phenomenon. In this latter case, the creative act provides the model of the complex phenomenon obtained by the integration of the models of the composing phenomena.

Since the starting phenomena are related together, or because they belong to the same phenomenology class, or because they show some similarities, or because they share some common elements, it is clear that the corresponding models are related together. Thus, the creative intellectual activity produces a submosaic of related models corresponding to a subfield of related phenomena. In our metaphorical representation, related phenomena are patches with some boundaries in common, similarly, related models are tiles with some boundaries in common. For example, in Fig.11.7, patches α, β and γ are three related phenomena, whereas, in Fig.11.8, tiles a, b and c are the corresponding three related models. Thus, the relation among phenomena is topologically represented by the closeness of the patches. Moreover, the relation among models is topologically represented by the closeness of the tiles.

The mosaic can be conceived as the representation of some knowledge, at a given time, of either a single man or the whole human culture. In the first case, creativity acts are performed by the man. In the second case, creativity acts are performed by the whole mankind.

We note that there can be patches to which do not correspond any tile. The lack of tiles for some patches is essentially caused by two reasons. The first reason is related to the fact that there is not a good model of a phenomenon. The second reason is related to the fact that a phenomenon has been not recognized yet as one for which it is interesting to develop a correspondent model. Therefore, each model always corresponds to a phenomenon, but not vice versa.

In order to further detail, in the next Subsection, the product of a creativity act, we consider each tile as an agent of a particular agency, called *creative dynamic agency*

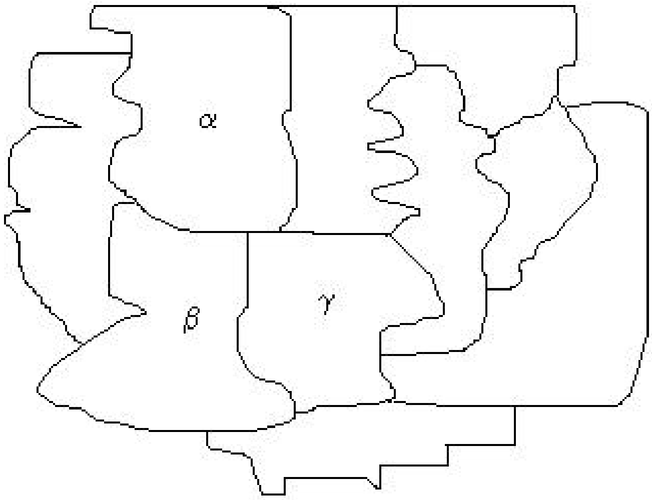

Figure 11.7 Phenomena as patches in a field.

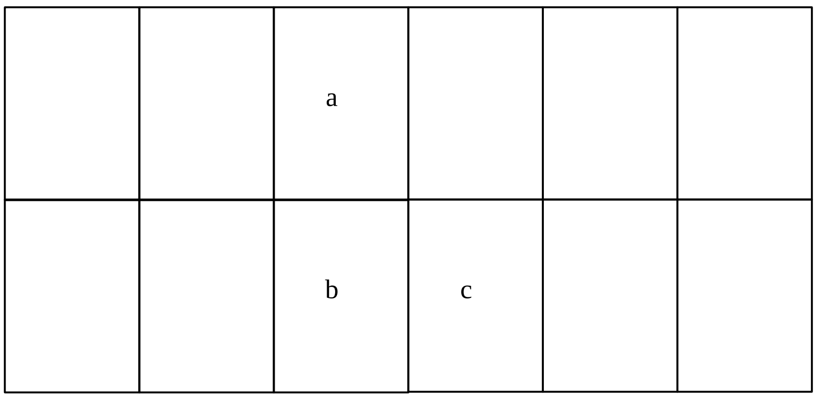

Figure 11.8 Models as tiles in a mosaic.

11.4.2 Micro description of creativity product

In this Subsection we address the description of how the newly invented tiles are topologically integrated within the old tiles. In other words, we address the problem of how the new knowledge is uniformly integrated within the old knowledge. Our presentation is based on the analogy with the integration among different agents performed for developing a dynamic agency (see Subsection 11.3.3).

We consider each tile in the mosaic as corresponding to an agent in a dynamic agency. In particular, each tile, called *creative agent*, has both an operative part and a cooperative part. The first one addresses the representation of the phenomenon for which the model (i.e., the tile) has been developed. The second one addresses the representation of the connections existing among the model (i.e., the tile) and other related models in cooperating together to reach a global and major representation based on each individual minor representation.

In order to describe the topological integration of the new tiles within the old ones, we individuate three classes of tiles involved in a creative act (Fig.11.9):

- *black tiles*: the tiles corresponding to the newly invented models;
- *gray tiles*: the tiles, corresponding to previously invented models, with some boundaries in common with black tiles;
- *white tiles*: the remaining tiles, corresponding to previously invented models, without any boundaries in common with black tiles.

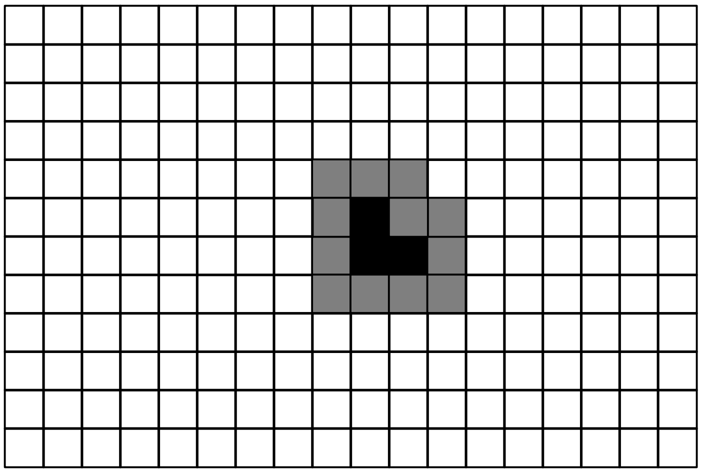

Figure 11.9 Black tiles, gray tiles and white tiles in a mosaic.

Thus, the product of the creative activity is a mosaic composed of three different types of tiles.

The black tiles correspond to the newly created models, thus they are new in the whole structure, namely both in the representation of the models and in the representation of the connections with other related models. The gray tiles correspond to the old models which are related to the new invented models. Therefore, as a consequence of the insertion in the mosaic of the black tiles, gray tiles maintain their representation of the models but they have to modify their connections with the related models. Actually, for gray tiles, only the connections with other gray and black tiles are modified, whereas the connections with white tiles remain unmodified. The white tiles are models that are not interested by the invention of the new tiles because they are not directly related to any new model. Thus, white tiles are changed neither in their operative parts nor in their cooperative parts.

To summarize, the characterization of each tile as black, gray, or white gives evidence of the newness of the parts embedded in the tile. In particular, a black tile has both new operative part and new cooperative part. A gray tile has old operative part and new cooperative part. A white tile has both old operative part and old cooperative part.

Therefore, since each tile and, hence, each model corresponds to an agent, the cooperative part of a tile corresponds to the co semiagent, whereas the operative part of the tile corresponds to the op semiagent.

Creative dynamic agency is composed of the black and the gray tiles, which, intended as creative agents, have to be uniformly organized in a common framework. In fact, as detailed in the next Subsection, both the black tiles and the gray tiles require the invention of cooperative parts.

It is important to stress that the creative act, which produces both the black tiles and the cooperative parts of the gray tiles, cannot be completely modelled. Thus, the new models are called black tiles because they are newly invented by means of an inscrutable human creative intellectual activity. Similarly, the cooperative parts of the gray tiles are newly created by means of an irrational intellectual activity, thus the impenetrable composition of a black (i.e., new) cooperative part with a white (i.e., old) operative part produces a gray tile. In conclusion, there is a difference between the degree of novelty of the product (which is represented by black, gray, or white) and the inscrutability of the creative act which delivers the new products. Moreover, the two characteristics are orthogonal in the sense that the irrationality of the creative act does not interfere with the property of a tile of being black, gray, or white.

In order to further detail the description of the product of a creative act, we illustrate three different interesting situations that arise when a newly created black tile is inserted in a mosaic (see Fig.11.10).

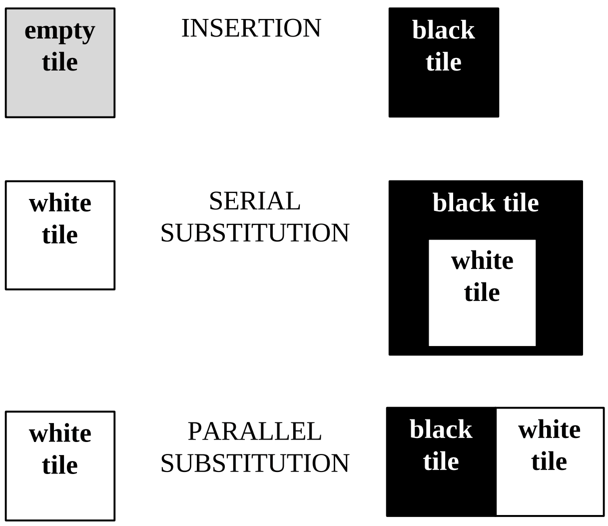

Figure 11.10 Three ways for inserting a new tile (right) on an old tile (left).

- The first case is called *insertion* and is related to the situation in which the new tile is a model of a phenomenon for which there is not, at the moment of the invention, a model in the mosaic. In this case, the black tile is inserted on a “empty” tile which means that there was not a model for a particular phenomenon (see Subsection 11.4.1).
- The second case is called *substitution* and is related to the situation in which the new tile is a new model of a phenomenon for which there is, at the moment of the invention, an old model in the mosaic. In this case, the black tile is inserted on the white tile which represents the old model of the phenomenon. As particular cases of substitution, we have individuated the two following interesting ones.
    - *Serial substitution*: the new model contains, as a particular case, the old model. Thus, the new black tile contains the white tile.
    - *Parallel substitution*: the new model is an alternative to the old model. Thus, the black tile and the white tile are placed side by side to form the new tile.

We return on the implications of these different ways of inserting a new tile within old tiles in Subsection 11.4.4.

Thus, the product of a creative act is represented by a creative dynamic agency, and the way in which such a machine functions describes the way in which the various models, corresponding to the various tiles, are integrated together. A more detailed description of how every agency, and in particular creative dynamic agency, works is out of the purpose of this paper and can be found in [1] [3] [4].

On the other hand, it clearly falls within the scope of this paper a further detailed description of how the creative dynamic agency is constructed. In fact, such description, representing the creative process, provides the advance of the epistemology on creativity within the epistemology of rationality which is presented in this paper. Therefore, we are going to illustrate, in the next Subsection, the structure of the process which starts from phenomena and ends to models organized in a mosaic.

11.4.3 Creativity process

We are now in the position for outlining the sequence of steps that constitute the process of creativity, namely the process that produces models of phenomena. This process is represented by the process of designing and constructing a dynamic agency, which has been presented in Subsection 11.3.3.

The proposed novel methodology of the creative process is partial, namely we illustrate the rational description of the sequence of the steps of the process, but we think that each step cannot be completely modelled.

The process of creativity is organized in three main steps which are presented in the following description (see Fig.11.11).

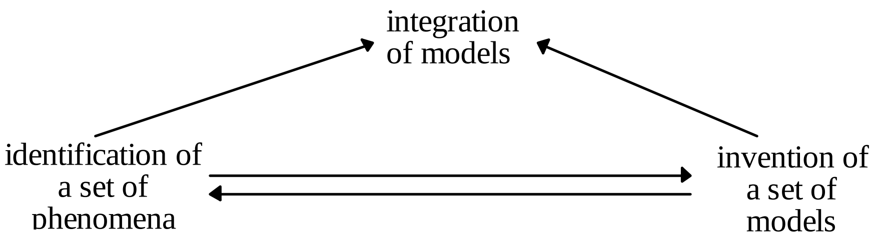

Figure 11.11 The creativity process.

- *Identification of a set of phenomena*. In this step (see Subsection 11.4.1) the set of related phenomena to be modelled are recognized and isolated from the other phenomena of reality. In other words, a set of patches is identified among the patches of the field of phenomena of the reality. For example, in Fig.11.7, the set of identified patches is {α,β,γ}. Identification of a set of phenomena corresponds to the decomposition of the problem in the case of dynamic agencies.
- *Invention of a set of models*. In this step (see Subsection 11.4.1) the set of models of the phenomena identified in the previous step are created; in addition, some of the already invented models, in particular those which are related to the new ones, are chosen out. Thus, the operative parts of the creative agents composing creative dynamic agency are identified. More precisely, the operative parts of black tiles are invented and are inserted in the mosaic. Moreover, the set of gray tiles, for which new cooperative parts are needed, is identified as the set of neighboring tiles. For example, in Fig.11.8, the set of invented tiles, corresponding to phenomena {α,β,γ} of Fig.11.7, is {a,b,c}. Actually, {a,b,c} is the set of the operative parts of the black tiles. Invention of models corresponds to the composition of the fixed agency in the case of dynamic agencies which consists in the recruitment of real op semiagents from the inventory. The recruitment interests two types of real op semiagents (each one corresponds to an operative part of a tile): the newly devised real op semiagents and

the already devised real op semiagents: the first ones correspond to the operative parts of the black tiles, the second ones correspond to the operative parts of the gray tiles.

- *Integration of models*. In this step (see Subsection 11.4.2) the newly invented models are integrated in a common framework within the old models, in particular, within those old models which are related to the new ones. Therefore, each creative agent composing a creative dynamic agency is completed with cooperative part. In other words, the cooperative parts of both the black tiles and the gray tiles (identified in the previous step) are invented in order to uniformly organize the tiles. In particular, the cooperative part of each black tile is newly created for representing the new connections among the black tile and the other black and gray tiles. The old cooperative parts of the gray tiles are eliminated because they do not adequately represent the new situation with the new models. Thus, the cooperative part of each gray tile is, as well, newly created for representing the new connections among the gray tile and the other black and gray tiles. Moreover, the new cooperative part of each gray tile has to maintain the existing connections among the gray tile and the white tiles. The integration of models corresponds to the coordering in the case of dynamic agencies.

The proposed creativity process, which produces a complete creative dynamic agency, presents an interesting particular case: the reorganization of the knowledge, without the invention of new models. In this case, the initial step is not performed since no model is invented, therefore no phenomenon has to be selected. The second step is partially performed: more precisely, some models, namely gray tiles, are identified in the mosaic. The identified models are those for which the reorganization is going to be performed. The third step is completely performed with the particularity that the tiles interested by the insertion of the new cooperative parts have the operative parts unmodified, since they are gray tiles.

This special case of the more general creativity process can be seen as a form of “weak creativity” which does not consist in creation of new models, but in reorganization of the existing models.

11.4.4 Properties of creative dynamic agency

The approach of creative dynamic agency has several interesting and important properties that we are going to illustrate in this Subsection. In particular, we recall some concepts presented in previous Sections and further detail them.

The first property is that the proposed framework enables an extension based on the conception of each creative agent as a creative subagency. This implies the introduction of the concept of *subtile* for representing the fact that a tile can be itself composed of several subtiles organized in a submosaic. This property is very important for describing the interesting situation of a model of a phenomenon composed of various subphenomena. In this case each subtile of a tile represents the model of a subphenomenon of the phenomenon whose model is represented by the tile. Moreover, the possibility to consider a tile as a set of subtiles is important in the insertion by substitution of a new tile within a mosaic (see Subsection 11.4.2 and Fig.11.10). The new tile can be the hierarchical (in the case of serial substitution) or heterarchical (in the case of parallel substitution) composition of the old model together with the new model.

This consideration introduces the second property of creative dynamic agency: the approach is suitable for representing both the incremental evolution of a model and the invention of alternative paradigms. In fact, as illustrated in Subsection 11.4.2, the insertion by substitution of a new model within the old models can be performed in two interesting ways: serial substitution and parallel substitution. The first way corresponds to the incremental evolution of a model in which the new model improves and dominates the previous one. The second way corresponds to the invention of alternative paradigms in which the new model coexists and competes with other alternative models. Actually, in this case, the models are called paradigms (see Subsection 11.2.1). An example of the incremental evolution of models is related to the well-known principle of persistence of the formal properties proposed by Hankel, for which the properties of a formal framework conserve their validity in a more general formal framework. For example, the properties of the sum of natural numbers remain valid in the extension to integer numbers. An example of invention of alternative paradigms is the explanation, given by Minsky [19], of the complexity of human mind. For Minsky there is not any global model of the mind, but there are several alternative partial models which coexist competing together.

The third property of our approach is the fact that the paradigm of creative dynamic agency is a new approach that, from one side, presents the product of the creative act as linked with the notion of creative dynamic agency, whereas, from the other side, presents the partial description of the design process of creative dynamic agency. In particular, the product of the creative act is described in terms of tiles (i.e., creative agents), each one composed of an operative part and of a cooperative part, and organized in a topological structure called mosaic. The process of creativity, corresponding to the design process of creative dynamic agency, is a sequence of steps which starts from identification of phenomena to be modelled and ends to uniform integration of models. The descriptions of the product and the process are based on the product and the process of design and construction of a dynamic agency (see Subsection 11.3.3). The application of the framework of dynamic agencies outside the technical field of artificial intelligence, as in the case of creativity, involves a precise definition and delimitation of the roles of rationality and irrationality. Moreover, the description of what is rational has to be not too limited, namely the partiality must not be too high, because, in this case, the framework is not able to explain anything. In the case of creativity, we recall that creative dynamic agency is a rational description of the general structure of the product and, partially, of the process of creativity which embeds irrational elements as parts of the structure. Thus, creative dynamic agency is a tool for describing the integration between rationality and irrationality in the intellectual creative activity.

The fourth property is the role assigned to the activity of critique (see Subsection 11.2.1). The critique is now intended as a dynamic mechanism for learning in performing creative acts. In other words, the critique improves the creative acts by progressively perfecting them. More precisely, we can conceive a history of creative acts, each one being performed in a “better” way than the previous one. The criterion for deciding whether a creative act is “better” than another can be based on several parameters such as the extension of the scope of the activity, the degree of the modification to the established knowledge and the generality of the invented models.

The fifth property of the approach based on creative dynamic agency is the separation between the creative invention of models of phenomena and the creative invention of the topological framework among these models. This is one of the key points of our proposed partial methodology for creativity. The separation between invention of models and invention of their relationships is present in each creative agent composed of both an operative part, namely the model, and a cooperative part, namely the contribution of the agent to the global topology. Thus, the division of each tile into two parts envisages the division of the creative act into two parts: the invention of the models of phenomena and the invention of the connections among new models and old models. In other words, our approach, centered around agency, which is a cooperation machine, further expands the level of the rational (less partial, even if not total) description of the creative act. This expansion is driven by the powerful role played by cooperation. It enables, by means of the modern problem solving technique represented by agency, a balance between truth finding in modelling a phenomenon (the operative part of a creative agent) and consistency saving in integrating together various interrelated models (the cooperative part of a creative agent).

The last property is the validity of the description provided by creative dynamic agency also in the case in which one thinks that the product or the process of creativity can be fully modelled. In other words, although this is not the epistemological approach of the authors, creative dynamic agency is a good model for representing creativity considered as a completely rational intellectual activity. In this case, the partiality of the description introduced in the previous Subsections is eliminated. Therefore, if one adopts the epistemological point of view of fully rational creative acts, then he asserts that the representation not only of the models in the tiles of the mosaic, but also of the detailed description of the steps of construction of creative dynamic agency, can be entirely specified. Thus, the important point is that the approach of creative dynamic agency is valid for two epistemological points of view: the complete rationality of creativity and the non total rationality of creativity. In the first case, the design process of creative dynamic agency is specified in each of its parts, whereas, in the second case, which is the epistemological approach adopted by authors, such process is left unspecified in some of its elements.

11.5 Creative dynamic agencies and artificial intelligence

We have proposed (see Section 11.4) a novel approach, called creative dynamic agency, that represents a suitable description, organized at two levels of abstraction (macro description and micro description) of the product of creativity. Moreover, we have illustrated the sequence of steps that constitutes the process of creativity, namely the process that man performs to create models of phenomena. From the previous considerations, it is clear that we propose a partial description of the process: in fact, each step of it (identification of phenomena, invention of models, integration of models) cannot be completely modelled, whereas the sequence of these steps can receive a rational description.

We are now in the position to show the advantages and implications of adopting a dynamic approach both in our description of creative act and in artificial intelligence.

Dynamic agency, in artificial intelligence, is composed of several agents: each one of them has an operative part and a cooperative part, which allow to solve the critical problem called the Babel Tower Aporia (see Subsection 11.3.2). According to this approach, creative dynamic agency partially describes creativity, giving an account of operation and cooperation, in the form of identification of phenomena, invention of models and integration of models. This reflects the double face of intelligence between operation and cooperation, between heterogeneity and uniformity, and between methodological approach and inventive approach (see Subsection 11.2.2). Since our approach to the epistemology on creativity is embedded in a more general epistemology of rationality, what we have stated about intelligence is also valid for creativity, intended as a specific part of intelligence, which is composed of methodological elements and inventive elements. It is clear that only methodological elements can have, in our framework, a rational description, whereas inventive elements, namely irrational elements, cannot be modelled, in accordance to Bergson's proposal of a fabricative and a creative intelligence (see Subsection 11.2.2).

From the previous considerations, we can envisage a similarity between inventory of models and inventory of agents involved by a dynamic agency, which are respectively included in science culture and technique culture. This aspect reflects the circularity between science and technique in humanistic and scientific culture and emphasizes the importance of the development of dynamic agencies as a purpose, since it stimulates the affluence of new models of agents.

Adopting a dynamic approach also brings many epistemological advantages. In a dynamic agency, it is possible to solve critical problems by means of the cooperation paradigm: in particular, in addition to the Babel Tower Aporia, that we have mentioned before, the designer-user critical problem. This problem is due to the non correspondence, in the usual machines and systems of artificial intelligence, between the begin-designer and the end-user. The dynamic approach allows more flexibility both in design and in problem adaptation; this flexibility of dynamic agency derives from the passage from information machines to cooperation machines, which results in a more complex architecture. The passage from information to cooperation makes dynamic agency free from low level limits, by rising its abstraction level, and allows more adaptable software and hardware. Therefore, adopting dynamic agency, the begin-designer coincides to the end-user, allowing a better and more flexible performance.

An additional and valuable result of the proposed approach can be derived from the interpretation of the two critical problems of Babel Tower Aporia and of designer versus user conflict. This interpretation is oriented to draw the consequences of these problems when we are facing the important case of creative dynamic agency. We note that the elimination of the Babel Tower Aporia, within creative dynamic agency, indicates the property of this novel methodology of enabling several men, engaged, in various moments and places, in creative acts, to avoid to fall into the situations of misunderstanding, hostility, and mutual isolation. We further note that the elimination of the designer-user conflict, within creative dynamic agency, provides the powerful bridging of the gap between the subject performing a creative act and the subject requiring the satisfaction of an exigency of knowing reality. Thus, the property of communication among men engaged in creatively knowing is enhanced.

The study of dynamic agencies in artificial intelligence has furnished an interpretative tool for a partial description of creativity and for elements and considerations that stimulate it. This stimulus is suitable to make more efficient the agency design in order to be more sophisticated in describing the product of the creative activity; therefore the agency becomes more useful in correspondence with the enrichment of human culture, derived from a progressively better knowledge of creativity.

Our approach has considered the study of creativity through a modern and novel problem solving methodology and technique of artificial intelligence, namely dynamic agency. This is an useful way to partial understand creativity, as we have explained before, but also to make more efficient, from a scientific and technical point of view, dynamic agencies. Therefore, the study and the knowledge of creative act is not only a philosophical, in particular epistemological, issue, but also a scientific issue.

From one hand, the purpose of the process of the comprehension of creativity is philosophy (in particular gnoseology, namely what is knowledge and how can be reached) and the means is science: in fact, we use creative dynamic agency, namely a tool derived from artificial intelligence, to partially describe what creativity is and how it works, which is a philosophical issue. Hence dynamic agency provides an useful and precise approach to tackle the epistemological issue of methodology and creativity: it is an interpretative instrument to understand conditions which stimulate creative acts.

From the other hand, the purpose is scientific and the means is philosophical: in fact, we want to make dynamic agency more efficient. The incentive to study and describe creativity can be useful from a technological point of view: we describe creativity using dynamic agency approach, therefore it is possible, by studying creativity, to improve technical researches about agencies, that represent the most advanced and complex machines developed in artificial intelligence.

The previous considerations give a proof of the richness of the mutual exchange between science and humanistic culture, namely between artificial intelligence, intended as a science and an engineering, and philosophy, in particular epistemology. This synergic approach is also adopted by Thagard [21]: he proposes a new epistemological conception in the study of scientific reasoning, by exploiting some artificial intelligence techniques.

Finally, the deeper understanding, within the epistemology of rationality, of the new threshold dividing rationality and creativity provides fruitful and enlightening guidelines for educating man in the act of creativity. Thus, this is a pulse toward the promotion of both human and natural sciences and an emphasis to the modern approach driving toward unity between these two aspects of the same culture [17].

11.6 Conclusions

In this paper we have illustrated a novel partial methodological approach to creativity, called creative dynamic agency. Although dynamic agency is a novel problem solving paradigm within artificial intelligence research, we see as quite general the benefits offered by our approach toward an advance and a better understanding of the epistemology of rationality on creativity.

The proposed methodology is a peculiar blending of scientific and humanistic culture. In fact, the technical methodology of artificial intelligence, called dynamic agency, is applied to creativity, where it plays the role of a methodology for defining some rational aspects of creative act, leaving undefined several other irrational aspects. More precisely, our approach proposes an epistemology on creativity embedded in the epistemology of rationality envisaged by the debate between weak approach and strong approach to artificial intelligence.

Creative dynamic agency is suitable to represent the product and the process of creativity. In particular, the product of creativity is described as a mosaic of models which is similar to a dynamic agency, whereas the process of creativity is partially described as the sequence of steps performed for uniformly constructing the mosaic and it is similar to the process of designing and constructing a dynamic agency.

It is interesting to outline that, among the various types of products of creative activity, which we deem represented as creative dynamic agency, it exists the product of the creative act of describing the mind. It is a singular coincidence which validates the soundness of our approach. In fact, one of the well-known and appreciated proposals of description of human mind is the Minsky's approach which claims that the mind is represented by an agency, called "The Society of Mind" [19].

Finally, the creative dynamic agency approach, with appropriate changes, can be adopted also by those accepting the thesis of total rationality of creativity.

Future research directions will address the more detailed partial definition of the step of uniform integration of new models within old models, the analysis of the architecture of creative dynamic agency, the study of the multilevel structure of creative dynamic agency, and the more general topics of interactions between scientific culture and humanistic culture.

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