UVAL-MED a Universal Visual Associative Language for Medicine

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Abstract

We describe UVAL-MED, a Universal visual associative language for medicine, and propose its use in combination with diagnostic reasoning and decision support systems. When fully developed, our system will automatically translate SNOMED terms to UVAL-MED terms. Grammar and syntax for UVAL-MED are defined and its features as a language-independent tool are discussed. The percieved advantages of our graphical language for rapid integration of knowledge and the assessment of developing situations could thus facilitate decision making.

Introduction

This paper describes UVAL-MED and proposes it for use in medicine as an application of a general approach. In this approach expert knowledge is visualized through "pictures" of mental models assumed to be held by domain experts. UVAL-MED is directly derived from the Concept Graphics described earlier [1-3]. In this paper rules of grammar and syntax are defined to allow the generative assembly of concepts and data at different levels of complexity from visual primitives. When fully developed, the UVAL-MED based system will be capable of automatically translating SNOMED III [4, 5, 19] terms into UVAL-MED terms. The system will thus provide information in a highly ergonomic form that can be read and manipulated by both computers and humans almost regardless of the original language of the data. Questions of the design of graphical representations and their effectiveness have been addressed, among others by Fitter and Green [6], McKinlay [7], Chernoff [8] and more recently by Cole [9]. UVAL-MED incorporates, in a more explicit context, at least four of the five principles proposed by Fitter and Green [6]: **relevance**, providing the useful information, **representation**, of both meaning and underlying processes, structures **restricted** to correct expert knowledge in a **revisable** form. Concept Graphics as used in UVAL-MED incorporate the major advantages of Chernoff faces [8] while avoiding their disadvantages [3]. Cole [9] has defined the terms **integrality** and **meaningfulness** for graphical data displays. A part of this paper discusses the desirability of these qualities in different types of graphical data displays. Wang et al. [3] described an intelligent interface for a diagnostic expert system based on Concept Graphics. In this paper, we discuss the perceived advantages of the use of UVAL-MED as an alternative representation for the **Diagnostic Units and Diagnostically-Operative Causal graphs** (DOC graphs) developed by Jang [10,11].

UVAL-MED grammar and syntax

UVAL-MED is directly derived from the Concept Graphics described earlier [1-3]. Here, the rational basis for the design of the graphics is reinforced and their use is extended to display, when requested, **causality, conditional causality and enablement** [12]. Two subcategories for graphics are defined: Situation Graphics and Process Graphics.

1. Primitive icons represent their meaning either explicitly in shape and color (the heart, the brain), as a metaphore of their meaning (Alcoholism: a hand holding a wine glass) or in a few cases, an invented symbol that must be learned (pain).

2. New concepts are generated by combining primitive icons [2].
3. Concept Graphics in UVAL-MED are assemblies of composite or primitive icons that are displayed together in a square of uniform size. Neither shape nor size of individual icons is standardized. They are determined by considerations of comprehension and design. Wherever possible, the same icon will occur at the same size and place in the square. Concept Graphics folow the principle of connectedness [6,13]. Icons simply occur together in the same square to define the context of a situation.
4. In UVAL-MED Concept Graphics can be displayed in a causally connected mode. Causal, enabling or non causal relations are made explicit, based on the arrow types of Rieger [12].
5. In UVAL-MED primitive or composite icons with their modifiers, time references etc, are highligted as a unit upon request and explained.
6. Diagnostic solutions produced by an expert system will be displayed in UVAL-MED as graphics in progressively distant planes (in perspective) with their attached diminishing probabilities. Two or more co-occuring diseases will be in the same plane. One would then click each proposed disease to obtain its typical time sequence, displayed as a series of graphics with a time scale. One would display the diagnostic problem at hand on the same screen for comparison.

A graphical representation language for integration and assessment of knowledge

Our earlier work [1] has demonstrated that second year medical students briefly exposed to Concept Graphics in nephrology, in addition to text of equivalent information content, performed significantly better on a subsequent quiz than controls exposed to text alone. The advantage appeared with questions requiring correlation of a number of diagnostic elements, not for memorization of a single fact. A significant advantage was also found in the listing of two pathognomonic criteria for the nephritic syndrome. A more complete study is currently under way involving 4th year medical students and residents in surgery. We believe that graphical representation can enhance the ability of the user to integrate knowledge acquired through reading and other means and to integrate rapidly developing or new situations based on prior domain knowledge. Graphics would help "connect" with possibly dormant prior knowledge and could thus facilitate decision making.

Some examples of the graphical language

In Figure 1. a textbook description of acute cholecystitis is represented. Note the cause-effect arrow. Cause: the common bile duct is blocked by stones. Effect: jaundice.

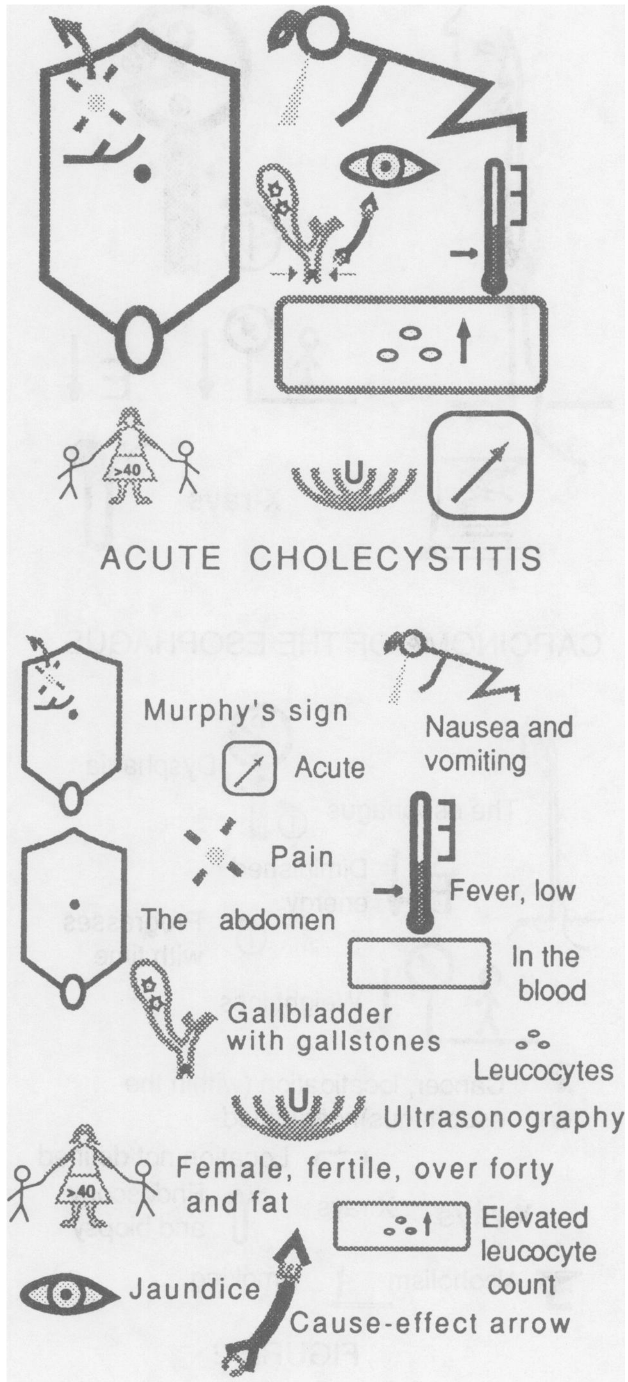

FIGURE 1

Figure 2. represents a textbook description of cancer of the esophagus. Note here the notation that the cancer can occur anywhere within the esophagus in contrast with a situation where a specific location is indicated.

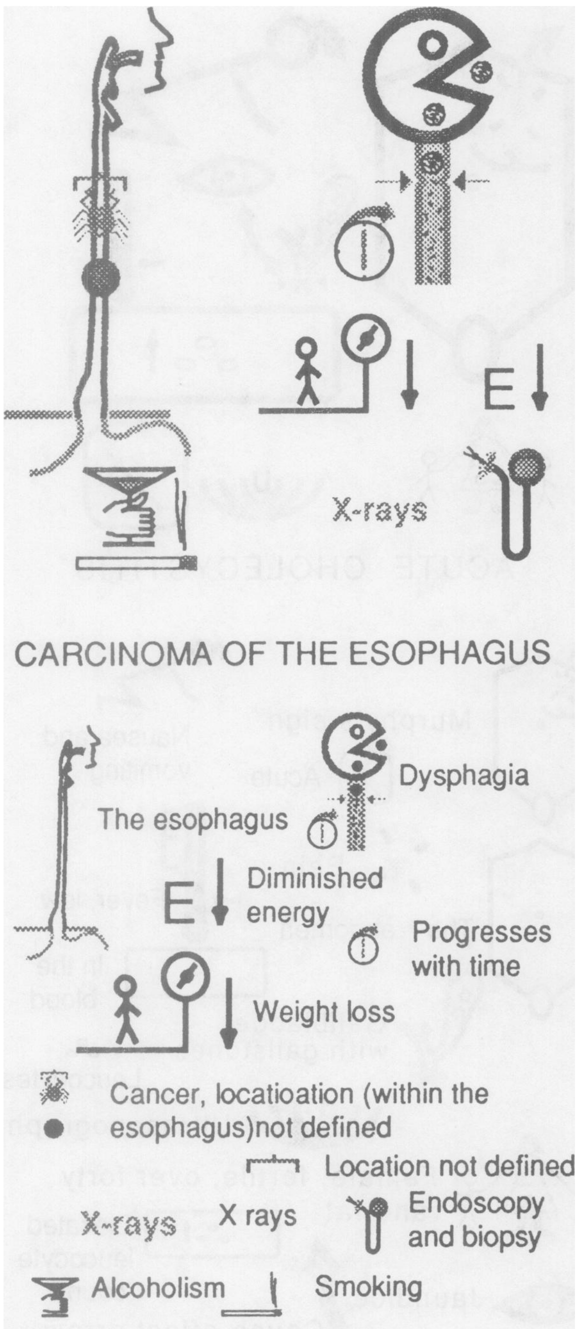

FIGURE 2

UVAL-MED, expert mental models and situated cognition

We propose that users of UVAL-MED or other model-based associative languages would gain advantages in the construction of their own correct mental models of knowledge and of situations requiring a decision. Johnson-Laird and Shafir [14] and Legrenzi et al. [15] advance the hypothesis that both reasoning and decision making depend on the construction of mental models. Future work will be needed to compare possible benefits of our approach with other forms of knowledge and data representation.

Integrality and meaning

Cole [16] has proposed two principles of graphical data display as fundamentally significant criteria. These are **integrality** and **meaningfulness**.

Cole [16] has compared his elegant displays of mechanical ventilation data of ICU patients with Concept Graphics, among others. He has concluded that while the metaphor graphics describing mechanical ventilation data are both high in **integrality** and in **meaningfulness**, Concept Graphics are high in **meaningfulness** and low in **integrality**. Integrality here is described as a quality that allows immediate recognition of a pattern and in which any changes to that pattern would be clearly understood as changes in the real world. This works very well when the graphic display has only one type of shape, a rectangle in Cole's example, assuming a number of meaningful roles.

It seems relevant to ask whether displays of high integrality would be predominantly processed automatically [17, 18]. If this possibility is considered plausible, we may advance the hypothesis that displays of low integrality but high in meaning as well as relatively high in the number of variables under consideration could be treated by controlled search and controlled processing [17], at least when first encountered. Is high integrality a "good" quality for a graphic display? We argue that the answer would depend on the use for which the display has been designed. That is, where one should look for integrality and where it may have negative effects. Shiffrin and Schneider [18] have shown that subjects trained to process images automatically, expecting certain categories of symbols in the same role, perform very poorly when the roles are switched.

The Concept Graphics should be considered as a set in order to discern patterns that help learning and processing. The analysis of a single member of our general surgery set done by Cole [16] lead to the conclusion that Concept Graphics have low integrality, because the multiple shapes of the component icons do not amount to a single salient pattern or overall shape. "Are there emergent features, features that exist when all elements are present and take on certain values, but would disappear if any individual element were to disappear?" [16]. Encoded information, to be useful, must be precisely organized in order to be read. This assumes an even greater importance when one moves away from natural language to perhaps more powerful but less familiar forms of expression such as graphic displays. Concept Graphics should be looked at as assemblies of their component parts before they are seen as a whole pattern. As the reader of a sentence in a paragraph assembles in his or her mind the elements expressed in words, the reader of a Concept Graphic should "put together" the separate elements of the "story" the graphic is telling and then also memorize, we hope without too much effort, the overall shape of the graphic for future reference. We propose that **integrality** should be sought in the component icons of Concept Graphics in order to facilitate search and comprehension of the overall meaning. The component icons such as the thermometer metaphor can be compared to the **radicals** in Chinese characters which often give the reader a clear message on the context of the complete character and help situate its exact meaning even if one were not previously familiar with the character. It would perhaps be easy to conclude that the 5000 chinese characters the native speakers of chinese possess have low integrality. This leads to the question of training in the use of Concept Graphics. Recognition of icons and graphics is not immediate and does require some training or practice. The UVAL-MED based system will translate automatically medical terms (SNOMED III terms) to their graphic equivalents. The graphics will also translate to natural language definitions upon request. A novice user should be able to train with little effort, we hope, while using the system.

UVAL-MED as a language-independent semantic code

SNOMED [19] is designed to allow translation of its terms into any language and multilingual versions of it are emerging. The need for a further development of auxiliary dictionaries, structured in a language-independant form on the basis of semantic analysis of medical information, has been addressed by do Amaral and Satomura [20]. We propose that UVAL-MED can be implemented as an **interlingua** that can situate the user at a glance regarding a medical situation, its past course and ramifications. We propse UVAL-MED as a companion to SNOMED with the capacity to express semantic units of different degrees of complexity and at different levels of abstraction, according to need. In order to implement automatic translation of assemblies of SNOMED terms into UVAL-MED representations it will be necessary to adopt the approach developed by Campbell and Musen [5]. These authors used conceptual graph theory to provide SNOMED III with a standard syntax. The example given in [5] "Substernal chest pain with radiation to left jaw and to left arm" can be readily assembled and visualized in UVAL-MED. A more elaborate treatment of this subject will appear elsewhere.

UVAL-MED representations in an intelligent interface for diagnostic and decision support systems

We chose HYDI, a recent hybrid system for the diagnosis of multiple disorders [11] for a discussion of the perceived advantages to users through alternative representations in UVAL-MED. "An optimal diagnostic unit is an instantiated causal graph, with a single elemental disorder root, such that the causal explanation identified by the graph can be immediately inferred to be the most likely causal explanation for all the findings in the graph" [11]. We propose that, at least in the context of simulation for learning and training purposes, an explicit visual representation of such **diagnostic units** in the form of causally linked Situation Graphics would enhance understanding and integration of medical knowledge. Situation Graphics are Concept Graphics containing only surface features of a medical situation without process explanations or statistical data on susceptible patient groups etc. We also propose that descriptions of underlying processes (Process Graphics when only a process is described) can enhance understanding and integration of the proper sets of symptoms and signs specific to a medical situation. Similarly, at higher levels of complexity, we believe that explicit visual displays in UVAL-MED could be advantageous as alternative representations of **Diagnostically-Operative Causal graphs**

(DOCgraphs), the form in which solved medical problems are stored in HYDI [11].

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