A Kabbalah System Theory of Ontological and Knowledge Engineering for Knowledge Based Systems

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***Abstract*—Using the Kabbalah system theory (KST) developed in [1], [2], we propose an ontological engineering for knowledge representation of domains in terms of concept systems in knowledge based systems in artificial intelligence. KST is also used for the knowledge engineering of the knowledge model building based on ontology. KST provides thus an integrative, unifying, domain independent framework for both the knowledge representation via ontologies and knowledge model building via knowledge engineering in knowledge based systems.**

Keywords—knowledge based system; knowledge representation; ontological engineering; knowledge modeling; knowledge engineering; artificial intelligence; Kabbalah; system theory; category theory

I. INTRODUCTION

One of the difficulties in the knowledge engineering (KE) of knowledge based systems (KBS) in artificial intelligence (AI) is the fact that knowledge is domain dependent. This means that knowledge based systems are in general domain dependent, knowledge bases are domain specific and cannot be re-used in general in another domain, a drawback that applies for early AI constructs such as semantic networks and expert systems. Ontological engineering [3],[4] is trying to solve that problem by building general ontologies defined as systems of generic concepts, their attributes and properties and relations between concepts. Individual concepts and objects are seen as instances of the generic concept. Such ontologies can serve as a common knowledge base on which to develop specific knowledge model building. The idea of ontological engineering is inspired from ontology, the philosophy of existence and its categories and relations between them. Aristotle 10 category based ontology (upper level ontology to be more precise) is one of the earliest well known ontologies [3].

The other main difficulty in KBS and AI in general is in capturing together in knowledge representation 1) the cognitive, 2) the behavioral / emotional and 3) the action / implementation and articulation levels of human knowledge in knowledge representation. This has been an obstacle to AI progress given that most of the focus has been on formal rules, learning models and knowledge modeling at levels 1 and / or 3 above only, the cognitive and action, implementation and articulation levels, missing completely the essential level 2, the behavioral and emotional together with its interconnections with levels 1 and 3. Human knowledge is cognitive and action based as it is emotions and behavior based.

In [1],[2] we introduced a Kabbalah system theory based on exploring and formalizing principles of the philosophy of Kabbalah [5],[6],[7] using system theory [8] in a mathematical category theoretic formulation [9], [10], [11], [12].

Kabbalah is an ancient philosophy of the creation and existence developed over centuries by Arizal (Ari), Rashash (Shalom Sharabi), Ramhal (M.H. ben Luzzatto), Yehudah Ashlag, Shimon bar Yochai [5], [6], [7]. Its central concept, the Tree of Life [7], integrates together the cognitive, emotional / behavioral and action / implementation levels of existence. The Tree of Life actually has three interconnected levels and they are exactly the cognitive, the emotional / behavioral and the action level.

We show here how to create a Kabbalistic Tree of Life general model or representation for any concept in any knowledge domain but also for a system of concepts and the relation between them (ontology). The Tree of Life of Kabbalah becomes thus a standardized model for both concepts and ontologies. This leads to building a Kabbalah based ontological engineering for knowledge representation in KBS using our Kabbalah system theory (KST) [1], [2]. KST, through its system dynamics and category theoretic instruments like pullback and pushout, is also the framework for knowledge engineering and knowledge model building describing concept formation and dynamics, knowledge ontology dynamics and transformation etc.

The advantage of our Kabbalah ontology is using a standardized architecture, the Tree of Life, whereas in ontological engineering every domain has a different type of ontology architecture. Every concept will be represented by a Tree of Life and ontologies as systems of concepts will also be represented as a tree of Life etc.

II. A KABBALAH BASED ONTOLOGY USING THE TREE OF LIFE ARCHITECTURE

According to the Kabbalah philosophy, existence can be described in terms of 10 fundamental attributes / qualities or basic structural components called “sefirot” in Hebrew / Aramaic which means counts (each one is called a sefira), grouped in three categories [7]:

- Cognitive level (including objective, spiritual knowledge, meta-knowledge) : Crown (will, faith and desire, meta-knowledge level called Keter in original Hebrew or Aramaic), Wisdom (idea called Chochmah in Hebrew / Aramaic), Understanding (Binah) and Knowledge (Da'at) which in fact prepares the transition and implementation of understanding at the emotional level. We are not going here into the detailed structure of this sefira, we did so in [1].
- Emotional / behavioral level: Lovingkindness (Chesed), Judgment, Strength, Rigor or Severity (Gevurah) and Harmony or Beauty (Tiferet) which is connected to the next level below
- Action, implementation, articulation level: Perseverance or Endurance (Netzach), Victory or Majesty (Hod), Foundation (Yesod) and Kingship (Malchut)

Despite their metaphorical anthropomorphic names, they do represent a very general metaphoric coordinate system of 10 general basic attributes (11 sefirot including Knowledge which normally is not represented in the same time with Crown, we will often refer to this as "10+1 sefirot"), properties, attributes that can be used to describe complex systems in general and existence. In fact, ontology attempts to find a sort of philosophical, generalized, abstract Cartesian-like system of coordinates for existence. From this point of view Kabbalah can be seen as one of the first attempts to create ontology to describe existence, creation and creatures. In the Tree of Life, the ten sefirot fundamental units or components are interconnected by 22 arcs based on the interactions between them and between each of the three fundamental levels described above, in which these sefirot are integrated.

The internal sub-structure of each sefira is again of the type of a Tree of Life made of 10 sub-sefirot of the same type as the original 10 sefirot. This way, each sefira contains an internal model of the Tree of Life and of each of the sefirot it is in interaction with. In principle, we can go on and speak of the sub-sub-structure of sub-sefirot which will also be in the shape of Tree of Life etc. This means that the Tree of Life has a fractal structure or an inter-inclusive structure. However, for purposes of our Kabbalah system theory we will restrict ourselves to the first order sub-structure of the Tree of Life described by sub-sefirot of sefirot.

We can use the Tree of Life structure to create here a model, representation or architecture for a concept:

- Cognitive level of a concept: Crown (Keter) "K"- Concept meta-knowledge, Wisdom (Chochmah) "C" - Idea of the concept, Understanding (Binah) "B" – the meaning, essence and understanding of a concept, Knowledge (Da'at) "D" – Practical relevance of a concept. This level is denoted by CBD or ChaBaD.
- Emotional, behavioral level of a concept: Lovingkindness (Chesed) "C'" - synonymous to the concept, the is-like the concept, Strength, Judgment (Gevurah) "G" – Strength, rules, the "is-not-like" a concept, antonymous to the concept, Harmony (Tiferet) "T" – Beauty, balance, harmony of a concept. This level is denoted by C'GT or ChaGaT.
- Action, implementation, articulation level of a concept : Endurance (Netzach) "N" – Endurance of a concept, continuity of a concept, concept as an object, permanent entity, Victory or Majesty (Hod) "H" – Concept occurrence and perdurance [3], discontinuity of a concept, concept as a process on and off, Foundation (Yesod) "Y" – Concept re-actualization, updating, renewal, channeling towards implementation and Kingship (Malchut) "M" – Practical manifestation and implementation of a concept. This level is denoted by NHY.

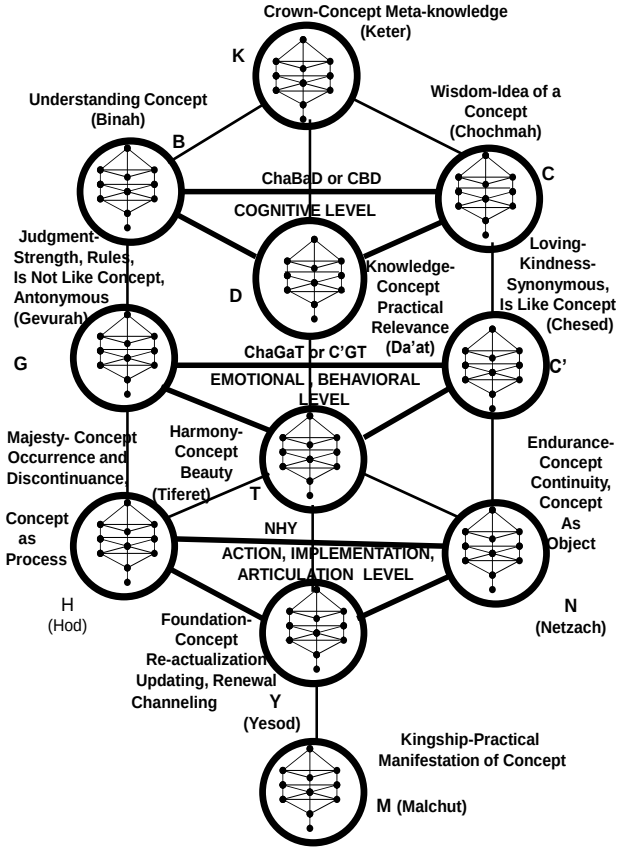

Fig. 1. A Kaballah ontological model for a concept based on a Tree of Life representation: the Tree of Life has three levels (cognitive, behavioral / emotional and action / implementation) and 10+1 basic components called "sefirot". A concept is represented in terms of its 10+1 "sefirot" main sub-concepts, coordinates, components, properties, attributes. Each main coordinate or component of a concept has an internal Tree of Life sub-structure representation..

We can now represent our new Kabbalah ontological model of a concept based on the Tree of Life given in Fig. 1. A concept is represented as a Tree of Life of it main attributes, properties, sub-concepts grouped in the 10+1 Sefirot of a Tree of Life acting as a generalized coordinate system. Each sub-concept or attribute, each property is also represented by its internal sub-Tree of Life structure

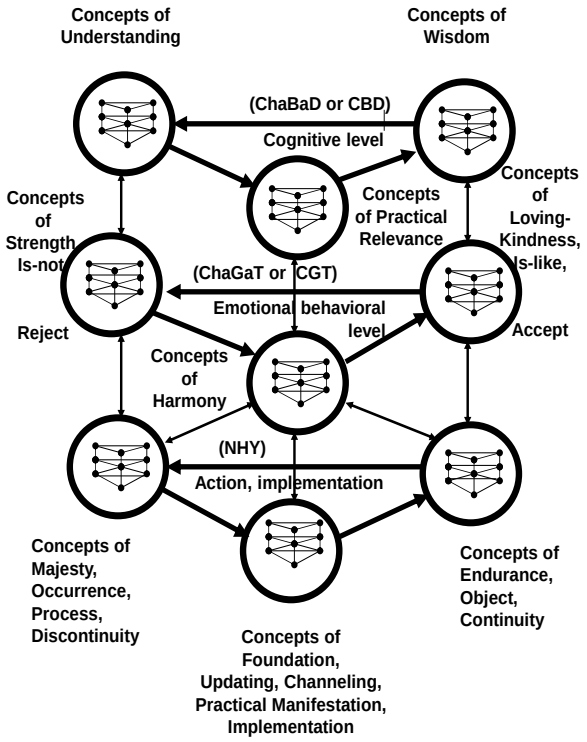

Fig. 2. A Kabbalah system theory based ontological engineering model for an ontology seen as a system of concepts, their properties, attributes and relations between concepts. An ontology is represented by the simplified form of the Tree of Life. Here each sefirot represents a concept or class of concepts which has an internal simplified sub-Tree of Life structure too. According to our Kabbalah system theory, this simplified form of the Tree of Life is modeled by a hierarchical 3-level feedback control system.

The Tree of Life of a concept can be represented in a simplified form showing only its three triadic levels that we explained above which were denoted in Fig. 1 by CBD (ChaBaD), C'GT (ChaGaT) and NHY, notation based on the initials of the three sefirot at each level. Such simplified representation is often used in Kabbalah to focus on the three interconnected hierarchic levels and is called in Hebrew "Drush HaDaat".

We can build next our new Kabbalah based ontological engineering model for an ontology seen as a system of concepts, their properties, attributes and relations between concepts. An ontology will be represented by the simplified form of the Tree of Life as in Fig. 2. Here each sefirot represents a class, category of concepts of the ontology which is also modeled by an internal simplified sub-Tree of Life structure.

We developed in [1], [2] a Kabbalah system theory of the simplified form of the Tree of Life given in Fig. 2. System theory emerged as a program to address, in a holistic rather than reductionist way driving and controlling or control engineering different type of systems and the interdependence between these in a unified formalism [8]: input or cause, output or effect, states, feedback from states or output back to input called control or feedback control meant to drive the system to a desired state or objective etc. System theory has been so far very little applied to AI, knowledge engineering, ontological engineering yet all these are called "engineering". We will introduce here a system theoretic interpretation of knowledge engineering seen as achieving desired outputs and objectives based on driving, controlling a knowledge based model, an ontology etc which is the general objective of control system engineering in general. Our Kabbalah system theory is based on modeling the simplified Tree of Life in Fig. 2 as a 3-level feedback control system: the three triadic levels discussed before CBD, C'GT. NHY operate each as a feedback loop with the mid-line sefirot D, T, Y acting as feedback "controllers" moderating, modulating balancing the interaction between respectively C and B, C' and G, N and H. These three feedback control systems are vertically interconnected both ways, up and down, to achieve hierarchic feedback control [1].

One of the main merits of the Kabbalah system theory approach developed in [1], [2] is that it is both holistic and reductionist. System theory approach is holistic which leads to de-emphasizing reductionist aspects and this was a drawback. Postmodern approaches aim to restore the emphasis on the reductionist, de-constructivist aspects [1]. Our Kabbalah system theory is both holistic and reductionist given that each sefirot is "deconstructed" in detail through its sub – Tree of life model. From this point of view, Kabbalah system theory is a postmodern system theory. The structure of the reductionist model is the same as the holistic model due to the inter-inclusive structure of the Tree of Life.

III. A Kabbalah System Theory Approach to Ontological Engineering, Knowledge Engineering and Knowledge Based Modeling

The main feature of the system theoretic approach is the emphasis on cause-effect relations and the dynamics of systems. Ontologies are in general static, represented by hierarchically branching trees yet one wants a dynamic ontological engineering to act as a base for knowledge based modeling and knowledge engineering [3]. All these are dynamic in nature and so is learning, concept formation and evolution etc.

This is why we concentrate in this section on developing Kabbalah system theory dynamic models for the ontological engineering framework in Fig. 2. These models will be in fact Kabbalah system theory models for knowledge engineering and knowledge based modeling rooted in the ontological engineering model of Fig. 2. We will provide thus a common, unifying, integrative framework for ontological engineering and knowledge based modeling / knowledge engineering.

The first step is to model the dynamics of the ontology backcloth or foundation, concept formation dynamics within the ontology Tree of Life model from Fig. 2. For this purpose we introduced in [1] the mathematical category theoretic formalism as the mathematics behind our Kabbalah system theory. This is based on the operations of pullback and pushout which we need to re-define here for ease of understanding. A category is made of objects, morphisms (maps) between objects and morphism composition [9], [10].

Definition 1 The pushout of objects A and B over object C in a category containing objects A,B,C connected by the morphisms g: C → B , f: C → A, is an object PO of that

category together with morphisms n: B → PO and m: A → PO in the category morphism set such that i) the diagram in Fig. 4 commutes m o f = n o g (where "o" denotes morphism composition) and ii) PO has the universality property meaning that for any other object P in the category and morphisms m': A → P and n' : B → P that satisfy the commutativity of the diagram in Fig 3 m'o f = n' o g, there exists a unique morphism p: PO → P such that p o m = m' and p o n = n' (see Fig. 3).

We introduce next pullback, dual to pushout, by y-define here for ease of understanding.abbalah system theory. This is based on the operations of pullback and pushout which wreversing the morphism arrows in Definition 1.

Definition 2 The pullback of objects A and B over object C in a category containing objects A,B,C connected by the morphisms g: B → C , f: A → C, is an object PB of that category together with morphisms n: PB → B and m: PB → A such that i) the diagram in Fig. 4 "commutes" that is f o m = g o n where "o" denotes morphism composition and ii) PB has the universality property meaning that for any other object, P, in the category and morphisms m': P → A and n' : P → B that satisfy the "commutativity" of the diagram in Fig 4 that is f o m' = g o n', there exists a unique morphism p: P → PB such that m o p = m' and n o p = n' (see Fig. 4).

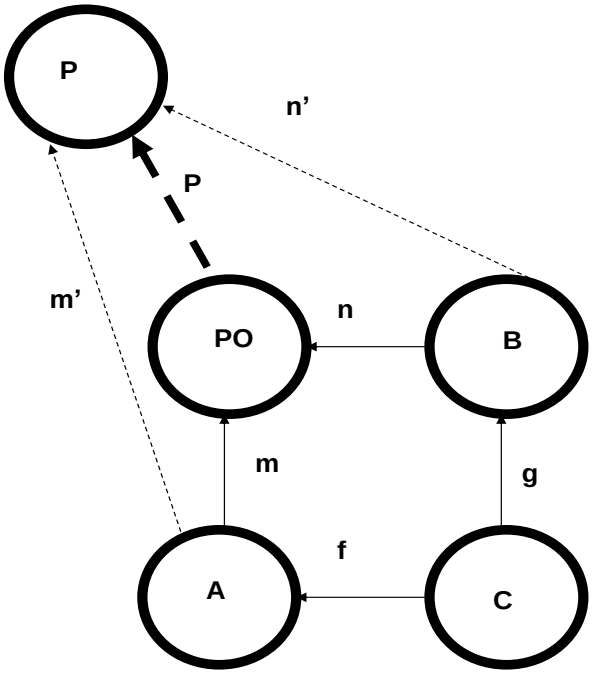

Fig. 3. The category theoretic commuting diagram definition of the pushout PO of objects A and B over C including the universality property (stability, robustness) of PO with respect to any other P. Objects can be concepts, sefirot, classes or categories of concepts etc.

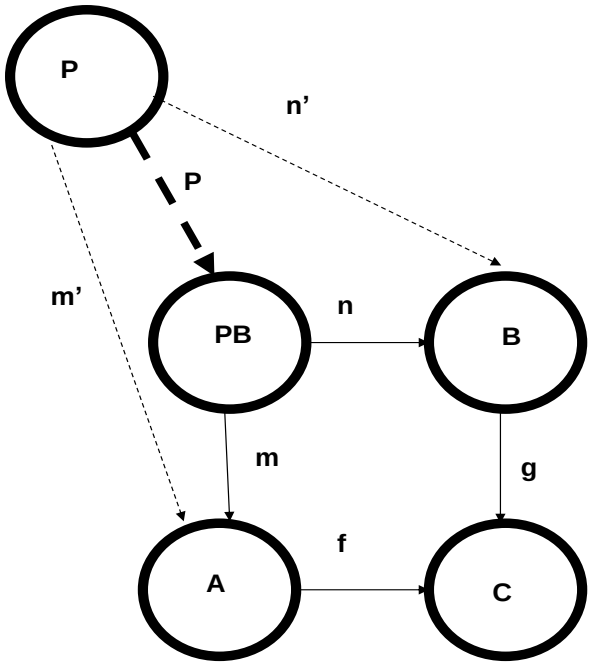

Fig. 4. The category theoretic commuting diagram definition of the pullback PB of A and B over C including the universality property (stability, robustness) of PB with respect to any other P. Objects A, B, C can be concepts, sub-concepts.

The Tree of Life in Fig. 2 can be seen as a diagram in the category of graphs and morphisms between graphs mapping vertices to vertices and edges to edges. Each sefirot corresponding to a class or category of concepts is represented by its own Tree of Life graph and the connections between sefirot as classes or categories of concepts can be modeled by morphisms between graphs. By considering the levels CBD, C'GT, NHY as 2-dimensional faces we can model the sub-Tree of Life of each concept or concept class as a simplicial complex which has vertices, edges or arcs and also two dimensional (triangle) faces CBD, C'GT, NHY. The Tree of Life in Fig. 2 can then be seen as a commuting diagram in the category of simplicial complexes and simplicial maps between them [10]. We obtain the algebraic category theoretic model for the Kabbalah based ontology of Fig. 2 given by Fig. 5.

In the algebraic category theoretic framework of Fig. 5 for the Tree of Life ontology model in Fig. 2, we can define, impose or calculate pullbacks and pushouts across the Tree of Life based on Definitions 1 and 2. It was shown in [13] how pullbacks and pushouts can be used to model concept formation based on bottom up learning and generalization, induction (pushout) and top down validation or verification, deduction. The universality property in Definitions 1 and 2, applied to concepts as pullbacks/pushouts, gives the structural stability of concepts.

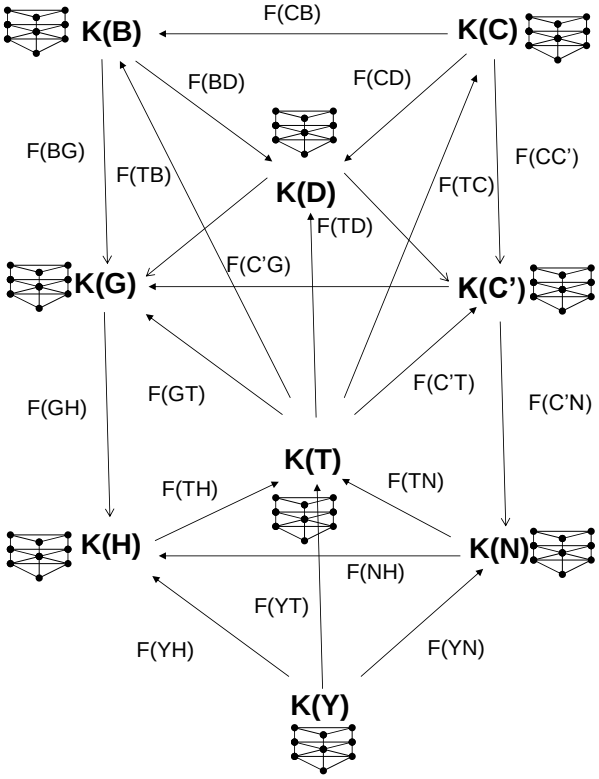

Fig. 5. Algebraic category theoretic model for the Kabbalah system theory based ontological engineering framework in Fig. 2: each concept or class of concepts of the ontology is represented by a simplicial complex of sub-concepts or attributes/properties and the connections between them are simplicial maps between simplicial complexes, denoted F(CB), F(BD),…based on the notation for the domain and co-domain sefirot. The overall diagram is a commuting diagram in the category of simplicial complexes .

In the Tree of Life ontology model in Fig. 2, pullback and pushout are a powerful model for concept formation dynamics across the ontology. One of the examples, is the construction, concept formation, of Harmony (Tiferet) concept, represented by K(T) in Fig. 5, as pullback / pushout of Wisdom (Chochmah) concept, K(C) in Fig. 5, and Understanding (Binah) concept, K(B) in Fig. 5, over Knowledge (Da'at), K(D) in Fig. 5. This was formulated in detail in [1], in general, not for concepts in particular. According to [11],[12], pullback describes system dynamic behavior while pushout is a model of system interconnection. The "blending" of concepts to yield new concepts can be modeled by pushout [14]

The dynamics of the Tree of Life ontology model can be modeled as we explained above, as a diagram in the category of simplicial complexes of each sefirot concept or class of concepts C, B, D….denoted K(C), K(B), K(D),…together with possible pullback and pushout square sub-diagrams within the Tree of Life commuting diagram in Fig. 5. The edges denote simplicial maps between simplicial complexes. This is ontology base dynamics.

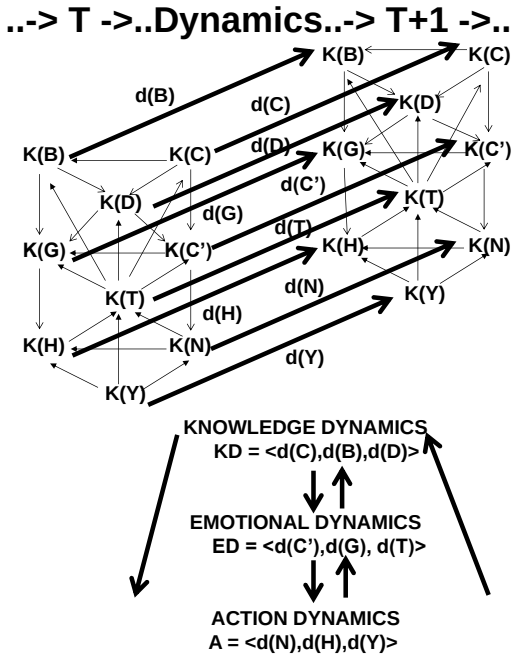

Fig. 6. Knowledge engineering and model building dynamics modeled as a transformation in time of the Kabbalah ontological model in Fig. 2 through a commuting diagram.

The knowledge engineering and knowledge modeling dynamics based on this dynamical ontology is given by the transition from the ontological Tree of Life at one stage to the next stage. This is represented by morphisms (maps) from the three levels of state of knowledge about the concepts (sefirot) at one stage to the three levels of state of knowledge about the concepts at the next stage, a sort of overall morphism between ontological Trees of Life yielding the overall commuting diagram in the category of simplicial complexes given in Fig. 6. We have in fact three sub-dynamics: cognitive, emotional and action, implementation dynamics describing dynamic transformations at each of the three levels of the Kabbalah ontological base model.

If we consider different ontologies modeled by two different Trees of Life in Fig. 6, then we have ontology mapping or transformations from one ontology to another mapping cognitive level to cognitive level, emotional / behavioral level to emotional / behavioral level and action level to action level.

IV. CONCLUSION

The Kabbalah system theory based ontological and knowledge engineering introduced here, based on the Kabbalah system theory [1],[2] unifies in a common framework both the concept formation dynamics in the ontological base and the dynamics associated with knowledge engineering and knowledge model building.

We have a longitudinal dynamics of the knowledge engineering and knowledge modeling, from one Tree of Life model to another whereas the pullbacks / pushouts of concept formation reflect transversal ontological base dynamics, across the Tree of Life base, due to learning, evolution at the level of the system of concepts of the ontology base.

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