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Fusion of the Methods

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Abstract

The objective of this study was to explore the research methods, synthesize methods as one unified method and based on that outline a roadmap towards information acquiring and applying in artificial intelligence (AI). The unified method was created by using analysis and synthesis in the design science. Exploration of the research methods revealed three clusters of methods: methods to describe interdependence models, methods to analyze and optimize interdependence models, and methods to classify interdependence models. Further, interdependence models were located as instances into the class model, influence of data and time were added to give dynamic behavior and the unified methods was observed. The method was further evaluated in acquiring and using information in the artificial intelligence.

The analysis yielded that in the whole-part (WP) - structure parts and the whole they form, represent interdependence relationships between and inside the whole or part instances. Methods include analysis and optimization.

On the other hand according to the analysis, parts and the whole they form, represent instances of the class (C)-structure meaning that instances of the WP-structure belong concurrently also to the class structure. This connects WP- and C-structures.

For artificial information acquiring and using purposes the structure gives hints of a latent method. The requirements for the latent method are introduced.

The whole-part-class (WPC)-structure with analysis and optimization methods facilitates the synthesis of the research methods and hints that different research methods are parts of the unified method. Further, the unified method serves as a proposal for the road-map for the artificial general intelligence.

1. Introduction

According to the Oxford dictionary [1], knowledge is facts, information, and skills acquired through experience or education; the theoretical or practical

understanding of a subject. Further, the dictionary says that intelligence is the ability to acquire and apply knowledge and skills. On the other hand, the objective of the research methods is to increase knowledge by a scientific method, for example, convert tentative belief to accepted knowledge [2] and apply the knowledge which leads to intelligence. Thus, research methods are suitable building blocks for our design science study in synthesizing methods as one method and in validating the utility of the method. In this study, the designed artefact, unified method is designed to imitate the knowledge acquiring and applying process and how the acquired knowledge and skills are used. Hawking [3] states that a good theory needs not to be watertight but to facilitate progress of science and a good theory is based on a reasonable amount of assumptions, fits to a large set of observations and predicts certain measurements. To facilitate the progress of science in artificial intelligence the unified method ought to give the first step of the roadmap towards artificial general intelligence.

The problem of “intelligent computer” of artificial intelligence is approached from many directions. According to Nielsen [4], “in the early days of AI research people hoped that the effort to build an AI would also help us to understand the principles behind intelligence and, maybe, the functioning of the human brain. But perhaps the outcome will be that we end up understanding neither the brain nor how artificial intelligence works.”

Novel important approaches of AI include deep neural networks. After 2006 the problem of intelligent computer has been approached by using, for example, deep neural networks. Neural network contains neurons, weights and their connections. Deep neural networks consist of a many-layer structure where different layers are specialized to different levels of the hierarchy. It means that there are two or more hidden layers. According to Nielsen [4], the reason for this kind of networks with new training algorithms, is the ability of deep nets to build up a complex hierarchy of concepts. Nielsen [4] explains the structure: “It’s a bit like the way conventional programming languages use modular design and ideas about abstraction to enable the creation of complex computer programs. Comparing a deep

network to a shallow network is like comparing a programming language with the ability to make function calls with no ability to make such calls. Abstraction takes a different form in neural networks than it does in conventional programming, but it's just as important". Goodfellow et al. [5] list different approaches to machine learning, modern practical deep neural networks and avenues of deep learning research. Bengio [6] discusses learning algorithms for deep architectures in particular those used to construct deeper models such as Deep Belief Networks. The synthesis of the research methods has basically similar objectives as the modern neural network studies. Therefore, also the results might remind the results of the modern neural studies.

Many research methods exist; therefore in this study for the purpose of synthesis, categorizing and generalizing research methods reduces the amount of units to work with and helps in understanding the relationships between the methods. In the real world research methods need to stand out from the rest and therefore differences between the research methods are often emphasized, but similarities of the research methods may offer more valuable information for synthesizing: in this study the research methods are generalized [1 and 7] and categorized according to their objectives in acquiring and using knowledge for the purpose of the synthesis of the research methods. According to the Oxford dictionary [1], generalize is defined as "to form general notions by abstraction from particular instances." Further Lee and Baskerville [7] explain how to use the different types of generalizability (not just statistical). Generalization is justified because many research methods use their own names, for example, for variables, relationships, classes, etc. Therefore, describing the fusion of the methods by trying to list many different synonyms used by different research methods might blur the idea.

Research methods increase human knowledge and intelligence, but what connects different research methods together, which method supports learning, which method is used in innovating or in reasoning, and how different methods together with data and time are synthesized as one method?

The objective of this study is to explore the research methods, synthesize methods as one single method and based on that approach the artificial acquiring and applying of intelligence to outline the first step of the road-map towards artificial intelligence. The research problem is: what is the unified method to support the acquiring and applying process of artificial intelligence?

The used research method was design science [8, 9, 10, and 11]. Selection of design science was justified, because the artefact could not be predicted based on any earlier design [9] and the objective was to solve

construction problems [10]. The special feature in our design science approach is that research methods by themselves serve as building blocks of the artefact.

The paper is structured as follows: First, we introduce the related research. Then the research process is described in Section 3. The analysis results are presented in Section 4. Finally, the discussion and conclusions are given in Section 5.

2. Related research

In the scientific community there is an ongoing dispute if an intelligent computer is possible. The progress in artificial intelligence is often based on increased computing power and on improvements of the computing algorithms. Nielsen [4] writes that "I believe it's not in serious doubt that an intelligent computer is possible". Nielsen [4] formulates his research question: "Rather, the question I explore is whether there is a simple set of principles which can be used to explain intelligence? In particular, and more concretely, is there a simple algorithm for intelligence?" Nielsen calls for a simple set of principles or a simple algorithm for intelligence. Nielsen [4] gives examples that support the existence of a simple set of principles or a simple algorithm for intelligence and writes that his own prejudice is in favor of there being a simple algorithm for intelligence, but he doubts that it may not be possible to find. Opposite opinions have been expressed, for example, Minsky's [12] society of mind theory explains the human intelligence or any other cognitive system as a vast society of individual agents (simple processes). Intelligence is based on a vast number of different agents and agents can represent, for example, different types of processes with different purposes, different kind of knowledge and different methods for producing results. According to Minsky [12], "the power of intelligence stems from our vast diversity, not from any single, perfect principle". Seemingly, Minsky's view sounds to be in contradiction with the existence of a simple set of principles or a simple algorithm for intelligence, but a closer look reveals that Minsky's agents also perfectly fit with the unified method as well as Nielsen's simple set of principles or a simple algorithm for intelligence.

As the Oxford dictionary [1] states, intelligence is the ability to acquire and apply knowledge and skills. Artificially acquiring knowledge means machine learning. According to Mitchell [13], "a computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in, as measured by P, improves with experience E." Another dimension of intelligence,

applying knowledge, refers to analysis and optimization of acquired (learned) knowledge.

How the research methods are used as building blocks in the design of the fusion of the methods? Tradition is to categorize research methods, for example, into quantitative and qualitative research methods. Research methods are often categorized based on their differences in answering the research question, but methods can also be categorized for the purpose of synthesis according to their similarities [14] in acquiring and applying knowledge. In this study, categorizing quantitative and qualitative methods according to their objective in acquiring and applying knowledge, reveals similarities of the quantitative and qualitative methods and possibly shows that different research method are just pieces of the same method. Many research methods have their own “vocabulary” that leads to synonyms. Many synonyms (e.g. variable, property, attribute etc.) and using the same terms in different meanings hinder the synthesis of the methods. For example, the term, dimension, is difficult. In grounded theory the term, dimension, expresses the location of the property, for example, the property “size” along the continuum from “small” to “large”. In this context the term, dimension, does not mean the dimension of the space in question as in the context of quantitative methods, for example, with mathematics.

Mathematical methods serve as examples of quantitative methods. Mathematical methods to describe interdependence relationships are called functions and they are expressed by variables and mathematical operators. The category of interdependence includes, for example, functions and equations of mathematics, physics, statistics, etc. The category of quantitative interdependence covers also outliers like ultimate regression models e.g. multi-layer perceptron (MLP) networks [15 and 16], which also explain interdependence, etc. Cause-effect models are special cases of the interdependence models that describe real causality between the variables. Methods of analysis and optimization include, for example, methods to solve equations or methods to calculate the value of the function and different optimization methods like linear and nonlinear programming, gradient methods, Monte Carlo methods, genetic algorithms [17, 18], etc. Mathematical methods have different kind of limitations because of, for example, measurement scale of observations, continuity, correlation-causality, inverse function or not, etc. Mathematical classifying methods include, for example, methods of set theory, cluster analysis, discriminant analysis, Kohonen self-organizing map [19], fuzzy sets with membership function [20], etc. Often mathematical methods are used in deductive way, because the theory is known or at least partly known. It means that the soundness of the existing

theory can be tested by using mathematical method, but the theory can also be changed according to the data if the mathematical method proves the theory to be wrong which as for leads to induction.

Qualitative methods are used in a very similar way. In qualitative studies concepts with their properties are observed, for example, like in grounded theory [21]. Concepts represent classes of constructs (instances) and the construct (instance) of a class represents the interdependence relationships that describe how the values of the properties (attributes) are changed. The way how the values of the properties (attributes) are changed can be described, for example, by qualitative expressions like “a little”, “a lot”. The “qualitative interdependence” is usually expressed by words.

Analysis and optimization in qualitative studies mean reasoning when classes, instances and interdependencies are known. Results of “analysis or optimization” are derived by interpreting how the values of the properties (attributes) are changed (by methods) and how interdependencies affect the result. Categorization (classification, conceptualization) is done by looking for within-group similarities coupled with intergroup differences [14]. In categorization similarities can be found among variables (attributes, properties) of the category or among the behavior of the category (verbal description, methods, functions). Often qualitative methods are used in inductive way. It means that the theory or hypotheses are derived from the data and the objective is theory or hypothesis generation. Whereas, testing of theory refers to deduction.

Grounded theory [21] gives an example of qualitative methods: The theory development starts with open coding phase. First, in grounded theory the objective of the open coding phase is to classify the data into categories. The process of grouping concepts that obviously belong to the same phenomena is called categorizing, and it is done to reduce the number of units to work with [21]. Seed categories help when starting categorizing. The open coding process starts with seed categories [22] that contain essential stakeholders, phenomena, and problems. Seaman [23] notes that the initial set of codes (seed categories) comes from the goals of the study, the research problems, and predefined variables of interest. During the open coding, categories are modified: New categories appear and existing categories are merged, because especially in the beginning of the coding, new information appears. Second phase in the theory development is the axial coding. The objective of the axial coding is to further develop categories by defining their properties, dimensions and causal conditions or any kinds of connections between the categories. The dimensions represent the locations of the property or the attribute of a category along a continuum [21]. As the last step, the

phenomenon represented by a category is given a conceptual name [21]. Basically, grounded theory explains how to establish categories (concepts) and interdependence models (constructs) that explain the theory.

Objectives of the quantitative and qualitative methods are very similar. Acquiring and applying intelligence contains iterations of the trial and error process [24]. Qualitative methods seem to offer more knowledge during the inductive phase because usually there is no theory available whereas quantitative methods seem to offer knowledge during the deductive phase because some theory or hypotheses may be available for testing.

To solve our research problem we need to place into the structure research methods that explain the interdependence relationships with research methods that class interdependence models (objects, constructs, functions, etc.) into categories, add data and time and analyze or optimize interdependence models – this synthesis facilitates observation of the unified method. Klein and Myers [25] discuss the principle of hermeneutic circle, which claims that “all human understanding is achieved by iterating between considering the independent meaning of parts and the whole that they form”. In our study, whole-part structure and class structure may form a common structure and analysis and optimization can offer tools for using the structure.

3. Research process

The research process was iterative (Figure 1). Design science was selected as the research method because it offers theoretical background for exploration and synthesis in building the artefact, evaluation of the artefact, design science is wide enough to cover technical, social and informational resources in building the new method and design science approach can contain other research methods [26]. Our objective was to build an artefact to facilitate observation of the method. According to Nunamaker et al. [11], design science based systems development provides the exploration and synthesis of available technologies that produce the artefact (system) that is central to this process. According to March and Smith [8], design science is used for the construction and evaluation of the artefact and to develop associated theories. March and Smith [8] further separate two cases: The construct, model, method or instantiation may already exist or be totally lacking. In the latter case research is emphasized. The artefact that we designed in this study was novel and no comparable artefacts did not exist. March and Smith [8] write about the evaluation of the theory: "The

model should be evaluated in terms of their fidelity with real world phenomena, completeness, level of detail, robustness, and internal consistency".

The unified method consists of methods that explain interdependence structure, class structure, and analysis and optimization. According to Hevner et al. [27], technical artefacts are allowed in design science. Van Aken [28] widens design science to social innovations and Järvinen [26] further widens “the view on design science with the third resource type, informational resources used in the development of a new innovation”. Hence according to Järvinen [26], “the new innovation can be based on new properties of technical, social and/or informational resources or their combination”.

Design science was selected and the selection was justified: In design science the artefact may change the “reality” because it may facilitate new system and design science is used for studying unknown areas or new ideas [9]. In design science one can start from problem/solution/theory and build an artefact [8]. Design science is used to build new things based on ideas, which are at least partly based on earlier research [10]. The artefact can be e.g. construct, model, method or instantiation and design science is artefact-centric [8]. According to van Aken [28], “in design science research, the focus is on the so-called field-tested and grounded technological rules and a technological rule is a prescription to follow if one wants to achieve in a certain setting a given outcome”.

First, the research methods were categorized for the purpose of synthesis according to their objective in acquiring and applying knowledge. Then, the structure was designed to connect different research methods. The structure was designed so that different research methods can be placed into it to imitate the artificial acquiring and applying process of knowledge. For the purpose of synthesis, data was added to the structure to explore the influence of observations and the effect of time was added to make the structure dynamic as a function of time. Dynamic structure together with data facilitate the observation of the fusion of the methods. Because some methods may be latent the evaluation of the unified method should also reveal requirements for the latent methods. As the last step, the unified method was “field-tested” with examples of commonly known research methods.

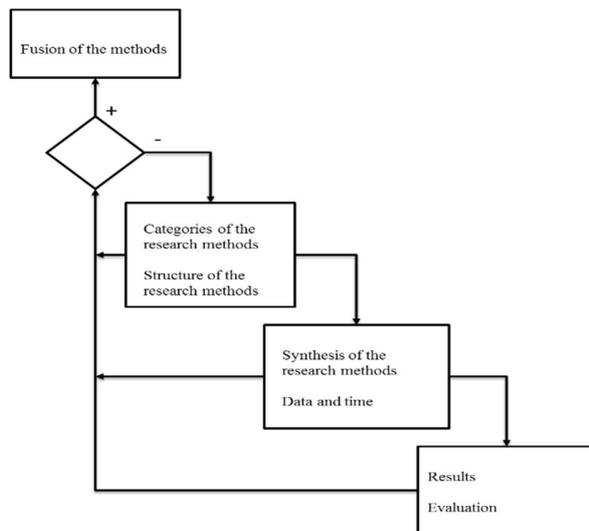


Figure 1. Research process

3.1 Categories of the research methods

Researchers like to select one or a couple of research methods and emphasize the superiority of their selection compared to competing methods because analysis using limited amount of methods is easier than using synthesis of methods. Synthesis requires knowledge of the various research methods, holistic view of the methods, capabilities to unify synonyms or components and separate overloaded terms with different contents, etc. This explains why more attention is paid on differences than on similarities of the research methods. Exploring similarities offers a new viewpoint for synthesis of the research methods. If we take a bird's eye view over the research methods we observe that there are many research methods that basically acquire same or similar knowledge and use it with similar objectives. Methodological triangulation [29] and mixed methods approach [30] give hints of these similarities. Methodological triangulation means that multiple research methods are used and their results are compared to each other [29]. Mixed methods approach consists of different analyses [30]. Combining different analyses is based on methodological pluralism. Methodological pluralism states that there is no one "correct" method of science but many possible methods [31]. Therefore, the objective of the research method in acquiring and applying knowledge was selected as the criteria to categorize methods. Generalization in this context means that, for example, MLP-networks are generalized as regression models that define regression functions and therefore belong to interdependence models, because the objective of the MLP-networks'

training is that the network learns the interdependence between the inputs and outputs based on the observed data. Correspondingly, methods of constructs (instances) change the values of the attributes creating interdependences between the attributes and therefore they also belong to interdependence models, but methods that class object into classes (categories) do not belong to interdependence models but they belong to classification models.

3.2 Structure of the research methods

The structure that connects the research methods was designed so that different research methods can be placed into it and it concurrently explains how the methods are connected to each other. The work was started by exploring within-case similarities and cross-case differences of the research methods [14]. Categories of the research methods were placed into the structure and links between research methods were established. The observation how an interdependence structure and a class structure are linked to each other led to the architecture of the system.

3.3 The role of data and time in the structure and utility of the method

Observations (data) and time were added into the model. Methods change the values of the attributes along the time so attributes have different data values at different moments of the time. A special case is a static instance where attribute values are not changed along the time. Adding time and data as a function of time changes the static structure into dynamic structure and enables observation of the unified method. According to the design science method, the theory was evaluated.

3.4 Visual interpretation

Understanding the fusion of the methods is easier by using visual interpretation. Also visual interpretation serves as a field test. The objective of the visual interpretation is to illustrate the fusion of the methods as a set of objects that map to the surfaces of the geometry. Visual interpretation clarifies the development of the structure because it simplifies the development by reducing the dimensions of the space to fit to the representation purposes. In visual interpretation the structure is illustrated as objects of the three dimensional space. Originally, the short-term memory [32] is cited to use 7 ± 2 elements meaning that a practical size of the space at one time could have 7 ± 2 dimensions. Nowadays, the short-term memory is estimated to have 4 ± 1 dimensions. In visual

interpretation the space is reduced to three dimensional space to make illustrations possible and expressed as two dimensional drawings.

4. Results

According to the research process, the artefact was iteratively developed and tested. Analysis results consist of 7 observations with justifications and selected field tests. The field tests serve as a sample of the unlimited population of tests. In the following, the results of the analysis are described.

Fusion of the methods:

1. Research methods can be clustered into three categories: First, methods to describe interdependence models, second, methods to analyze and optimize interdependence models and third, methods to classify interdependence models (and parts of them) (Table 1). Interdependence model maps to whole-part (WP) structure, classification model maps to class (C) structure and analysis and optimization models analyze and optimize interdependence models.
2. Research methods can be synthesized as one method: Interdependence models are concurrently instances of the class structure (whole-part-class, WPC-structure), and analysis and optimization methods are used to analyze, optimize, decide the relevance of the parts or the wholes (interdependence models) and apply the structure.
3. In acquiring information the WPC-structure is achieved by imitating the iterative trial and error process [24] by adding and removing observations as a function of time.
4. Knowledge is stored in and applied by using the WPC-structure.
5. Artificial, computerized innovations and creativity require a quantitative classification method of the interdependence models to browse the class structures, evaluation method to guide the browsing process and a method to generate variants of the interdependence models. The method is latent.
6. The dimensionality of a practical interdependence model is low.
7. Summary of the results.

Fusion of the methods was evaluated by randomly selected field tests.

Table 1. Examples of methods to describe interdependence, analysis and optimization and classification

	Methods to describe interdependence models (cause-effect as a special case)	Methods to analyze or optimize interdependence models	Methods to class objects into categories	Terms used to describe interdependence (cause-effect)	Terms used to describe category	Terms used to describe variable
Quantitative methods: Examples of research methods and terms used in e.g. mathematics, physics and statistics.	Mathematical functions and equations, functions and equations of physics, e.g., regression models, correlations, multi-layer perceptron networks, etc.	General calculations in mathematics, e.g. solving equations, maximization and minimization e.g. linear and nonlinear programming, gradient methods, Monte Carlo methods, genetic algorithms, etc.	Quantitative methods class variables not interdependence models. Methods of set theory, cluster analysis, discriminant analysis, Kohonen self-organizing map, fuzzy sets with membership function, etc.	Function, equation, mapping, control surface, etc.	Cluster, set, etc.	Variable, attribute, etc.
Qualitative methods: Examples of research methods and terms used in e.g. discovery of regularities.	Constructs described by qualitative methods e.g. constructs in axial and selective coding in the qualitative grounded theory method or in shaping hypotheses in the case study research, etc.	Use of the created theory or hypotheses to explain the phenomenon. The theory explains e.g. the behavior or how to find the optimum, etc. The theory can be created by using e.g. qualitative grounded theory or by the case study research.	For example, open coding in the qualitative grounded theory method where the interdependence (cause-effect) models are clustered into categories, within-case analysis and cross-case analysis in the case study research, etc.	Construct, whole, part, behavior etc.	Cluster, category, concept, class, etc.	Attribute, property, variable, characteristic, etc.
Design and implementation methods in software engineering: Examples of terms used in object-oriented (OO) programming.	Whole-part structure, object (instance) in the object-oriented programming.	Analysis, optimization, simulation, etc. of the object (instance) or of the whole-part structure.	Building the class structure, classification in object oriented design.	Object, instance, whole-part structure.	Class, superclass, subclass, abstract class, concept.	Attribute, variable, etc.
Visual interpretation	Surface (special cases: curves, lines, points).	Moving on the surface: Analysis and optimization when using the surface as a control surface and when evaluating the relevance of the surface.	Collecting classes of analogous surfaces.	Surface (special cases: curves, lines, points).	Classes and variants of the surface, different control surfaces, etc.	Variable.

4.1 Research methods can be clustered into three main categories: Methods to describe interdependence relationships, methods to analyze and optimize interdependence models, and methods to classify interdependence models

Clustering research methods by their objective in acquiring and applying knowledge yielded three categories:

First, research methods explain the **interdependence relationships**. For example, in quantitative analysis functions, equations, etc. and constructs in qualitative analysis represent interdependence relationships – variables and the behavior. OO-paradigm is not a research method, but a practical notation in presenting the design. In designing with OO-paradigm, objects (instances) of a class represent interdependence relationships. As a visual interpretation in quantitative analysis, functions and equations define a surface in the multidimensional space of variables (attributes) (Figure 2). Surface is the visual interpretation of the quantitative interdependence model, for example, at the time T_0 variables (attributes) of the interdependence model have their values and the values of the attributes at time T_0 define a point of the surface in the multidimensional space defined by attributes (Figure 2). On the other hand, in qualitative methods constructs represent wholes or parts or together whole-part (WP)-structures. WP-structure defines methods and attributes and how the methods change the values of the attributes aka how the attributes (properties) get new values (Figure 3). Respectively, whole or part or whole-part structure defines a surface in the multidimensional space of attributes. Similarly in qualitative analysis, at the time T_0 attributes (properties) have their values and the values of the attributes at time T_0 define a point of the surface in the multidimensional space defined by attributes (properties) (Figure 2). So we observe that both quantitative and qualitative methods that describe interdependence relationships define a point of the surface at a certain moment of the time in the multidimensional space of variables (attributes). Quantitative functions and equations map to qualitative constructs (wholes or parts) or whole-part-structures and vice versa.

New observations are handled in a similar way independently of the quantitative or qualitative methods. When the time is started, for example, at the time T_1 attributes (properties) have new values according to the qualitative constructs or quantitative functions. Now the values of the attributes (properties) define a new point of the surface (Figure 2). This mechanism creates the surface and imitates knowledge acquiring along the time. In other words, the computer

learns to know the surface that describes the behavior (interdependence) of the construct (aka instance, function, etc.). The values of the attributes at different moments of the time (e.g. T_0 , T_1 , etc.) are stored and this imitates memory. Memory consists of the values of the attributes along the time – points of the surface. When there are in the memory enough observations of the attribute values along the time the interdependence is known or in other words the surface describing the behavior is known - or the (mathematical or not) expression that describes the surface is known (Figure 2).

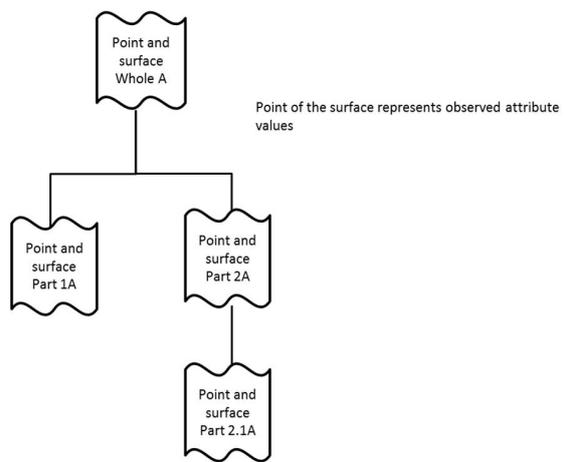


Figure 2. Interdependence models of the whole-part-structure expressed as “surfaces” of the wholes and parts

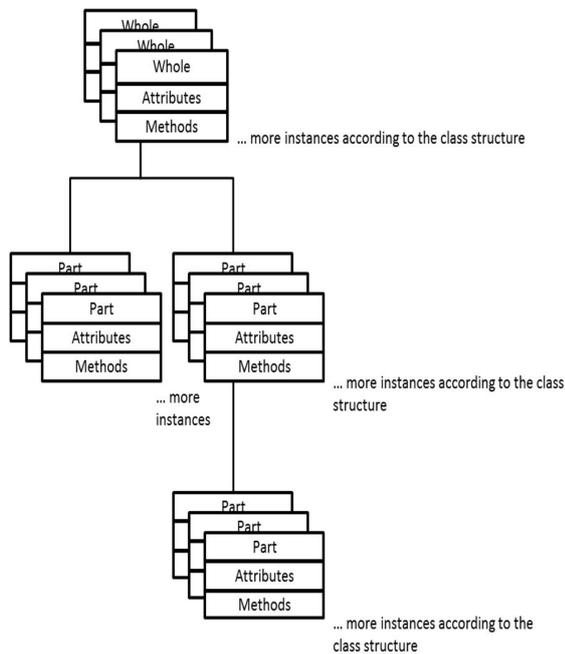


Figure 3. Whole-part-class (WPC)-structure

Second, research methods **analyze and optimize** interdependence models. When the surface is known, or at least partly known, it is possible to move along the surface by means of analysis and optimization. Analysis and optimization mean orientation or moving on the surface defined by the interdependence relationship (e.g. instance of a class, WP-structure, construct, function, equation, etc.). Analysis can be interpreted as answering the question: “Where are we on the surface” and optimization can be understood as “hill climbing” or finding other maximum or minimum. Acquired surface can be used as a control surface.

Repetitive trial and error process generates new observations (points) of the surface and in this way it tightens the surface aka the description of the behavior. Analysis and optimization are valid only on limited areas i.e. known areas. There are numerous constraints that guide analysis and optimization. Constraints are well known from the mathematical analysis and optimization. For example, the surface that describes the interdependencies may contain irregularity areas, excluded areas, unknown areas, etc. Techniques to extrapolate, for example, mean analysis or optimization on the unknown areas of the surface referring to uncertainty. Valid and invalid areas of the interdependence surface are stored when building up the artificial memory. Emptying the memory is the opposite operation consisting of removing the surfaces or parts of them. Repetition is a special case of analysis and

optimization. Repetition creates “hard-wired” paths on the surface to minimize the need for analysis and optimization.

Third, research methods **class** objects (aka interdependence models, constructs, instances, etc.) into categories with the exception that commonly used quantitative classification methods class attributes into classes and qualitative classification methods class instances (attributes and methods i.e. interdependence models) into classes. The quantitative classification method is latent or at least not well defined: The method should classify interdependence models as “close” or “distant” aka it should quantify the distance (anomaly, error, similarity etc.) between the interdependence models. The method should also judge if the interdependence models are “analogous” and “similar” in some sense meaning that they might, for example, be instances of the same class or “different” and “dissimilar” meaning that they may belong to different classes. The method should find by browsing the class structures an “almost” similar or suitable interdependence model where, for example, values of attributes or attributes themselves (components of the attributes) are just slightly different on the area of operation. Also the search for the suitable interdependence model can contain optimization of some attribute or attributes, for example, multiple criteria optimization and development of the object functions. The method we propose measures distance and angle between surfaces aka interdependence models. Methods like distance between vertex points [33], distance between triangles of the surface, Hausdorff distance [34], etc. exist and qualitative classification methods already classify interdependence models. According to the fusion of the methods, the dimensionality of a practical interdependence model is low; this may help the use of the proposed quantitative classification method. The method outlines computerized innovations and artificial general intelligence because it can be used in automating the search for suitable interdependence models from the class structures aka browsing class structures to find innovative interdependency models (functions, instances, constructs).

Both qualitative and quantitative research methods have existing classifying (categorization) methods and algorithms. For example, the open coding in the qualitative grounded theory method [35] explains categorization. When designing using object-oriented software engineering terminology, instances are classified into classes [36]. In the case study research analyzing within-case similarities and cross-case differences produce categories [14]. Quantitative classification algorithms class attribute vectors, for example, Kohonen self-organizing-map [19].

According to the grounded theory [35], when the categories are created the relationships between the categories can be defined. Instantiating the class structure and the relationships leads to the whole-part-structure where interdependence models are connected to each other. Representations, for example, whole-part-structure used in the object oriented-analysis, block structure used in connection with quantitative methods and instances of the cause-effect graphing used in connection with qualitative methods describe interdependence relationships (Figure 4). Cause-effect graphs are used to illustrate the relations between the categories in qualitative analysis; instances of the cause-effect graphs describe relations between the instances. Block-structure may describe both attributes and methods (e.g. mathematical operations inside the block). Interdependence relationships describe how the parts affect the whole and vice versa if the mapping allows inverse use. Within limitations of the question whole-part structure maps to block-structure and to instances of the cause-effect graph and vice versa. Wholes, parts, and whole-part structures are interdependence models and vice versa.

Ishikawa's fish bone diagram [37] is used to show factors causing the effect. Sub-causes are usually grouped into major-causes. Fish bone diagram highlights causes (attributes) and gives hints about their interdependence, but it does not include neither methods nor mathematical operators that change the values of the attributes; so Ishikawa fishbone diagram does not describe whole-part structure but only attributes and their relationships in the structure (Figure 5). Ishikawa fish bone diagram represents cross-section of the attributes and their relationships, but it does not give exact interdependence.

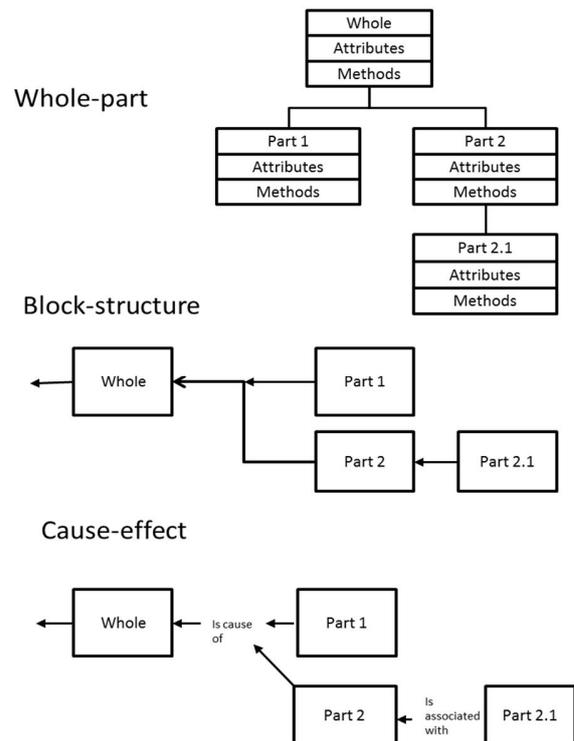


Figure 4. Whole-part structure, block-structure and cause-effect graph

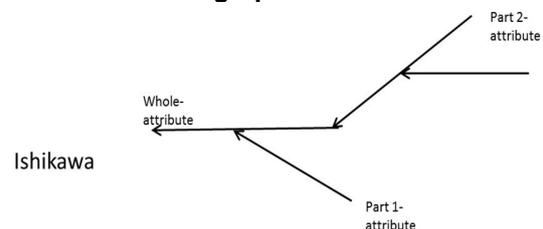


Figure 5. Ishikawa fishbone diagram

To acquire artificial knowledge the whole-part structures needs to be created and improved by adding and refining new wholes and parts aka interdependence models. The improvement processes of the WPC-structures imitates artificial learning and innovating.

The justification why only whole-part- and class-structures were selected to build the structure for the fusion of methods was the observation that all studied research methods either dealt with interdependence in the WP-structures or classification in the C-structures including analysis and optimization methods. Special cases include research methods that, for example, prove existence of the solution. Basically, they represent static cases of the interdependence model. Also a special case of the interdependence structure is the interdependence structure without a block structure, when the instance of

the whole is the same as the instance of the part. Analysis and optimization methods are not parts of the structure but they are used to offer information when applying the structure for artificial reasoning, decision making; in general for applying knowledge. Reasoning or decision making do not always require optimization but often analysis of the interdependence model is sufficient. In those cases analysis means understanding the behavior of the model and deriving conclusions based on the known behavior or in mathematical terms by usual calculations.

4.2 Research methods can be synthesized as one single method: Interdependence models are concurrently instances of the class structure. Analysis and optimization methods are used to analyze, optimize, decide the relevance of the parts or the wholes (interdependence models) and apply the structure

Wholes and parts of the WP-structures (interdependence models) are concurrently instances of the class structures. Together WP-structures (interdependence models) and class structures form the endless whole-part-class (WPC)-structure. Basically this means that there is a path from any instance to any instance; “everything is connected to everything”, but not directly. Figure 3 describes a WPC-structure example and Figure 6 describes its visual interpretation as control surfaces.

Parts and the whole they form can be processed at different abstraction levels. Higher abstraction level contains bigger and more complicated wholes (e.g. buildings, ships, networks, etc.) that can be divided in lower abstraction level into always smaller parts (e.g. atoms, electrons, quarks etc.). New interdependence models can be added as parts of the whole or removed or they can be varied to change the behavior of the whole to imitate innovativeness, artistry, etc. Features like artificial creativity, artistry, selection and innovativeness require the selection of the new parts (interdependence models from the class structures) or variants of the parts by using the proposed method aka “distance and angle between surfaces”. For example, if we think that the whole is a car and its part is an engine. Now, if we replace the engine with a stronger engine (aka change the part) the car’s (whole’s) behavior changes, for example, it has a better performance. Artificial general intelligence requires automating the design process. In other words, in browsing the class structure the proposed method calculates distances and angles between surfaces that describe engines, for example behavior (control) surface of the engine in the

multidimensional space defined by attributes e.g. power, torque, fuel consumption etc. of the different engines, for example gas engines, diesel engines, electric engines etc.

Analysis and optimization are used to evaluate the values of the attributes, the behavior of the parts or of the whole that they form, in general to apply the knowledge. If the result of the analysis or the optimization is not satisfactory, a modified instance, a new instance of the class or an instance of a comparable class can replace the tested instance in the search for a satisfactory result. Of course the process shall be aware of the constraints and the objective – what we are searching for – to facilitate the analysis and optimization. When fitting new instances into the interdependence model, analysis and optimization refer to mathematical or logical operations, for example multiple criteria optimization. Artificial general intelligence requires the browsing of the class structures, moving from one abstraction level to another in the class structures, switching between induction and deduction and analyzing suitability of the interdependence models.

The WPC-structure implements Nielsen’s simple set of principles or a simple algorithm for artificial intelligence [4] by explaining how WP- and C-structures are connected and facilitates synthesis of the research methods as one single method. The structure also implements Minsky’s agents where agents can represent different types of processes [12] because the structure can contain any kind of processes.

4.3 The WPC-structure is acquired by imitating the iterative trial and error process by adding, tuning and removing observations as a function of time and applied by the analysis and optimization methods

Cross-section of the WPC-structure represents the situation at the moment of time, for example, T_0 . Instances, wholes and parts, of the categories exist at time T_0 , but the structure does not evolve, neither artificial learning nor innovating is not possible, and the analysis and optimization give only one result valid at time T_0 . As a visual interpretation, the WPC-structure is reduced to a single point in the multidimensional space of the attributes. When starting the clock, methods start changing the values of the attributes generating new points of the surface (observations). Each point of the surface with the attribute values is stored and this process imitates the artificial memory – the data is stored as points of the surface aka data of the instances is stored as the function of time. Now interdependence

relationships and the structure itself can be analyzed and optimized to estimate the relevance of the wholes and parts. Also wholes or parts can be replaced by more suitable wholes and parts to imitate artificial memory, learning, creativity, innovativeness etc.

When the first version of the WPC-structure is acquired, it is tested by imitating the trial and error process [24] (Figure 3 and 6). Basically, the trial process is reminds artificial learning, but in a sense opposite that now the surface is used as control surface; in learning the behavior is saved in the form of a surface and when trying the behavior is derived from the saved surface.

Computerized imitation of the artificial learning process means storing observations of the behavior of the interdependence model in the multidimensional space defined by attributes as a function of time, fitting a surface along the observations and applying the surface to to generate the behavior. “Enough” points facilitates fitting the surface via the points that further defines the behavior. Behavior is referred with many synonyms like function of the surface, method of the instance or object, behavior of the interdependence model, etc.

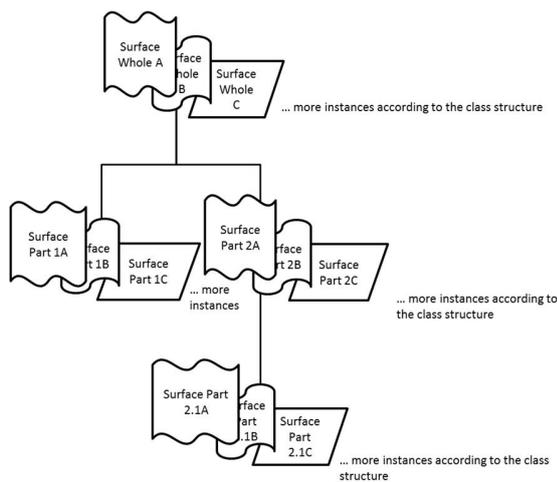


Figure 6. Whole-part-class (WPC)-structure with “surfaces” of the wholes and parts

4.4 Artificial knowledge is stored and applied by using the WPC-structure and therefore computerized implementation of the WPC-structure outlines the road-map for the artificial general intelligence

The fusion of the methods states that interdependence models are concurrently wholes or

parts of the whole-part-structure and instances of the class structure building up a network. The logic structure of the network is a matrix where one logical dimension is the whole-part structure and another dimension is the class structure. As architecture, the WPC-structure consists of an endless network where wholes or parts are connected to wholes or parts and where wholes and parts are concurrently instances of the classes. The network architecture facilitates parallel processing meaning that many elementary operations may be executed concurrently. It also saves memory space because every interdependence model aka instance is saved only once. Synthesis of the research methods refers also to the synthesis of the architecture. The physical architecture of the designed artefact refers to a kind of a modern deep neural network where interdependence models refer to neurons and interconnections between wholes and parts (interdependence models) and their class structure refer to synapses. Also the WPC-structure consists of the blocks like the deep neural networks consist of the hierarchy of the concepts. WPC-structure is endless in all directions and the only limiting factor of the structure is the ability to acquire new interdependence models from new class structures.

History of artificial intelligence contains paradigms for computationalism, connectionism and spreading activation. Computationalism is a family of theories about the mechanisms of cognition; in roughly terms computationalism says that cognition is computation [38]. Systems that implement connectionism are networks consisting of very large numbers of simple but highly interconnected units [39]. Spreading activation describes the method how the search process propagates in the network structures, for example, neural networks or semantic networks. When the search process propagates the activation spreads from source nodes to other linked nodes [40]. The idea in associative retrieval is that it is possible to retrieve relevant information by retrieving information that is “associated” with some information the user already retrieved [41]. The used mechanism is spreading activation. Fusion of the methods synthesizes also the architecture because the architecture implements computationalism, connectionism and spreading activation. Computation is used, for example, in acquiring, evaluating and applying the interdependence models (WP-structures, surfaces), connectionism is used in the acquiring and applying the WPC-structure (interconnections between W-, P- and C-structures) and activation spreads, for example, when activating wholes and parts or when replacing wholes or parts of the WP-structure by browsing the class structure (activations of Ws, Ps and Cs). Physical architecture refers to a hierarchical deep

neural network [3, 4] with afresh definitions of neurons and synapses.

4.5 Computerized, artificial innovations and creativity require a quantitative classification method of the interdependence models to browse the class structures, evaluation method to guide the browsing process and a method to generate variants of the interdependence models.

First, what is an efficient method to browse the class structures? We propose distance and angle. When using the distance and the angle between surfaces' as the browsing key neither identifier nor key of the interdependence model is needed because the interdependence model itself serves as a browsing key: The distance and the angle between the surfaces is the measure of the distance (anomaly, error, similarity etc.) between the compared surfaces. This is also efficient use of memory resources because the data serves as the data and as the key to the data. It also refers to a safe structure because the data is not lost when losing keys, only the data of the damaged area is lost. For example, if we are browsing the class structure of the engines to find a more powerful engine to a car, the method should, for example, classify interdependence models describing engines as similar or analogous or as dissimilar or distant compared to the objective of the search. The method imitates association. If we are looking for an engine, we have in our mind an interdependence model of the engine, for example "control surfaces" describing an engine and we do not mix it, for example, with the interdependence models of the wheels aka "control surfaces" of the wheels, because both attributes and methods are different: the distance and angle between the control surfaces of engines and wheels is long, undefined.

Mathematical methods, for example Kohonen self-organizing-map [19] with Sammon description [42] can give a measure of the distance between the attribute vectors. Distance between surfaces has been approached by distances between vertex points of the surfaces, distances between triangles of the surfaces, Hausdorff distance [34], etc. Proposed solution uses integrals over the difference inside the selected area. The integral quantifies the "distance" between the surfaces and the angle between the surfaces is quantified by normal of the partial derivatives in selected points. The surfaces (interdependence models) are classified based on these two quantifications. Also various quantification methods (e.g. texture of the surface) can developed to speed up the browsing process.

Second, when a candidate surfaces (instances) are found, their suitability can be evaluated, for example, by multiple criteria optimization. If the surface is not suitable the optimization gives information, how to change the object functions (how to change surfaces, instances) to reach the objective and try again.

4.6 The dimensionality of a practical interdependence model is low.

The fusion of the methods says that there is a path from everything (interdependence model, attribute, method) to everything meaning that through the WPC-structure everything is connected to everything by some path. This further means that the dimension of the attribute space is practically unlimited, which easily leads to complicated models with many variables. However, the dimensionality of a practical interdependence model seems to be low to keep the acquiring and applying of knowledge doable within the limitations of computing, connectivity and activation resources. Exceeding practical dimensionality easily leads to faulty operations.

Mathematical models often contain many variables. Working with mathematical models may blur our thinking of the dimensionality of the space at issue and confusion with the abstraction levels may lead to the unintended use of the variables. For example, in a "flat" (no whole-part structure aka no block structure) model variables may in fact affect on different abstraction levels or variables can be components of the same variable. Often, when we analyze more carefully the model we observe that different variables are rather components of the same higher abstraction level variable as, for example, principal component analysis may show. All problems are not suitable for principal component analysis, but the objective to be careful with the abstraction levels can help. Of course the variables in the same model can originate from different abstraction levels, but then the model should include whole-part structure. Exploring the class structure of the interdependence models can help in the selection of the affecting variables.

Theory of the short-term memory [32] offers an estimate of the dimensionality (7 ± 2) of a practical interdependence model. Current studies have still reduced the dimensionality and nowadays the short-term memory is estimated to handle 4 ± 1 variables concurrently. If the amount of the variables (attributes) in the interdependence model exceeds the recommendation of the theory of the short-term memory, it gives a hint to divide the whole or part further into parts. For example, we can improve the

performance of a car by replacing the engine with a stronger engine aka by selecting a new engine from the engine-class and adding a new engine-part into the car-whole, but the improved performance of the car can also be reached by adding a new part into the engine-part, for example, a turbocharger with its own attributes and methods. In this example we improved the performance of the whole (car) by adding a new part (turbocharger) into the part (engine) of the whole.

4.7 Summary of the results

First, the artificial intelligence system collects observations from the real or virtual instances by using measurement instruments, manual or automated inputting from existing databases etc. and saves the information concerning instances in the form of a surface, $y = f(x_1, x_2, x_3, x_4, \dots)$. In the beginning the behavior (methods) of one instance of the class are described as a surface and the behavior (methods) is inherited to all instances of the class. Also in the beginning, instances may contain only one observation point of their surface. This one observation separates the instance from other instances of the class. Later when new observations appear the surfaces of the different instances are improved. Special cases include, for example, curve, line and point. The surface can be linear or nonlinear. The surface is created by fitting a polynomial along the observations as a function approximation. Fitting is first started by linear approximation and then continued to higher order polynomials until the fitting is acceptable in the case in question. Surface can also be based on existing information (behavior). Discrete surfaces are also considered as surfaces. Also valid areas, constraints, discontinuities, etc. are recognized based on the observations or any other source of data. Descriptions of the surfaces are updated when new observations or related data appears. The surface describes the interdependence model (variables and behavior). This is the proposed process of artificial knowledge acquiring.

Second, the collected surfaces are organized and stored in classes, for example, surfaces describing car engines belong to car engine-class and surfaces describing wheels are collected to car wheel-class aka instances' surfaces are stored in classes. Surface classes are interdependence model classes. The classification is based on distance and angle between surfaces. Surfaces or parts of them can also be removed (emptying the memory). Creating and updating surfaces together with classification and storing of the surfaces is the proposed process of the artificial memory.

Third, instance surfaces are linked to each other according to the requirements in question to form

interdependence models (whole-part structure, block structure, function). In this whole-part structure of the interdependence model, each whole or part is described by a surface. The instances (wholes or parts) belong also concurrently to the class structure. This connects whole-part structures to class-structures and vice versa. This also specifies the architecture of the system and, for example, the car engine is the engine-part of the car-whole instance, for example, my car and it participates in the interdependence model of the car and facilitates, for example, moving. Concurrently my car engine-instance belong to the car engine-class. This is the proposed architecture.

Fourth, interdependence models are applied by moving on the instances' control surface. This is done using numerous analysis and optimization methods of mathematics. This is the proposed process of artificial apply of knowledge.

Fifth, the system can browse the class structures to find new instances to add, remove and modify the functionality of the interdependence model in question.

In case of deduction, when the new instances are available, the problem can be described as a multiple criteria optimization problem, where $f_1(x), \dots, f_m(x)$ represent equations (surfaces) of the instances of the class structure aka wholes or parts of the whole-part structure in question:

$$\max \{f_1(x), \dots, f_m(x)\}$$

$x \in X$ belongs to R_n ;

X is the set of the feasible solutions.

Usually no such a solution $x \in X$ exists, that maximizes all the functions $f_1(x), \dots, f_m(x)$ concurrently. Multiple criteria optimization can usually give Pareto-optimal solutions to this problem. In the Pareto-optimal solution any value of the objective cannot be improved without concurrently impairing the value of some other objective. The system can be programmed to browse instances of the class structures, try new instances $f_{1n}(x)$ and solve new multiple criteria problems, for example,

$$\max \{f_{1n}(x), \dots, f_m(x)\}$$

Innovativeness emerges in case of induction, when the suitable new instances are not available but the new variants of the instances need to be developed which leads to modification of the multiple criteria problem itself. This means modifying object functions aka criterion functions f_1, \dots, f_m . The system can be programmed to change the multiple criteria problem into a new problem:

$$\max \{f'_1(x'), \dots, f_m(x)\}$$

and solve the problem. Changing the instance description (criterion function) means, for example, adding, removing modifying variables (or parts of them) or changing the behavior of the instance $f'(x')$.

The search for the new instances in deduction and the development of the new variants of the instances in induction is based on the distance and the angle of the compared surfaces. The distance (aka anomaly, error, similarity etc.) between the surfaces is quantified using integrals over the difference inside the selected area (A).

$$\iint_A |f_1(x_1, x_2) - f_2(x_1, x_2)|^2 dx_1 dx_2$$

The partial derivatives of the surface are calculated in the selected points and the normal of the partial derivatives is set. The angle between the normals of the surfaces quantifies the angle between the surfaces. The partial derivatives of the surface expresses the influence of a certain variable at that point. The optimization of the requested variable is done by first searching optimum of the requested variable on the surface inside the selected area (A). If the result is not sufficient, it is possible to move along the surface to the direction expressed by the partial derivative (e.g. gradient method, Monte Carlo, evolutionary computing, etc.) of the requested variable, take a new selected area and solve again the multiple criteria optimization problem. Solution is either an existing instance of some class or a new developed variant of the instance. The candidate surface is selected based on the quantification of the distance and the angle and the optimization of the requested property. In the system the data serves as the data (surface, interdependence model, instance, function) and the key (quantification of the distance, error, anomaly, etc. between surfaces) to the data. The process outlines the requirements to automate the artificial innovation and design process.

4.8 Evaluation of the theory

The fusion of the methods was evaluated to estimate technological rules [28] by randomly selected examples. Computationalism, connectionism and spreading activation are not separately mentioned in examples because they express basic operations at architecture level implementation.

4.8.1 Acquiring information and emptying the memory

- to facilitate artificial acquiring each whole and part (surface) are continuously improved by new observations; to facilitate adaption to new situations, innovations, creativity, etc. each whole and part are continuously compared to other instances of classes and some of them may be replaced by a more suitable instance. In summary, when acquiring knowledge the surfaces are created, updated and classified, when dealing with interdependence the surfaces are used as “control surfaces” and when innovating the class structure of the WPC-structure is used as the source of the new instances or as the starting point for development of new instances.

Emptying the memory means removing, for example, whole-part structures (interdependence models, surfaces), observations (points of the surface), classes etc. The process is opposite to artificial acquiring.

4.8.2 Memory and associative memory

- memory is embedded in the WPC-structure, because each “surface” of the wholes and parts consists of points (observations). Enough points facilitate surface fitting via observed points. The surface describes the behavior (methods, functions). An good artificial memory consists of many “surfaces” of wholes and parts and classes where they belong.

Associative memory refers to the class structure of the instances aka close surfaces or points, the internal structure of the instance (interdependence model) or WP-structure of the interdependence models. Associative memory refers both to the C-structure and the WP-structure.

4.8.3 Analysis, optimization and decision making

- these activities are not direct parts of the WPC-structure like WP- and C-structures but they are related to the development and applying of the WPC-structure; in general acquiring and applying the saved knowledge. Analysis and optimization are tools, for example, when using the knowledge (moving along the surface) and in evaluating the suitability of instances during the artificial trial and error process. Decision making is needed, for example, when browsing the class structure to find suitable interdependence models during the innovation process. Decision making requires both the proposed method, “distance and angle between surfaces”, in browsing the class structures and analysis and optimization in evaluating the suitability of the interdependence models.

4.8.4 Artificial innovations and creativity – this basically latent method can be imitated by the “distance and angle between surfaces”– the tool quantifies the similarity (distance, error, anomaly, etc.) of the surfaces

of the interdependence models. With this tool it is possible to browse and explore the class structures, evaluate candidate surfaces, develop new surfaces, fit new interdependence model candidates into the whole-part structure and evaluate their suitability. Artificial innovativeness and creativity necessitate instance descriptions that can be browsed by computers. The fusion of the methods says that notation of the interdependence model is a surface that contains data and it concurrently serves as the key to the data. A first guess of the instance description could be a “control surface” that is based on 4+/-1 attributes measured by measurement instruments or in the beginning manually inputted. Nowadays web browsers, based on heuristics, can partly browse instance descriptions and associate similar instances. The search is not based on the described method but keywords. The benefit of the proposed method is that the keys are not needed and therefore cannot be lost.

4.8.5 Inheritance, induction and deduction – in the fusion of the methods inheritance is almost similar as inheritance in the object oriented design, but here a subclass can inherit attributes and methods from a superclass and vice versa, because the network is not directed. As an example, son can inherit behavior and attributes from his father and vice versa. This definition of inheritance also denies super- and subclasses, making the network in this sense equal. Inheritance is used in generating variants when browsing the class structure to find new instances for the innovation process.

Induction is the artificial learning process of a new interdependence model and deduction is the process when the interdependence model is used as a “control surface”. In the artificial trial and error process the control jumps back and forth between induction and deduction to update the surface or to find and fit a suitable interdependence model.

5. Discussion and conclusions

The objective of this study was to explore the research methods, synthesize methods as one single method and thus form a roadmap towards artificial general intelligence. Many leading scientists and engineers, for example, Hawking [43], Bostrom [44], Kurzweil [45], Musk, Gates etc. have predicted the appearance of general artificial intelligence. Estimates, like year 2040 for human like artificial general intelligence and year 2060 for artificial super intelligence, have been given. Fusion of the methods proposes one approach towards artificial general intelligence.

Fusion of the methods was developed using design science approach. Research methods were first clustered and then used as building blocks in designing, how the methods link to each other, how they form a single structure and how the data and time affect. The fusion of the methods was observed based on the designed artefact. According to the design science approach the applicability of the theory was tested.

The fusion of the methods consists of 7 observations. First, research methods can be clustered into three main categories: Methods to describe interdependence models, methods to analyze and optimize interdependence models and methods to classify interdependence models (and parts of them).

Second, research methods can be synthesized as one single theory: Interdependence models are concurrently instances of the class structure and analysis and optimization methods are used to analyze, optimize, decide the relevance of the parts or the wholes (interdependence models) and apply the knowledge stored in the structure.

Third, the WPC-structure is achieved by the iterative artificial trial and error process by adding and removing observations as a function of time.

Fourth, artificial intelligence is acquired, stored and used by the WPC-structure and therefore implementation of the WPC-structure can be computerized.

Fifth, to facilitate artificial innovations and creativity a quantitative classification method of interdependence models is required. The proposed method classifies, for example, an interdependence model as similar or analogous or as dissimilar or distant compared to another interdependence model by estimating the distance and the angle between the surfaces in the multidimensional space of the attributes.

Sixth, the dimensionality of a practical interdependence model defined by attributes is low.

Seventh, as summary the results of the study propose a roadmap towards artificial general intelligence.

The fusion of the methods was evaluated by randomly selected field tests.

Järvinen [2] expresses a taxonomy of the research methods. According to Järvinen [2], taxonomies help to select the most suitable research method, because the problem dominates the method selection, not vice versa. Although, the clustering of the research methods here is novel, different taxonomies of the research methods give hints how to cluster the methods. Definition of the method can also give a hint that the method may be a part of a wider cluster. For example, different quantitative and qualitative methods, already according to their definition, define interdependence, classify, optimize, analyze etc. When moving towards detailed design and implementation level, for example, object

oriented paradigm gives hints of the design and implementation techniques and structures [46-50 and 36].

Fusion of the methods is a new method and therefore it cannot be directly compared with any earlier results, but methods to increase the validity of the study, for example, methodological triangulation [29], mixed methods approach [30] and methodological pluralism [31] show that same or similar results can be achieved with different methods. This indirectly suggest that different research methods are more parts of the one single method than independent methods.

Trial and error is a known problem solving and learning process [24]. Here the artificial trial and error process is used to add, modify, delete, etc. observations in the WPC-structure as a function of time.

According to the fusion of the methods, artificial intelligence is acquired, stored and applied by the WPC-structure and therefore computerized implementation of the WPC-structure can facilitate artificial general intelligence. Klein and Myers [25] discuss the principle of hermeneutic circle, which claims that “all human understanding is achieved by iterating between considering the independent meaning of parts and the whole that they form”. Klein and Myers [25] indirectly refer to the WP-structure. WP-structure (interdependence model) is also visible in the modern deep neural networks as Nielsen [4] states: “Deep neural networks consist of a many-layer structure where different layers are specialized to different levels of the hierarchy.”

As an architecture, the WPC-structure consists of an endless network where wholes or parts are connected to wholes or parts and where wholes and parts are concurrently instances of the class structure. The architectural structure resembles massive hierarchical deep neural network structures [4, 5]. Fusion of the methods synthesizes the architecture. Architecture of the artefact implements computationalism [38], (achievement, evaluation and use of the interdependence models), connectionism [39] (connections between W-, P- and C-structures) and spreading activation [40 and 41] (activations of Ws, Ps and Cs). Spreading activation is related with many tasks of the WPC-structure – for example, activation of wholes and parts and replacement of wholes or parts of the WP-structure when browsing the class structure. Parallel processing is suitable in this architecture because two or more interdependence models can be active concurrently.

The fusion of the methods refers to the latent method, quantitative classification of interdependence models, and proposes as the method “distance and angle between surfaces”. The method, based on quantification of the distance and the angle between surfaces is presented.

The question concerning the distance between the surfaces has been discussed in the literature, for example, distance between vertex points [33] or triangles of the surfaces, distance between two free-form surfaces [51], Hausdorff distance [52], etc.

The development of the unified method gave hints of the practical size of the interdependence model. The estimate for the dimensionality (4+/-1) of a practical interdependence model is adopted from literature of the theory of the short-term memory [32]. Principal component analysis is the traditional tool to explore dimensionality of the problem.

To guarantee the validity of the study evaluation of the theory offers some “randomly selected” field tests. The limitation of the study is that the road map towards artificial general intelligence is unknown and therefore the design serves just as a proposal, but the study aims to facilitate the progress of science. The fusion of the methods proposes a roadmap to build artificial general intelligence. The results of the study may help in developing artificial general intelligence and its derivatives.

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