Knowledge Representation: Conceptual Graphs vs. Flow-Based Modeling

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Abstract - One of the basic principles of knowledge representation is that it is a language by which people say things about the world. Visual depictions appear particularly useful for representation of knowledge, e.g., Peirce's Existential Graphs, and Sowa's Conceptual Graphs (CGs). Recently, a new flow-based model for representing knowledge, called the Flowthing Model (FM), has been proposed and used in several applications. This paper is an exploratory assessment of the capability of FM to express knowledge, in contrast to CGs. Initial examination suggests that FM contributes to expressing knowledge in a way not provided by CGs. In addition, FM seems to produce a new aspect that may complement the CG formalism. Such exploration can promote progress in knowledge representation and modeling paradigms and their utilization in various applications.

Keywords: Knowledge representation; conceptual graphs; diagrammatic representation; flow-based knowledge representation

1 Introduction

During the past 40 years, visual depictions have been used in the area of knowledge representation, specifically using a semantic network, e.g., [1-2]. Many of these representations concentrate on the fields of linguistic knowledge (e.g., [3]), knowledge in large-scale development of applications, or logical aspects of semantic networks. A basic principle of knowledge representation, as a medium of human expression, is that it is “a language in which we say things about the world” [4]. This paper focuses on this aspect of knowledge representation, in contrast to such features as logical reasoning or computational efficiency.

To limit the scope of this paper, it examines Sowa’s Conceptual Graphs (CGs) and contrasts them with a newly developed conceptual representation based on the notion of flow. The CG was developed as “a graph representation for logic based on the semantic networks of artificial intelligence and Peirce existential graphs” [5; italics added]. Initially, Sowa developed CGs as an intermediate language for mapping natural language assertions to a relational database. They have also been viewed as a diagrammatic system of logic to express meaning in a precise form, humanly readable, and computationally tractable [5].

CGs have been applied in a wide range of fields [5]. In artificial intelligence, CG formalism offers many benefits, including graph-based reasoning mechanisms, plug-in capabilities over data structures, and good visualization capabilities [6]. In addition, a conceptual graph can serve as an intermediate language for translating computer-oriented formalisms to and from natural languages [7]. They provide a readable but formal design and specification language.

The research CGs have explored novel techniques for reasoning, knowledge representation, and natural language semantics. The semantics of the core and extended CGs is defined by a formal mapping to and from ISO standard 24707 for Common Logic, but the research CGs are defined by a variety of formal and informal extensions. [5]

CGs are an intuitive, visual way of creating a semantically sound representation of knowledge [8], and many extensions have been proposed (e.g., [9-10]).

Recently, a new flow-based model for representing knowledge, called the Flowthing Model (FM), has been proposed and used in several applications, including communication and engineering requirement analysis [11-15]. This paper is an exploratory assessment of the capability of FM to express knowledge in the domain of CGs. Initial examination has suggested interesting results when CGs and FM-based diagrams are drawn to depict the same representation. FM seems to produce a new aspect that may complement the CG formalism.

CGs have a solid foundation, not only in the area of knowledge representation but also in reasoning. It is a well-known formalism that hardly needs describing. FM is still an informal description, but it introduces an interesting high-level schematization of knowledge-related problems. It is based on the notion of flow and includes exactly six stages (states) where “things” can transform from one stage to another in their life cycles. The paper examines CGs and FM to contrast common concepts and differences between the two methodologies. Several advantages can be achieved from such a study:

- Enhancing conceptualization of the common concepts by modeling them from completely different perspectives
- Benefiting the foundation of knowledge representation by subjecting the same piece of knowledge to two dissimilar views of modeling
2 Flowthing Model

A flow model is a uniform method for representing things that “flow,” i.e., things that are created, processed, released, transferred, and received. “Things that flow” include information, materials (e.g., goods), and money. They flow in spheres, i.e., their environments. A sphere is different from a set in the sense that a set is a static structure, whereas a sphere includes flowthings (current members) at different stages in a progression and possible directions (lines) of movement from one stage to another, or movement from/to the spheres of the flowthings. A sphere may have subspheres.

An FM representation is a depiction of the structure of a scheme resembling a road map of components and conceptual flow. A component comprises spheres (e.g., those of a company, a robot, a human, an assembly line, a station) that enclose or intersect with other spheres (e.g., the sphere of a house contains rooms which in turn include walls, ceilings). Or, a sphere embeds flows (called flowsystems; e.g., walls encompass pipes of water flow and wires of electrical flow).

Things that flow in a flowsystem are referred to as flowthings. The life cycle of a flowthing is defined in terms of six mutually exclusive stages: creation, process, arrival, acceptance, release, and transfer.

Fig. 1 shows a flowsystem with its stages, where it is assumed that no released flowthing flows back to previous stages. The reflexive arrow in the figure indicates flow to the Transfer stage of another flowsystem. For simplicity’s sake, the stages Arrive and Accept can be combined and termed Receive.

The stages of the life cycle of a flowthing are mutually exclusive (i.e., a flowthing can be in one and only one stage at a time). All other states or conditions of flowthings are not exclusive stages. For example, we can have stored created flowthings, stored processed flowthings, stored received flowthings, etc.; thus stored is not a specific stage. In contrast, there are no such stages as, e.g., created-processed, received-transferred, or processed-received stages. Flowthings can be released but not transferred (e.g., the channel is down), or arrived but not accepted (wrong destination), ...

In addition to flows, triggering is a transformation (denoted by a dashed arrow) from one flow (or stage) to another, e.g., a flow of electricity triggers a flow of air.

Example: In 1883, Peirce [16] developed a graphical notation for logical expressions called an existential graph (EG). Fig. 2 shows this graph for the statement You can lead a horse to water, but you can't make him drink [17]. Fig. 3 shows its corresponding FM representation.

In Fig. 3, there are three spheres: Horse, Water place, and Person. A person creates an action that triggers the transfer of the horse to the water place. In the water place, the horse is received and processed. Process here refers to doing something to the horse, in this case, trying to make the horse drink, but the end result is that the horse does not drink.

It is possible to model that the person actually tries to force the horse to drink by triggering another action (e.g., actually forcing the horse’s mouth into the water; see Fig. 4). Not drinking indicates that whatever “processing” was used on the horse (e.g., getting it wet), the horse did not drink.

As can be seen, it is difficult to present a technical comparison of two diagramming methodologies; however, putting them side by side allows for a visually mediated awareness of the features and expressive nature of each methodology. This general approach is adapted in this paper regarding CGs and FM. Of course, this analysis does not extend to the reasoning capability embedded in CGs.
3 FM and CGs

This section contrasts conceptual graphs and FM by re-casting several CG diagrams in FM representations.

A. Example 1

In CGs, functions are represented by conceptual relations called actors. Fig. 5 shows the CG for the equation

\[ y = \frac{x + 7}{\sqrt{7}} \]

According to Sowa [5], the equation would be represented by three actors (diamond-shaped nodes). “The concept nodes contain the input and output values of the actors. The two empty concept nodes contain the output values of Add and Sqrt” [5].

Fig. 6 shows the corresponding FM representation. We assume that \( x \) is input and 7 is a stored (available) constant in the manner of programming languages. Accordingly, \( x \) and 7 are received, each in its own flowsystem, and both flow to Add (4). In Add, they are processed (added) to trigger the creation of a sum that flows to Divide. On the other hand, 7 flows to Sqrt to be processed to create a square root that also flows to Divide. In Divide, the division operation is performed (which term is divided by which can be specified beforehand in the process stage), to Create \( y \) as output.

Contrasting the two representations from a style point of view, it appears that CG uses extra constructs (represented as shapes in the graph) accompanied by a potentially infinite number of verbs, e.g., add, divide, subtract, … while FM utilizes the notion of flowsystem, repeatedly using the generic six stages.

B. Example 2

Mineau et al. [8] present an example of the text of instructions for decalcifying a coffee machine that can be represented by CG (Fig. 7; see their source of instructions):

In order to decalcify a coffee machine in an environment friendly way, one must fill it up with water and put in two teaspoons of citric acid (from the drugstore). Then, one must fill it up with clear water and let it go through the machine twice. [8]

Fig. 8 shows the corresponding FM representation, according to what is understood from the original description. First, two teaspoons of citric acid (circle 1) are added to water (2) to trigger (3) the creation of a mixture (4). The mixture is poured into the machine (5), followed by triggering (6) the state of the machine to be ON (7). Note here that triggering indicates a control flow. After that the mixture is processed (7) and then released to the outside (8), followed by triggering (9) of pouring water into the machine (10) - twice.

Fig. 5. Functions represented by actor nodes (from [5])

Fig. 6. FM representation of the function

Fig. 7. CG representation of decalcifying (partial, from [8])
Again, it is difficult to present a technical comparison between the two diagramming methodologies (e.g., showing number of nodes, their shapes, edges, …). However, putting the diagrams side by side provides the reader a sense of the expressiveness or understandability of each method, since, as stated by [4], knowledge representation is “a language in which we say things about the world.”

### C. Example 3

According to [5], the most common use of language is to talk about beliefs, desires, and intentions. As an example, the sentence Tom believes that Mary wants to marry a sailor, contains three clauses, whose nesting can be indicated by brackets:

Tom believes that [Mary wants [to marry a sailor]]

The outer clause asserts that Tom has a belief. Tom’s belief is that Mary wants a situation described by the nested infinitive. Each clause makes a comment about the clause or clauses nested in it. The original sentence can be interpreted as,

Tom believes that there is a sailor whom Mary wants [to marry]. That is, there is a sailor whom Tom believes that [Mary wants to marry]. Fig. 9 shows these interpretations using CGs with case relations.

Fig. 10 shows a corresponding FM representation of the second interpretation. Tom (who is an existing person, as indicated by the ability to Create) has an existing (Create) belief (box inside Tom) in a Proposition (idea existing in his mind – Create). The inner part of the figure (box drawn with thick lines, blue in the online version) is a description of the proposition. It does not have Create because it is the schematic portrait of the proposition, the same way a blueprint of the house is not the house itself. The proposition is about Mary, who has a desire: being married to a sailor.

Now, suppose that Mary and the sailor are existing persons. Then the mapping between “reality” and what’s in Tom’s mind is shown in Fig. 11. In the world of Fig. 11, there are three persons (spheres): Tom (1), Mary (2), and the Sailor (3). The “real” Mary (2) and Sailor (3) trigger images (concepts) of Mary (4) and Sailor (5) in Tom’s mind (we could have a box for Mind in Tom’s sphere, but this is implicitly understood). Thus, Mary (7) and Sailor (8) in the proposition “refer to” (trigger) these images of Mary and Sailor (5 and 6). Apparently, the “real” Mary (2) did something (9) that triggered the creation of a belief in Tom’s mind (10).
Now, suppose that there is a sentence in "reality" (e.g., published in a magazine) that Tom believes that Mary wants to marry a sailor; accordingly, this sentence, as shown in Fig. 12, exists (is created, circle 11). Furthermore, suppose that Tom himself first expressed that sentence. Accordingly, Tom’s belief is converted into a mental linguistic “sentence” (Fig. 12, circle 12), I believe that Mary wants to marry a sailor, that is triggered (13) by his belief.

The purpose of these assumptions is to demonstrate certain aspects of FM. The resultant FM “knowledge” representation seems to be a clear map of the various “items” involved in the situation: Tom, Sentence, Mary, and the Sailor have different “realizations” according to the sphere (e.g., Mary in reality, in Tom’s mind, and in a linguistic expression). Inside Tom, we find the “concepts” of Mary, Sailor, his Belief, and his Sentence. Within that belief, we find the proposition and its “meaning.” Comparing the FM (Fig. 12) with the CG (Fig. 9) with its two interpretations, it seems that the FM description provides “something” that has not been captured by the CG.

D. Example 3

Sowa [5] gives a CG for the sentence John is going to Boston by bus (see Fig. 13(a)). The rectangles represent concepts, and the circles represent conceptual relations. “An arc pointing toward a circle marks the first argument of the relation, and an arc pointing away from a circle marks the last argument” [5]. There are three conceptual relations: agent (Agnt), destination (Dest), and instrument (Inst). Fig. 14 shows the corresponding FM representation. In Fig. 13(b), John flows to the bus, and after he gets on the bus, the bus flows to Boston.

According to Sowa [5], The CG can be translated to the following formula:

\[(\exists x)(\exists y)(Go(x) \land Person(John) \land City(Boston) \land Bus(y) \land Agnt(x, John) \land Dest(x, Boston) \land Inst(x, y))\]

But such a formula introduces new information, that John and the bus exist (e.g., the sentence is not song lyrics). Boston’s existence is implied implicitly (no (3z) and Location (z, Boston)). Accordingly, we modify the FM representation by making John and Bus exist (Create), as shown in Fig. 15.

Comparing the two representations, it seems that CG needs additional “semantics” (case relations) by trying to apply roles to concepts (e.g., agent, destination, and instrument), however, this is not used uniformly, e.g., Boston is a location. FM looks more uniform and “simple.”

Additionally, the FM representation of Fig. 13(b) may be susceptible to logic formulas, e.g.,

\[(\exists x)(\exists y)(flow(x, y) \land flow(y, Boston) \land Is(x, John) \land Is(y, Bus))\]
4 Expressing Constraints

This section applies the FM model to specify constraints in a known CG-based case study. In FM, the constraint is an integral part of the flow-based diagrammatic model.

The Sisyphus-I case study [18] is a well-known resource allocation problem where it is required to allocate the members of a research group to different offices, given certain constraints. “Constraints are used to verify the validity of worlds (the world description, enriched by implicit knowledge rules, must satisfy every constraint)” [19]. For constraints, an intuitive semantic could be if information A is present, then we must also find information B [19].

Fig. 15 (from [19]) shows a sample constraint representation in pure CG (using graphs with colored nodes). Fig. 16 shows the corresponding FM representation. The FM representation seems to be simpler since “in” is implicit in the diagram and there is no need to have colored nodes. Note that “in” in Fig. 15 can be interpreted in different ways. It may mean the assignment of the office as a “place of work.” In this case, Fig. 17 expresses that the office is where the boss or the person does his or her work. Or, we can merge the two interpretations of Figs. 16 and 17, and consider “in” to mean the office that takes (receives) the boss when he/she comes to the company and where the boss works.

Consider another constraint described in the literature of the Sisyphus-I case study: If offices are shared, smoking preference should be the same. In other words, smokers and non-smokers should not be allocated to the same room [20]. Fig. 18 shows its CG representation. The figure is not complete because the purpose here is not to present a complete and fair description of the constraint and its representation; rather, the aim is to show the type of diagramming method used and to contrast it with the FM description.

Fig. 19 shows the corresponding FM diagram, drawn according to our understanding of the involved constraint. In Fig. 19, the sharing sphere (circle 1) has two types of offices: smoking and nonsmoking (2 and 3). If there are two persons in any of these offices, say, x and y, then their preferences are the same. Note that x and y are spheres that have two sub-spheres, Work and Preference. Process in the subsphere (e.g., 4) indicates that the person is performing work (e.g., not a visitor). Create (e.g., 5) in the office sphere indicates that the preference is mandatory.
5 Conclusions

This paper focuses on two approaches to diagramming knowledge representation: Conceptual Graphs (CG), and a newly proposed diagramming methodology (FM) based on the notion of flow. The aim is to contrast common concepts and differences between the two methodologies and implicitly to raise the issue that FM may contribute to expressing knowledge in a way that is not provided by CGs. There is also the possibility that FM can be applied in reasoning, but this particular issue is not considered in the paper.

This paper is an exploratory assessment of the capability of FM to express knowledge in the domain of CG. By comparing examples, this initial examination seems to suggest the viability of FM-based diagrams to depict at least a high-level representation that is different in role and application in comparison with CGs. There is also the possibility of a new aspect that may complement the CG formalism. Further research will further explore such issues.

6 References


