Wisdom - the blurry top of human cognition in the DIKW-model?

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Abstract

Wisdom is an ancient concept, that experiences a renaissance since the last century throughout several scientific communities. In each of them it is interpreted in rather different ways - from a key ability to succesful aging to a human peak perfomance transcending mere knowledge. As a result, miscellaneous definitions and models exist. There is for instance the DIKW-hierarchy that tempts to integrate the concept of wisdom into information science, still without providing a proper definition. The work at hand tries to sum up current approaches (out of computer science as well as others) with a focus on their usefulness for the positioning of wisdom atop the DIKW-model and the actual usefulness of the term for information science. At the end, with our characterization of wisdom as a fluctuating concept, we propose fuzzy sets to model wisdom as a scientific concept.

Keywords: Wisdom, Knowledge, Information, Data, Fuzziness

1. Introduction

Wisdom has been referred to for more than twenty centuries. While an ancient concept, it experiences a renaissance since the last century throughout several scientific communities, for example in psychology, neurology and computer/information science. By all of them, it is interpreted in rather different ways – from a key ability to successful aging (lifespan psychology) to a human peak performance transcending mere knowledge (information science). As a result, miscellaneous definition approaches and integrating models exist.
The work at hand examines the integration attempt mainly used in information science – the Data-Information-Knowledge-Wisdom-Hierarchy (DIKW-Hierarchy), dating back to Ackhoff [1]. It displays wisdom at the top of the DIK-hierarchy, enhancing the concept of knowledge by still unknown properties. (A further description of the model and its implications can be found in Section 1.)
Whilst there exist definitions for the underlying terms of data, information, and knowledge, that several domains may agree upon, wisdom still withdraws from a real integrational view throughout scientific communities. Therefore, in Section 3, we review definitions used in different domains in order to outline their common points and discrepancies.
In Section 4, we finally try to apply the found definitions to the DIKW-model. We argue that none of the definitions we found in several different domains suggest a positioning of wisdom in a chain with data, information and knowledge except the one, Ackhoff proposed himself to justify his model. Section 5 offers a closing reflection on how our conclusions might affect the view of computer science, artificial and computational intelligence/ soft computing on wisdom and proposes directions of further research.

2. The Data-Information-Knowledge-Wisdom-Chain

Data, information, and knowledge can be defined as terms that directly build on top of each other. A first approach to distinguish the concepts may have been published by Nicholas L. Henry in 1974 [2]. Whereas he did not actually offer a hierachical representation, the necessary transition is strongly implied [3]. First notions of a hierarchy ordering the terms were proposed by Milan Zeleny [4] and later Russell L. Ackoff [1]. Both authours are credited with responsibility for the proposition of the DIKW pyramid (Fig. 2), altough none of them never references such a structure.

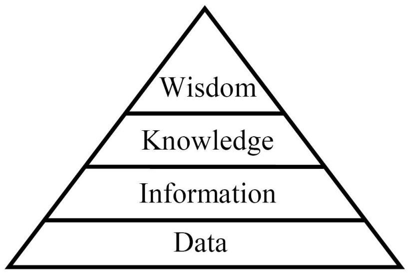

Figure 1: The Information (or Knowledge) Pyramid: Relations between data, information, knowledge and wisdom.

However, while the complexity of these concepts with respect to their context, required understanding and experience increases as discussed in [1] sometimes a different representation, as depicted in

Fig. 2, is used that include these aspects.
In the following, we briefly define *data*, *information* and *knowledge* as proposed by Ackoff, while the definition of wisdom as the core interest of this work will be referred to in the following section.

- *Data:* Data is given by simple sequences of signs and symbols that have no further meaning besides their simple presence.
- *Information:* Information is data that has been given meaning which allows to answer questions like "who", "what", "where", and "when". E.g. in computer science data stored in a (relational) data base is given meaning by naming a row (attribute) and assigning them to a (named) entity.
- *Knowledge:* Knowledge is information that is connected by some relations. It allows to answer "how"-questions.

Ackoff [1] distinguished as a further step (between knowledge and wisdom) also understanding. While knowledge in his view is simply based on collected masses of information, understanding requires in addition probabilistic or interpolative processes in order to answer "why"-questions. These processes could then be used to create new knowledge or information. On the other hand this definition also means that understanding can not exist on its own: it requires knowledge and some kind of reasoning mechanism.

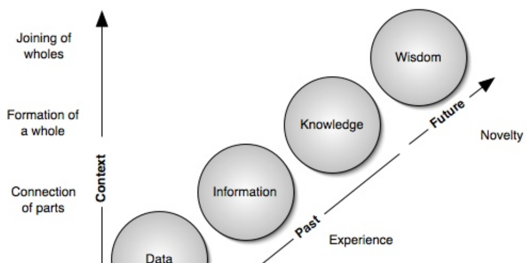

Figure 2: Relations between data, information, knowledge and wisdom (taken from [5])

2.1. Fuzziness of the concepts of Data, Information and Knowledge

Claude E. Shannon's information theory is statistical science. He opened his seminal article in 1948 with the assertion:

> *"The fundamental problem of communication is that of reproducing at one point, either exactly or approximately, a message selected at another point."* [6]

He conceived of communication purely as the transmission of messages – that is sequences of data – completely detached from the meaning of the symbols. Shannon included "new factors, in particular the effect of noise in the channel, and the saving possible due to the statistical structure of the original message and due to the nature of the final destination of the information" [6]. He introduced the variables of the information entropy and redundancy of a source, and its relevance through the source coding theorem and other statistical measures. The underlying logic-algebraic structure of statistics and probability theory is the Boolean algebra. Thus we consider probability theorie as a special case of fuzzy set theory that is covered by statistics and probability theory. On the contrary, fuzziness in information can not be covered by probablity theory and statistics because information is not synonymic to data.
Due to the fact that Shannon reduced in his article the concept of information to that of data (or signs) or message (i.e. a sequence of data or signs) there have been many misunderstandings in the history of information theory.
The mathematician, physicist and scientific manager Warren Weaver wrote his paper "The mathematics of communication" [7] to propagate Shannon's *Mathematical Theory of Communication* to a general and scientific interested public but moreover, he considered the concepts of information and communication in a philosophical way:

> *"In communication there seem to be problems at three levels: 1) technical, 2) semantic, and 3) influential. The technical problems are concerned with the accuracy of transference of information from sender to receiver. They are inherent in all forms of communication, whether by sets of discrete symbol (written speech), or by a varying two-dimensional pattern (television). The semantic problems are concerned with the interpretation of meaning by the receiver, as compared with the intended meaning of the sender. This is a very deep and involved situation, even when one deals only with the relatively simple problems of communicating through speech. [...] The problems of influence or effectiveness are concerned with the success with which the meaning conveyed to the receiver lead to the desired conduct on his part. It may seem at the first glance undesirable narrow to imply that the purpose of all communication is to influence the conduct of the receiver. But with any reasonably broad definition of conduct, it is clear that communication either affects*

conduct or is without any discernible and provable effect at all." ([7], p. 11)

In the revised version of the paper that was published in [8], Weaver explained the trichotomy of the communicaion problem in extenso and he devided it into three levels:

1. Level A contains the purely technical problem involving the exactness with which the symbols can be transmitted
2. Level B contains the semantic problem that inquires as to the precision with which the transmitted signal transports the desired meaning,
3. Level C contains the pragmatic problem pertaining to the effect of the symbol on the destination side: What influence does it exert?

Weaver underscored very clearly the fact that Shannon's theory did not even touch upon any of the problems contained in levels B and C, that the concept of information therefore must not be identified with the "meaning" of the symbols: "In fact, two messages, one which is heavily loaded with meaning and the other of which is pure nonsense, can be exactly equivalent, from the present viewpoint, as regards information." [8]
However, there is plenty of room for fuzziness in the levels B and C. The interpretation of meaning of signs, e. g. linguistic signs, names, words, is obviously a fuzzy process, and influence or effectiveness that is exerted to the receiver's side is a fuzzy process, too. We will have this fuzziness at the back of our mind following Weaver's continuing considerations.

Therefore, we can say that Information is data together with its meaning; a theory of this aggregation of technical and philosophical concepts requires a much more complex framework than usual mathematics.
Therefore, fuzziness in knowledge is fuzziness of a higher level than fuzziness of information: as we said already in the previous section, we consider knowledge as a collection of information connected by some relations, and these relations we would consider as fuzzy relations.

3. Wisdom – a fluctuating concept thorough centuries and domains

A clear specification of wisdom is not easy to find and several partly controversial definitions have been proposed. The approaches to grasp the concept differ in the various disciplines of science, technology and humanities – whilst social sciences tempt to formulate a explicite definition, natural sciences rather build models including and describing the term.
Ackhoff, for example, defined wisdom as evaluated knowledge, i.e. he defined wisdom as a process that makes use of knowledge in order to answer "difficult" questions while considering human factors like moral or ethical codes. Compared to the definition of understanding given above, this means that wisdom requires knowledge and – possibly several different – reasoning mechanisms that are able to handle complex additional constraints implied by, e.g., ethical codes.

3.1. Wisdom in Philosophy

Philosophers as the self-declared "lovers of wisdom" (Greek $\phi\iota\lambda o\sigma o\phi\iota\alpha$; Latin: "philosóphia" - "love of wisdom") provide us with the first known efforts of a proper definition of wisdom. In the early tradition, wisdom was widely defined as attempt to reveal the mysteries of the natural world and the life in it. Here we list four main theories of wisdom in philosophy:

- Wisdom as Epistemic Humility
  - (one is wise if he/she realizes that despite all his/her knowledge in certain domains he/she can never be wise on a global scale)
- Wisdom as Epistemic Accuracy
  - (one is wise if he/she can estimate the amount and areas of his/her knowledge and ignorance)
- Wisdom as Knowledge
  - (one knows what is important - includes factual knowledge and the knowledge of how to lead a good life)
- Wisdom as Knowledge and Action
  - (one not only knows how to live well, but also does it)

Dating back from the belief that absolute wisdom is only a property to (the) God(s), the first two approaches denote yonder as wise who is capable to acknowledge his limits. The latter two lay a particular importance on factual knowledge, the second one also demanding a wise person to actually implement his knowledge of a good life [9].

In a more recent work, the philosopher Sytse Strijbos offers a definition that bears resemblance to the latter approach [10]:

"Wisdom implies:

1. *correct insight into the situation*
2. *correct insight into what needs to be done* [...]
3. *appropiate action."*

Though all resemblance, Strijbos admitts that those are the basic needs to every human action that's not purely based on instincts and reflexes.

3.2. Wisdom in Psychology

The recent psychological research on wisdom can be summed up in three main streams:

- the Berlin wisdom paradigm [11]
- the Balance Theory of Wisdom [12]
- the Three-Dimensional Wisdom Scale [13]

Herein, the first two approaches are originated in more western values, with an emphasis on thought and knowledge, whereas the latter accents a integration of thought and emotion.

The *Berlin Wisdom Paradigm* defines wisdom as "expert knowledge of the fundamental pragmatics of life", and narrows those pragmatics to a set of criteria: rich factual knowledge, rich procedural knowledge, life span contextualism, relativism and the ability to understand and manage uncertainty [11]. In a further evaluation, Paul B. Baltes and Ursula M. Staudinger [14] identify six properties of wisdom:

1. *wisdom represents a truly superior level knowledge, judgment, and advice;*
2. *wisdom addresses important and difficult questions and strategies about the conduct and meaning of life;*
3. *wisdom includes knowledge about the limits of knowledge and the uncertainties of the world;*
4. *wisdom constitutes knowledge with extraordinary scope, depth, measure, and balance;*
5. *wisdom involves a perfect synergy of mind and character, an orchestration of knowledge and virtues;*
6. *wisdom represents knowledge used for the good or well-being of oneself and that of others;*
7. *wisdom, although difficult to achieve and to specify, is easily recognized when manifested.*

The *Balance Theory of Wisdom* extends the wisdom definiton from a list of mere knowledge parameters to a balanced application of that knowledge based on personal values: "Wisdom is defined as the application of successful intelligence and creativity as mediated by values toward the achievement of a common good through a balance among (a) intrapersonal, (b) interpersonal, and (c) extrapersonal interests, over (a) short and (b) long terms, in order to achieve a balance among (a) adaptation to existing environments, (b) shaping of existing environments, and (c) selection of new environments..." [12].
Monika Ardelt critizes the lack of emotional characteristics. In her *Three-dimensional wisdom scale*, she attempts to integrate not only knowledge based criteria as cognitive and reflective abilities, but also an affective component as the third dimension. The cognitive component measures the effort of the organism to acquire correct knowledge towards life's mechanisms, the reflective captures the ability to reflect on those mechanisms and oneself critically, whereas the affective component amends sympathizing love for other beings. Integral part of the theory is the impossibility to learn in a merely intellectual way - wisdom can't be learned out of books, it's based on personal experience and integrated application [13].

3.3. Wisdom in Neurology

Whilst research on wisdom in other domains dates back for many years, neurosciences' interest only evolved during recent years. Approaches attempt to interconnect the components of wisdom identified in psychological research with the findings of functional neuroimaging. The resulting model of brain areas responsible for the development of wise behaviour include frontostriatal and frontolimbic circuits and monoaminergic pathways. It is further proposed that the actual achievement of wisdom involves a necessary balance between the more primitive brain regions and the evolutionary newer ones. [15]

It might sound appealing to identify the brain areas engaged in wise behaviour and thus, provide the world with a proper definition of wisdom. Still, it is not definitely possible to model hard-to-describe unconscious processes via their underlying biological/chemical reactions. Keeping in mind the memories and experiences that create the necessary foundation to the development of wisdom, this task seems all but feasible. It won't be enough to identify the areas accessed during wise decision-taking, but even the nature of facts drawn from long-term memory would have to be termed.

Still, the conclusions of the neuropsychologic examinations may help to perceive some aspects of wisdom. The related areas are held responsible for creativity, impulse and motivation (corpus striatum), emotion and control (limbic system) and information integration (thalamus). Wisdom can thus be seen as a highly integrative, emotional and conscious, creative process. The underlying processes are of a fuzzy nature, an adequate scientific model of wisdom has thus to be fuzzy or fluctuating.

3.4. Wisdom in Computer Science

The concept appears in computer science mostly related with the search for criteria that might finally permit the design of a computational system that shows the ability to provide real or at least simulated wisdom. In his works towards computational wisdom, René V. Mayorga proposes the following attributes as outstanding in every wisdom definition [16]:

"Wisdom

1. *the ability to discern inner qualities and relationships*
2. *the exercise of good judgment/ knowledge"*

Mayorga also rather relates the concept of wisdom to the concept of intelligence than to those used in the DIKW-Hierarchy. Hereafter, “intelligence” would be the ability to choose a proper action by analysis of the situation and thus, attain a local goal; while “Wisdom” not only includes detailed analysis of the underlyling conditions, but also proper synthesis to act in a way that leads to “the attainment of global objectives” [16]. (Global objectives might contradict the current needs and wants of the individual, but lead to a greater payoff in a wider context of time or people.)

It results, according Mayorga, the following list of claims to be fulfilled by a wise computer system:

> *“Computational Wisdom* [17]
>
> - *Discipline dealing with low-, medium-, high-level data*
> - *It can include a learning and identification component for direct and/or inverse relationships*
> - *It can use knowledge in the A.I. sense; but in any case, acts upon it*
>   - *to discern inner qualities and relationships; and*
>   - *to yield good judgment*
> - *Additionally, it also deals with:*
>   - *Computational Stability*
>   - *Computational Adaptability*
>   - *Computational Fault Tolerance*
>   - *Speed approaching human-like turnaround*
> - *Error rates that approximate human performance”*

Mayorga does not offer a further explanation of the terms “low, medium-high level data”. With the DIK-model at hand, one could assume to meet just another formulation of the concepts used in there, high-level data referring to knowledge, medium-level data to information and so forth. Thus, wisdom does not only deal on the upper layer, connecting shreds of knowledge, but pervades all processing levels of data.

3.5. Summary of Wisdom Definitions

Wisdom is commonly seen as a human peak performance that is based on excessive knowledge and judgmental capabilities; whilst the particular attributes needed to achieve a wise mind can not be nailed down. There is a rough idea throughout different domains what could be part of wisdom, but no final version of a usable definition. Nevertheless, one can note some common points in all domains:

- based on a special kind of knowledge: It is agreed that a certain type of knowledge is needed to develop wisdom, whereas the definite type is hardly described.
- controlled emotion: Wisdom is neither pure rationality, nor pure emotion based; it creates a certain kind of “intuition“
- creativity: wise solutions often include a novel approach to a problem, a creative interconnection of knowledge and experience that leads to a better performance
- wise behaviour: the attribute “wise” is mostly awarded to a certain behaviour, seldomly to a person, never to a mere fact
- connected to special circumstances: a behaviour is not generally wise, but depends on the situation it happens in, the judging observer, the epoche,...
- peak-performance: Wisdom is a peak performance one can only achieve with a large amount of experience, knowledge and probably with age

The definitions certainly differ when it comes to an exact description of how wisdom-related knowledge looks like and what kind of behaviour has to be seen as wise, what attributes a wise mind must provide. The theories struggle with a lack of common sense – wise behaviour is seldomly acknowledged as such throughout all communities and ages. A behaviour that seemed wise at a time might seem merely foolish when looked upon after a decent time or when observed by a being with another set of experiences and knowledge. Furthermore it is hard to model the intersection between mere knowledge about how to conduct a good life and the moment a person actually acts upon that knowledge and though begins to act wise. So the point at which knowledge becomes wisdom might be hard to determine by any science. Whereas some definitions lack any reference on a necessity to act upon the achieved knowledge at all.

3.6. Fluctuating concepts in Historical Epistemology

Here we present our view on wisdom as a fluctuating concept with reference to Hans-Jörg Rheinberger’s *Historical epistemology* [18, 19, 20]. In this approach such “fluctuating objects” or “imprecise concepts” are also called “epistemic things” and Rheinberger points to some of those concepts in the history of sciences:

> *“For a long time in physics, such an object has been the atom; in chemistry, the molecule; in classical genetics, it became the gene. It is the historically changing set of epistemic practice that gives contours to these objects.”* ([18], p. 200)

As a molecular biologist and a historian of science, Rheinberger has predominantly followed the flux of the “gene” in the history of biology and he summarized: “There has never been a generally accepted definition of the ’gene’ in genetics. There

exist several, differenct accounts of the historical development an diversification of the gene concept as well. Today, along with the completion of the human genome sequence and the beginning of what has been called the era of postgenomics, genetics is again experiencing a time of conceptual change, voices even being raised to abandon the concept of the gene altogether." [19] Rheinberger concludes that this "boundary object of classical genetics has worked as a formal unit: That which, in an ever more sophisticated context of breeding experiments, accounts for the appearance or disappearance of certain characters that can be traced through subsequent generations." ([18], p. 220f).
For scientific research in general, he claims:

> *"If there are concepts endowed with organizing power in a research field, they are embedded in experimental operations. The practices in which the sciences are grounded engender epistemic objects, epistemic things as I call them, as targets of research. Despite their vagueness, these entities move the world of science. As a rule, disciplines become organized around one or a few of these "boundary objects" that underlie the conceptual translation between different domains."*

Epistemic things are not necessarily "objects" in the narrow sense; an epistemic thing is "a physical structure, a chemical reaction, a biological funtion whose elucidation is at the centre of the investigative effort. Since it is not and cannot be fixed from the beginning, it represents itself in a characteristic, irreducible vagueness, which is inevitable since it translates the fact that one does not exactly know what one is looking for." ([20], p. 310)
In this paper, we propose to characterize the concept of wisdom as an epistemic thing or a fluctuating concept in the sense of Rheinberger's *Historical epistemology.* We decline to sharpen the concept of wisdom to place it as a clear and distinct concept on top of the DIK-hierarchy. On the contrary, with Rheinberger's we argue "that the fruitfulness of boundary objects in research does not depend on whether they can be given a precise and codified meaning from the outset. Stated otherwise, it is not necessary, indeed it can be rather counterproductive, to try to sharpen the conceptual boundaries of vaguely bounded research objects while in operation. As long as objects are in flux, too, the corresponding concepts must remain in flux, too." In other words, he wrote: "Boundary objects require boundary concepts." ([18], p. 221)
Without despising the value of precision in science we want to stress that "precision itself has historically changing boundaries". Rheinberger accentuated the value of imprecision, vagueness or fuzziness in science and he referred to the theory of Fuzzy Sets: "Assessing what it means to be fuzzy, instead of eliminating vagueness altogether and implementing precision, has become a major concern in fields such as AI-research. Lofti Zadeh claims that 'there is a rapidly growing interest in inexact reasoning and processing of knowledge that is imprecise, incomplete, or not totally reliable. And it is in this connection that it will become more and more widely recognized that classical logical systems are inadequate for dealing with uncertainty and that something like fuzzy logic is needed for that purpose' " [18].

4. Wisdom atop of DIKW?

As already pointed out in Section 1, the aim of this paper is not a critique on the whole DIKW-Modell. That has been sufficiently covered in other works (i.e. by Martin Frické [21]). We exclusively focus on the position of wisdom in the DIKW-Modell and, for the time being, assume the claims of the works cited in the previous sections to be justified. Thus, we will not further discuss the fuzziness of the definitions of data, information and knowledge; it is adopted that the concepts build on each other in the described way and that their interrelationships are fuzzy [22].

Considering the first three steps of the staircase leading to wisdom, each level depends on the underlying ones. Data can be supplemented with meaning to achieve information. Information can be interlinked to create knowledge. But can every knowledge be used to achieve wisdom?
In several scientific communities there is a explicit distinction made between general knowledge and wisdom-related knowledge [23]. Thus, there might be interconnections of information that create knowledge - but that will not build a foundation for wisdom. The step going to wisdom consequently is no generalization as the others are; it is far more a constraint qualifying only certain parts of knowledge to be used as a base.
In fact, there is no definition of wisdom that supports an unlimitied enhancement of knowledge towards wisdom - except for the rather narrow and incomplete one Ackhoff proposes to found his model.

Furthermore, the three lower concepts are considered to be storable in a computer science' way. A statement that is undenied for data and at least assumed for information and knowledge. Wisdom however can not be stored, neither be transfered from one being to another. It implies deeper understanding of the wisdom-related knowledge and, to actually act upon this knowledge. The necessary knowledge might be transfered or stored in a inactive, objective way – the intrinsic motivation to act according to the achieved knowledge stays

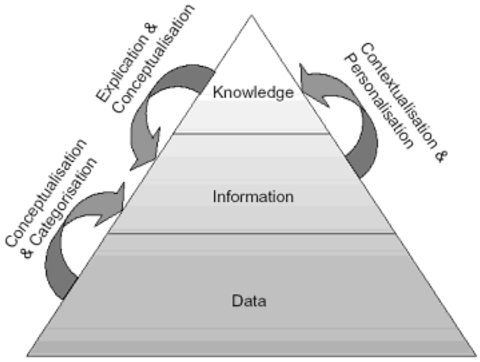

Figure 3: Data-Information-Knowledge-Pyramid [24]

untransmittable.

The perspective the DIKW-model offers on the concept of wisdom seems likely on first sight – but shows some serious discrepancies with all common definitions of wisdom we found in literature. Those definitions might differ in important points with the result that a wholistic definition can not be found at the moment – but they certainly agree on enough points that contradict its integration in the model as it is. We thus propose to get back to the original version of the model, only containing data, information and knowledge as concepts building on each other (Fig. 4).

In what concerns wisdom there have been several proposals of other approaches that could offer an alternative to DIKW for information science. For example the one offered in [16], that names wisdom in a line with intelligence as an underlying concept to DIK-development. We remind that intelligence was named as a process enabling a being to conduct correct behaviour to obtain a local goal out of an analysis of the actual situation; whilst a wise mind not only uses analysis, but also synthesis to choose wise behaviour appropriate to the situation to obtain a positive outcome on a global scale.

$$Intelligence : Analysis \rightarrow Action \quad (1)$$

$$Wisdom : Analysis + Synthesis \rightarrow Action \quad (2)$$

5. Outlook: Wisdom in Computer Science, Artificial Intelligence and Soft Computing

As wisdom is an acknowledged concept of human thinking and development, it still offers an interesting topic for further investigation:

1. How can computer science support the user to evolve wisdom?
2. Can wisdom eventually be emulated by machines providing the user with a wise work station?

In the previous section we already related the term “wisdom” with the concept of “intelligence”. We propose that wisdom could be considered as a extension of “intelligence” by the capability to use synthesis for problem solution (as already seen in [17]. As an extension the computational implementation of wisdom would firstly suffer from the same problems as soft computing/ computational intelligence does, for example the need to adjust to various environments, to interprete and act upon input in a correct way, etc. But also from supplemental ones as wisdom consists of a not only achievement and analysis of knowledge, but also of synthesis using parts of already achieved knowledge. A wise machine would not just collect information and interprete it to obtain knowledge, but also produce new knowledge out of knowledge parts it achieve and develop new ways to act, in a perhaps even creative way. Another problem evolving out of this view of wisdom is the fact that there is no generally accepted idea about what wise behaviour consists of. It is depending on the situation and on experiences and points of view of the judging observer.

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