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Epistemological Problems in Working with Ontologies

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ABSTRACT

The communication between agents does not only require the exchange of syntactically defined character strings. The agents also need to have a common knowledge background. AI-Research has been pursuing ontologies as an approach of formal language which can also be used to explicate knowledge backgrounds. Ontologies gain a particularly high practical relevance in the scope of the organizational knowledge management. Therefore information systems science has an increasing interest in ontologies.

Based on a definition of the term ontology, this paper examines problems of the theory of knowledge and the theory of language, which might be created in the construction of ontologies. Ontologies are interpreted as a special case of conceptual models. Thus, the content of this paper can be applied not only to the strict framework of ontologies, but also to the problems of theory of science in the area of information modeling.

Keywords: Ontologies, Philosophy of Science, information modeling, meta modeling, Incommensurability.

1. MOTIVATION

For decades the collaboration *of several part-autonomous actors* with the common fulfillment of complex tasks represents a central object of research for different object sciences, especially information system science and economics. A substantial object-scientific *problem* in this context focuses on *the coordination* of the actors. Regarding to specific restrictions the participants can decide the task-sequences autonomously, but they have to cooperate for fulfilling its common task. This coordination problem is not only an organization-specific problem. Since the beginning of the eighties it also became popular within computer science. A substantial driving force was the development of *multi-agent systems*, which followed as part of the distributed artificial intelligence research conventional expert systems as topic of international research efforts.

At the beginning the researchers turned to the content-wise arrangement of those concepts, which allows co-ordination of activities between part-autonomous participants. One result of this

research efforts were coordination concepts like the widely known contract nets or the partial global planning concept.

However at the end of the eighties it was clear that "one had begun with second before the first development step", because the most coordination concepts had assumed in speech analytical and epistemological naively manner that communication

between participants is undemanding and only a necessary condition for coordination. Several scientific papers to the speech act theory were published, which showed how the communication between agents in multi-agent systems should be structured with the assistance of communication-primitives. But these approaches remain at the surface of the real existing *communication problems*, because they regarded only the *permissible form of expression* for communication between artificial actors. Not task specific, but *common sense background knowledge*, which natural actors always *implicitly* presuppose and intensively use if they have to fulfil coordination tasks, was neglected. However, this background knowledge represents the semantic and pragmatic context of the task fulfilment. Disregarding this kind of knowledge coordination of cooperating actors often fails. Since the nineties there is an increased attention in the background knowledge based communication of the involved actors, as for instance in the context of the CYC-Project (cf. [36]).

The contribution takes these founding efforts up. A special set of instruments for the disclosure of background knowledge will be presented. With the assistance of these instruments the coordination-relevant background knowledge of actors will be explicated in such a way that it can be integrated into concepts purpose-oriented for the coordination of activities appropriately. In the contribution this requirement will be critical discussed, primarily from an epistemological perspective.

As shown above the communication between two or more actors not only requires the exchange of 'meaningless', i.e.

purely syntactically defined expressions, but also demands the exchange of meaningful information. The exchange of information requires the availability of a *common knowledge background*, so that the receiver can understand the information of the sender in the intended way. This knowledge background of each actor is influenced by different factors, which are of elementary significance to communication. As far as the communication is distributed between several actors, if need be even asynchronous, the possibly *divergent knowledge backgrounds* of the actors have to be explicitely specified.

Because -so the central *epistemological thesis* of this contribution- only the *explicit specification* of the available knowledge allows the systematic analysis of knowledge backgrounds of different actors. This analysis is necessary for uncovering differences in actor-specific knowledge backgrounds. If the knowledge differences are known, the commonly shared background knowledge, which is necessary for the content-wise understanding of communication acts of collaborating actors, have to be identified or constructed (if the knowledge does not exist). For a while the term 'ontology' has been discussed as a set of instruments, which is supposed to support communication between actors (cf. [16]). Ontologies should be support the communication of actors for coordinating their partial autonomous activities on a semantical level (cf. [16]). The contribution will working out some of *the substantial epistemological problems,* which arises when using Ontologies for communication and coordination purposes of collaborating actors.

The interest in ontologies was initiated by reports from research in artificial intelligence [56]; [43]; [16]. In the eighties a special attention developed for the question how artificial agents could be described and coordinated – for the purpose of agents' task sharing [27]. These questions increased in importance within AI – research with regard to collectives of autonomous robots and lately also to software agents ('softbots') on the internet. Since the beginning of the nineties discussions about the mentioned questions have started in other research areas, such as 'information modeling', 'knowledge sharing', 'knowledge reuse' (cf. [10]), 'distributed knowledge management' etc.

Meanwhile in the information systems science two independent trends in the area of knowledge management (cf. [42]) have lead to a strongly growing interest in ontologies. *On one hand* the organizational production of goods or services is characterized by distributed interaction of several people. The knowledge backgrounds of these people frequently diverge significantly. The more the intensity of knowledge propagates within the organizational value adding processes, the more seriously the knowledge divergence can affect the result of the processes. Therefore knowledge management should search for instruments, in order to identify knowledge divergences. In case these divergences affect the organizational task of coordination the identified instruments should remove or at least compensate them. *On the other hand* the explosion-like increase in popular- or pseudo-scientific literature initiates the need for precise instruments, which enable to conduct knowledge management not just as a 'narrative event' (cf. [38]), but to submit to methodic standards.

2. BASIC TERMINOLOGY

Necessity of Exact Scientific Terms

The exact use of language is a fundamental rule in each science, because it is essential for the communication of the scientists. Definitions are one mechanism to precisely determine the contents of a statement. They accomplish two different functions. *First,* they serve as abbreviations in the presentation of complex facts in extensive systems of statements. Usually symbols represent facts, in order to formalize the systems of statements. *Second*, definitions provide the means for the clarification, the specification and the fixed meaning. Without fixed meaning no discussion about contents inherent in language is possible. The use of definitions allows the interpretation of 'theories' [8] for the statement and [3] for the non statement view). A consistent use of language is impossible without exact, fixed meaning. Whereby minimal demand in scientific working is to commit to a fixed meaning.[1]

Versatility of the Term Ontology

The term ontology originates in the antiquity. Since then ontology is understood as the doctrine of being (cf. [5]; [6]; [18]). Thus, already ARISTOTELES addresses in his 'first Philosophy' the question of the 'being of the existent'. This means the question of an 'essence', which is 'objective' and independent of human cognition, as well as the question of ones own 'destiny'. In the scope of classical metaphysics these ontological 'considerations of being' took up considerable attention during the centuries. As a result of the crisis of the speculative idealism during the 19th century, it significantly lost consideration. The scientific philosophy of the 20th century saw a 'rebirth of ontology'. This was particularly initiated by HARTMANN'S papers about a "new ontology". The same course can be observed in HUSSERL, who saw his opinion about phenomenology as a universal ontology. It can also be seen in HEIDEGGER'S reports concerning 'fundamental ontology' and in SARTRE'S works concerning 'phenomenological ontology'. The double ontological relativity by QUINE is of particular importance (cf. [45]; [50]).

In contrast to the philosophical writings about ontology, information systems research in general is concerned with ontologies. The *plural* term of ontologies hints at a first difference to the philosophical understanding of ontology. There is not only one ontology. Thus by definition no statements about the being of the existent can be made by ontologies. No given, passive object is analyzed, but basic structures and laws of objects are actively created. Therefore ontologies are *artifacts made by humans* and purposive rational design aspect have to be taken into account. This terminological interpretation of ontologies causes a turning of ontologies towards problems of the theory of knowledge. If there are possibly several ontologies, which represent artifacts, the problems concerning the design

[1] Cf. [39], „[...] there is another and broader sense in which concepts or propositions may be exact or precise, namely, that their meaning is specified with absolute definiteness, so that our understanding of their content does not depend in any way upon personal interpretation."

have eventually the character of epistemology and language theory.

The term 'ontologies' is widely spread in literature (cf. [22]), which is not useful with regard to the clear use of the term. Mainly, two different interpretations can be differentiated.

In a *first* understanding, ontologies are verbal specifications. 'An ontology consists of a set of concepts and their relationships, forming a conceptual structure that underlies the interpretation of any system model.'([30], cf. also [40], 'an ontology characterizes some aspects for a class of applications'). Thus the structures, underlying any interpretation of aspects of the real world, are defined as ontologies.

A *second* understanding of ontologies derives from the research of artificial intelligence research. Within this interpretation different definitions of ontologies can be identified (cf.[24]; [21]; [22] and also[55]; [56]; [17]). The first definition goes back to NECHES ET AL.: 'An ontology defines the basic terms and relations comprising the vocabulary of a topic area as well as the rules for combining terms and relations to define extensions to the vocabulary.'[41]. The most common definition goes back to GRUBER (cf. [54]).[21] uses the same definition with a different understanding of the term conceptualization). Accordingly an ontology is 'an *explicit specification of a conceptualization'* [19]. A modified understanding of GRUBER'S definition relates the formal explication only to a commonly shared conceptualization (cf. [4]; [54]). GRUBER comprehends conceptualization as 'an abstract, simplified view of the world that we wish to represent for some purpose.' [19].

3. ONTOLOGIES AND PHILOSOPHY OF SCIENCE

Epistemological Implications in the Construction of Ontologies

The outlined definitions of the term 'ontologies' show an astonishing indefiniteness concerning the nature of reality and the perceptibility of real phenomena. Occasionally literature conveys the impression, ontologies would reflect the world, so that the philosophical technical term 'ontology' were used in a correct way. The plural usage of ontologies presupposes however that there are several 'worlds', as already indicated by the plural of the term ontology known from philosophy.

Several worlds could only be thinkable – besides seemingly bizarre cosmological exceptions – if the perspective of philosophy of science and the ontological perspective were combined. A naiv-realistic point of view allows the experience of reality 'itself', independent of the sensorial and cognitive distortions of the recognizing subject [7]. In this naiv-realistic point of view, ontology (here understood as the philosophical discipline) and theory of knowledge would coincide, so that the singular use of *the* ontology would be conclusive. The authors believe that the naiv-realistic perspective of cognition is overcome. Modern perspectives of cognition are e.g. the Critical Realism of ALBERT'S influence [1,2,7][1], the hypothetical realism going back to VOLLMER [57] or from another viewpoint – the constructive theory of science [37] or the Methodic Culturalism [25, 26] – a moderate constructivism. These emphasize the active, constructive achievement of the recognizing subject.

The following quote is one example for the combination of theory of cognition and ontology: 'Ontology is the branch of philosophy that deals with theories about nature of things in general (as opposed theories about particular things).' [60]. As far as this is a matter of theories about nature of objects, it is not regarded from the point of view of ontologies but from the epistemological viewpoint. Thus, in the context of the specified argumentation, it is more appropriate to talk about epistemology, which deals with the basic structures of reality. Indeed, the opposing point of view can be taken, that theories about the basic structures of reality are merely a mapping of the world 'itself' and therefore no differentiation between ontological and epistemological perspectives are necessary. This would imply the position of naiv-realism, which is rejected by the author quoted above [60], for WEBER represents critical realism. Nevertheless he stresses, that the usability of the BUNGE-WAND-WEBER ontology, to which he refers mainly, is independent of the chosen realism [57]. The authors do not agree with WEBER concerning this matter, since for example his proposed criteria for evaluation are not applicable without contradiction, independently of the assumed realism [47].

In accordance with the realism, the elements, which are constructed in the development of ontologies (see Fig. 1), will be addressed concerning the implications of theory of knowledge.

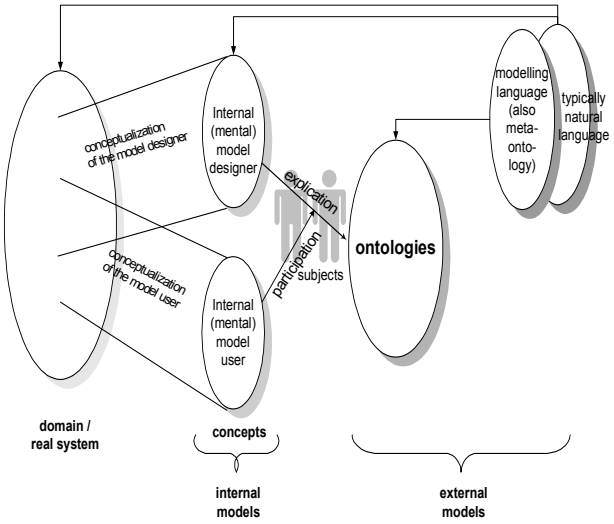

Fig. 1: Domain, conceptualization and ontology

A *domain* [17, 53] (*real system* [58, 59] *or extract of the Universe of Discourse*) represents pieces of reality which is either dependent or independent of the modeling subject (cf. [17], that for the purpose to create an ontology you have to start with a *given* domain). Often – at least implicitly – a domain is seen as pieces of reality, which are assumed given, independent of the modeling subject. This viewpoint is consequent from the perspective of naiv-realism, but not from the standpoint of modern epistemology. For instance, the epistemological perspective would understand the domain as an entity *conceptualized* by sub-

[1] For an analysis of different research approaches in information systems development see for example [14, 28, 29]. An overview about the historical development on the philosophical foundation in information systems can be found by [46].

jects. Thus the domain is the result of *pre-structuring* the scope of objects.

Not all authors share the opinion of a domain being pre-structured (cf. [17], and the explanation in the preceding comment). This fact is emphasized by the assessment of the ontological state of systems. *Systems theory* does not include a nomological hypothesis, which comprehends a statement about the nature of the real world. Rather, systems theory is a meta theory, which assumes that the world is a structure of systems. Though, this hypothesis can never be proven. It can be seen as 'glasses', which pretend a special view of the world, influenced by systems theory. Therefore, systems theory corresponds to a special pattern of conceptualization.

Nevertheless, especially the ontological understanding of BUNGE indicates to perceive the 'systemic' structure as an ontological attribute of the world [6]. The realistic position of BUNGE leads to declaring the world as a system. Within the Information Systems community, WAND and WEBER have picked up these beliefs (WAND defines his interpretation of an ontology –instead of ontologies in the AI-community– as meta-ontology, cf. [58]). BUNGE and also WAND and WEBER show distinct epistemological optimism, by attributing an ontological state to languages and patterns of conceptualization. For they assume system-like structures of the world, which are identical, independent of any empirical content (ontological realism). In contrast, the perspective of pessimism of cognition does not believe that the existence of system structures can be seen as ontological attributes. Since systems are not just given, but *constructed by subjects* in possibly different ways.

The purposive and epistemological dependence becomes even more obvious regarding conceptualization as opposed to domains. We define *conceptualization* as an abstract view on phenomena of reality, in which the perceiving subject is interested in order to fulfil some purposes. These two pragmatic facettes of perception determine which aspects of the perceived phenomena are relevant to the perceiving subjects. Thus conceptualization always signifies the distinction of relevant aspects of reality, dependent on purpose and subject. The result of the process of conceptualization is represented by 'concepts' or internal models, which are used to *pre-structure* the perceived pieces of reality. Conceptualization is always accompanied by knowledge imprinting pre-structuring of possible experiences of reality. Since the results – the concepts – are usually expressed as constructs of (natural) language, conceptualization maybe interpreted as an abstract pre-structuring of possible language-mediated descriptions of reality. Therefore a vocabulary, which offers terms for the description of real phenomena, is regarded as a central element of ontologies [19].

In the understanding of the authors, the result of the process of conceptualization does not yet represent a formalized model. In this respect, they don't follow the definition of conceptualization by GENESERETH/NILSSON [15] to which GRUBER also refers. If conceptualization was already an artifact of formal language, then an ontology, which is frequently defined as an artifact of formal language, would only be a doubling of conceptualization. In this case a translation relation between two formal languages could be established. This point of view is not shared here. For the doubling of conceptualization as an ontology would reduce the serious problems of *theory of knowledge* in the *construction* of ontologies to the 'simple' translation between two artifacts of formal language. It would therefore trivialize it.[1]

The outlined formalistic opinion of conceptualization shows lacking consideration of the intellectual achievement of the modeler. The authors consider this view to be quite daring, as of the complex problems connected with the conceptualization of reality. Empiric research shows the serious impact of patterns of interpretation on modeling [48]. Personal experiences, knowledge and fields of interest of the perceiving subject lead to a creation of perceptive or cognitive structures, which constitute the starting point of modeling. Disregarding the problems, which have to be managed during the conceptualization of reality, one could suspect that the supporters of the formalistic view on conceptualization represent naiv-realism.[2]

Ontologies as a special form of *conceptual models* are the result of a process of explications. The knowledge backgrounds of the actors shall be verbalized in conceptual models in order to make this expert knowledge accessible for knowledge based systems, as a means of artificial intelligence and information systems science. However, first attempts to explicate the numerous presuppositions of the pre-understanding of natural language turned out to be extremely difficult. In addition knowledge based systems require *formal representation* of the relevant information for their internal functionality. Important voices doubt in principle the possibility to fully and correctly reconstruct the 'essential meaning' or 'semantics' of perceptions of natural language by formal languages. An impressing example for these fundamental doubts is the 'Chinese room'–thought experiment by SEARLE and the following debate, which has not yet ended.

The Meaning of Language

As already indicated, any conceptualization depends on language. For example, an entity relationship model (ER-model) assumes the structuring of perceptions by means of objects and relationships as 'generic' forms of cognition. If this assumption is neglected, the terms "object" and "relationship" can no longer be used as basic terms in a language for the representation of information systems.

An observed domain as well as it's conceptualization represent a pre-structuring of the perceived and imagined reality. The term 'pre-structuring' is to express, that the conceptualization of reality and it's phenomena takes place *before* it is accessed by the perceiving subject for some purpose. However, the precedent relationship possesses only a 'logic of knowledge', but not necessarily a timely quality. Because often an extract of reality is detected, without having consciously conceptualized the concerned reality aspects ('lifeworld' context). Through a following recon-

[1] The authors are surprised, that the definition of GRUBER, which refers explicitly to GENESERETH/NILSSON, in view of which formal-linguistic representation doubling the explication so far yet was not criticized. GUARINI and GIARETTA showed the problems of the extensional interpretation of a conceptualization. They take an intensional interpretation of conceptualization [24, 21].

[2] [11,13,34], think, that there are a lot of researcher with a naïve realistic epistemology in the field of software engineering.

struction these 'lifeworld' and subconsciously used conceptualizations, which were implicitly underlying the earlier understanding of reality, can be explicated.

The idea of terminological pre-structuring of possibilities to perceive reality is not at all new, but common property of linguistic and cultural analytical philosophical traditions. Although the meaning of language is commonly accepted, there are disagreements about the linguistic relativity of conceptualization. After all two crucial questions have to be posed. First controversial is the question whether language as an undeceivable attribute of man is a plain reflection of the world. Second, in case of a negative answer to the first question, there is disagreement whether different languages influence thinking. Two opposing positions can be identified. On one hand, there are the proponents of a high linguistic relativity [35], as the late WITTGENSTEIN paraphrased with the frequently quoted term 'language game' [61]. On the other hand, there are the opponents of linguistic relativity ([9] recommended the combination of language relativity and realism), who share the mapping-driven perspective of the naiv-realism – at least on the level of language. Opposed to this debate, which only covers natural language, the authors take an offensive position of *linguistic relativism*. They award an outstanding meaning to language as an instrument for conceptualization of pieces of reality. For example STEGMÜLLER summarizes concisely, but precisely: 'The world is divided *not independent of language* into facts and just possible facts.'[49].

From the perspective of their intended application, ontologies should develop their advantages by their *commonly used* conceptualization of the world of experiences. It is necessary for distributed problem solving, to 'harmonize' the experiences of reality of any actor, which were created by their ontologies depending on purpose and subject. Organizations – besides extreme exceptions – are also based on the distributed interaction of several actors, whose 'world views' usually don't show a 'pre-stabilized harmony', like LEIBNIZ supposed in his theory of monads. Thus the linguistic philosophical point of view imposes the question whether two or more actors can share the same conceptualization. The advantages of the use of ontologies generally increase with the decreasing linguistic relativity of the conceptualization. As long as terms are just standardized, legitimate chances of success for ontologies exist – comparable to the 'triumphant advances' of the terminologies of ERP-systems in organizations.

Problems of Incommensurability

Ontologies claim more than just vocabularies, so that this attempt is more ambitious than a mere harmonization of terms (even though this an important aspect of ontologies). For instance it is important, that language is "loaded with theories", frequently being parts of the actors' background knowledge. Consequently theories define patterns of thinking, how to grasp the world [44]. Therefore the use of languages, which are influenced by different theories, requires translation relations between the languages. But QUINE brought up serious cognitive objections with his hypothesis of general indefiniteness of any translation between theories [45,50]. QUINE's objections together with other epistemological arguments, especially coming from KUHN, LAKATOS and FEYERABEND [31, 12], are the basis of the incommensurability thesis[1]. This thesis influences discussions within the theory of science as well as the sociology of science for the last years. It is also relevant for the practical application of ontologies, unnoticed of many authors. The point of attack of the incommensurability thesis is the shared ontology paradigm, which is the basis of constructing multi-agent systems as part of the DAI research. This paradigm „claims that several actors The 'shared ontology paradigm' claims that several actors share one common ontology. This is the base for a particularly severe problem of ontologies. Moreover, great hope exists to be able to compare different models with the help of ontologies: 'The reader should note that comparisons of conceptual models on the basis of their built-in terms are vulnerable to problems of synonymy, homonymy etc. In other words, two different models may be appropriate for the same class of applications, but use different terms to talk about these applications. We'd like to have a framework which deems these conceptual models as being comparable with respect to their intended subject matter. Ontologies help us achieve precisely this objectives.' [40]. Especially the last stated expectation of an instrument of comparison for different models of the same pieces of reality is the motivation for the enormous recent interest in ontologies of the information systems science. Such commonly used ontologies would immensely facilitate the task of comparing the efficiency of competing reference models for information systems and business processes.

However facing severe problems of incommensurability, it is doubtful if - and in the positive case how far - different conceptualizations of the same aspects of reality can be brought together in one shared ontology used by several actors. According to the paradigmatic incommensurability a commonly used ontology can not be achieved, while the actors act according to their own explanation, rationality, and language standards. The general objective of ontologies does not agree with the basic position of linguistic or theory relativism, unless the existence of a global paradigm is assumed. As soon as several competing paradigms - in the sense of divergent background knowledge theories - exist, the research intention of ontologies (as of 'shared ontologies') does not agree with the cognitive relativism.

In order to achieve the intended purposes of ontologies additional assumptions about the meaning of the problems of incommensurabilty are needed. First of all the hypothesis of the double ontological relativity by QUINE assumes, that at least one *framing theory* exists as a core component of the formentioned "global paradigm". The framing theory is the reference point for different theories of divergent ontologies, in which the different ontologies can be embedded. Without such a framing theory, the divergent theories cannot be set into proportion relative to a higher framing theory. Furthermore explanation, rationality, and language standards have to be set, which are adequate for all collaborating actors. If necessary these standards should be explicated within common sense ontologies.

[1] The term incommensurability was created by KUHN, cf. Kuhn (1970). He understands under incommensurability, that paradigms are incomparable, cf. Stegmüller (1987b), p. 299. One of the main problems is the theory dependent view of the world and due to this the incommensurability, cf. Feyerabend (1993).

4. OUTLOOK

The context of this paper only allowed a brief and basic analysis of the complex problems of theory of science and theory of knowledge, which have to be considered in the construction of ontologies. Although the authors hope to have shown the necessity of two postulates.

First a consistent basic position of theory of science and theory of knowledge is necessary for a convincing solution of the complex problems connected to the construction and evaluation of ontologies. Otherwise a complete interpretation of the works about ontologies would be necessary, in order not to expose the implicit assumptions of problems of theory of science and theory of knowledge. This always implies the risk of misunderstanding the author. Moreover, missing conviction to a basic position may lead to inconsistencies in the logic of the author – e.g. due to unawareness of the problems of theory of science and theory of knowledge.

Second, answers have to be found for severe problems in theory of science and epistemology, which are even heavily discussed within philosophy and theory of science (as for example QUINE'S hypothesis about double ontological relativity). In this context of researching and developing ontologies, the implicated borders of different epistemological basic positions should be taken into account. A realistic position, for instance, raises the potentially largest expectations of progress in knowledge about ontologies. Whereas a position of linguistic or theoretic relativism would impose restrictions onto the possible applications, due to theory of science and epistemology. Therefore the objectives of researching and developing ontologies are not independent of the accepted basic assumptions of theory of science and epistemology. These facts explain the relevance of the meta sciences theory of science and epistemology in respect to object sciences, such as information systems science. It also suggest to serious scientists the necessity for reflections of their basic positions concerning theory of science and epistemology.

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