Which Graphical Approaches should be Used to Represent Medical Knowledge?

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Abstract

Medical knowledge is growing both in quantity and complexity. Although sources of medical knowledge have been digitalized, the way the knowledge they contain is presented to users has not changed and is still highly text-based. However, it has been shown that this information could be presented more efficiently using graphical approaches, such as graphical languages and information visualization. We present here a survey of existing methods and applications, and discuss the potential value of these methods for medical practice. These graphical approaches have great potential for improving medical knowledge consultation, provided they are well-designed, well-evaluated and standardized for re-use.

Keywords:
Data Display; Nonverbal Communication; Visual Perception

1. Introduction

Medical knowledge is growing both in quantity and complexity, and it is becoming increasingly difficult to find the right information. Most medical knowledge sources have been digitalized, but the way knowledge is presented to the user has not changed, and still relies principally on text-based approaches. According to the well-known proverb, 'a picture is worth a thousand words', L. S. Elting *et al.* [1] showed that a picture can worth a thousand of medical words. Healthcare professionals need information in three different situations, each of which could benefit from graphical approaches:

- During a consultation: as the patient is present, the professional is stressed and lacks time but the information concerned is often simple. This situation is ideal for graphical approaches, which can reduce the volume of knowledge displayed and provide more rapid access to that knowledge.
- After a consultation, to investigate a specific point in greater detail: the professional is less stressed, and the knowledge involved may be complex. A graphical approach would probably not be accurate enough to represent the complex medical knowledge, but could make it easier to find the right reference text rapidly.
- In continuing education: a graphical approach could make the knowledge more accessible and attractive.

A literature review showed that two complementary approaches can be used: graphical languages and information visualization. We present here the various techniques, with their pros and cons. We also survey existing medical applications and discuss their potential value for use in medical practice.

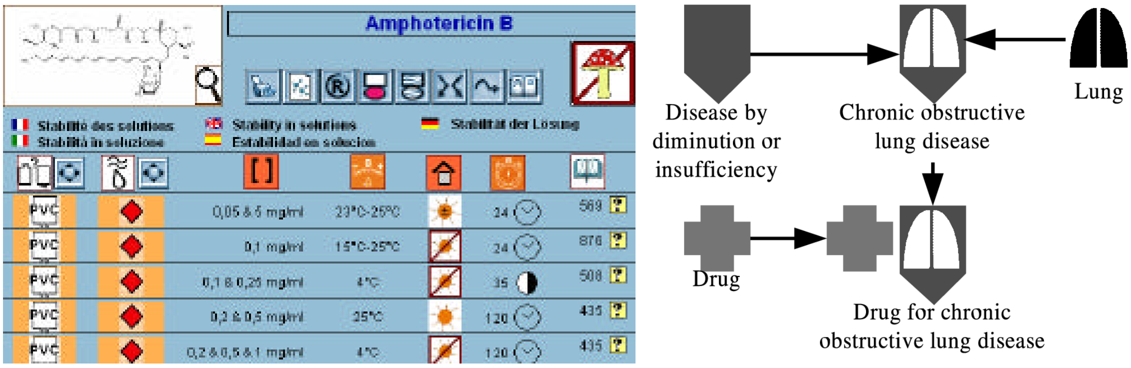

Figure 1: On the left, the stability of amphotericin B expressed in the graphical language of Stabilis 2 (reproduced with the agreement of the authors). On the right, example of pictogram construction in VCM.

2. Graphical languages

Graphical languages are found everywhere today, from traffic signs to computer software icons and modeling (unified modeling language, UML). As simple as they seem, these languages are governed by the complex rules of *semiotics*, the science of signs and sign systems. Graphical languages have several advantages over textual languages:

- They tend to be universal. They can be understood without learning by analogy: words have arbitrary meanings, but we can guess the meaning of pictures of concrete things. They are also independent of native languages, although it is difficult to achieve complete independence from cutural background.
- They are more concise and more attractive to the eye than text, and can be read faster. Under certain circumstances that allow pre-attentive perception, it is possible to search items in a picture very rapidly (< 200 ms), regardless of the number of items [2].

However, graphical languages have some drawbacks: they are less precise than native textual languages, and they often have greater technical requirements such as color printing or animated display. Graphical languages are therefore most appropriate for simple information that must be understood rapidly or universally. Graphical languages often optimize one of these two aspects. For example, chemical product labeling focuses on universal understanding, as everyone must be able to understand the labels, whereas traffic signs focus on the rapid transmission of information, as trained drivers must be able to assimilate the information conveyed by traffic signs as rapidly as possible. Graphical languages for use in medicine also falls into these two categories:

2.1 Graphical languages for patients

These languages involve simple information, convyed in a fashion that can be understood by everyone, using iconic pictures and few, if any grammatical structures. An example is provided by the United States Pharmacopeial Convention (USP) pictograms for drug patient leaflets [3]. These pictograms deal with dose planning, adverse effects, administration route, safe practices for administration, drug storage, interactions with food, contraindications, etc. The pictograms are in black and white and are followed by a sentence in English.

2.2 Graphical languages for health professionals

These languages aim at easing the access to complex medical information. They are specialized and may therefore require a learning period and a medical background, and thus they may use more abstract symbols. When they can't represent complex information, these graphical languages can be used in addition to text in order to take the advantages of both graphical and textual languages. Graphical languages are of particular value when the patient is present, as the professional may be short of time.

Stabilis 2 [4] is a knowledge base on the stability and compatibility of injectable drugs. For each drug, it provides information concerning drug's therapeutic classification, storage, stability in various solutions, incompatibilities, etc. (figure 1, left). It uses a graphical language of about 150 pictograms but has no real grammatical structures. These pictograms make Stabilis native language-independent, whereas most knowledge sources (medical literature, specialized reference books) are available only in English.

VCM (*Visualisation des Connaissances sur le Medicament*, Drug Knowledge Visualization) is a graphical language that we are developing at the LIM&BIO for representing drug knowledge, such as the Summary of Product's Characteristics (SPC) and the therapeutical parts of clinical guidelines (CG). The intended users are health professionals, such as physicians and pharmacists. VCM relies on solid cognitive and semiotic bases. It includes a set of pictograms (currently about a hundred) for anatomical sites, etiologies, pharmacological targets, and adjectives (such as 'forbidden', 'recommended' or 'risk of'), together with simple grammar to combine these pictograms and build 'composed pictograms' such as disease or drug pictograms, and then sentences concerning contraindications, adverse reactions, and so on (figure 1, right).

VCM has been designed to extend textual language but not to replace it, as it cannot achieve a similar level of precision. For example, specific concepts such as the diseases 'asthma' and 'chronic obstructive bronchitis' cannot be represented directly by the language. We use only more generic concepts, such as 'chronic obstructive lung disease', determined with the inheritance relations of medical classifications such as the International Classification of Diseases (ICD10). When more details are required, physicians should refer to the text version.

3. Information visualization

Information visualization (IV) aims to represent a given piece of information graphically, to make that information more accessible and, in some cases, to allow 'visual data-mining'. IV focuses on abstract information with no spatial or geometric properties, and thus no obvious graphical form. Many items of medical data and knowledge are neither spatial nor geometric and fall into the field of IV: for example drug knowledge, patient characteristics and antecedents, clinical results, whereas anatomy and anatomical examinations (*e.g.* X rays) do not. L. Chittaro [5] reviewed the use of IV in medicine, and K. Andrews [6] has produced an almost exhaustive list of IV systems.

IV relies on *interactivity* to involve users. *Fisheye* is used to generate this interactivity; it separates information into the *focus* (information interesting for the user) and the *context* (information less interesting for the user). The user interacts with the system to specify the focus and the context. The focus is then displayed in more detail than the context. There are two types of Fisheye: filtering and deforming Fisheyes. In the *filtering* Fisheye, the context is hidden, like in zoom-based technics. In the *deforming* Fisheye, a larger area of the screen surface is devoted to the focus than to the context. An example of deforming Fisheye is a 3D perspective in a virtual reality tool, in which the nearby objects are the focus and appear larger.

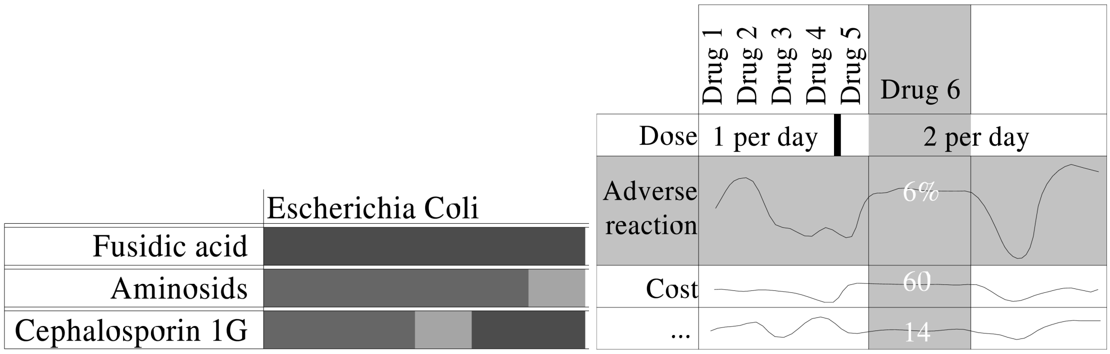

Figure 2: On the left, table displaying antibiotic spectra [8]. On the right, example of a table lens for drug comparison (the selected row and column in gray are the focus).

IV technics are traditionally classified according to the structure of the visualized information, as spatial/geometric properties in IV are often based on the structure of the information.

3.1 Texts

Several methods have been proposed for texts, including greeking and Fisheye, but these methods either deform the text or make it unreadable. As a consequence, none of them appears to be suitable for medical texts; we therefore suggest that graphical languages are the most appropriate way to represent texts.

3.2 N-dimensional data

2D and 3D graphics have been widely used to display medical data for overview or monitoring purposes. An example is provided by interactive parallel bar charts (IBPC), a system designed by L. Chittaro *et al.* [7] for visualization of the clinical data acquired by hemodialyzer devices. However, this system is less useful for the representation of medical knowledge.

3.3 Object-attribute matrices

In medicine, object-attribute matrices may be applied to patients (*e.g.* patients involved in a clinical trial), drugs, diseases and so on. Several visualization methods exist, and these methods highlight the differences or similarities between objects.

Tables can display object-attribute matrices with about 660 cells on screen. A *table lens* can multiply this number by 30. In a table lens, the user can choose how rows and columns are displayed: as numerical values or graphics. This method is highly suitable for highlighting the differences between objects. M. Spenke *et al.* [9] have successfully used the table lens method to display medical data, such as blood parameters, and C. Wroe *et al.* [10] have used such methods to display a drug ontology for authoring purposes. However, table lenses are also likely to be useful for clinical purposes, such as drug comparison. For example, C. Duclos [8] used tables to display antibiotic spectra. Each spectrum is represented by an horizontal bar, the length of which indicates the prevalence and the color of which indicates the susceptibility or resistance (figure 2).

Glyphs are an ideal method for finding similar objects. Each object is represented by a glyph, a small picture arbitrarily modified according to the object's attributes. Similar objects therefore have similar glyphs. L.S. Elting *et al.* [1] have evaluated the use of glyphs for monitoring purposes.

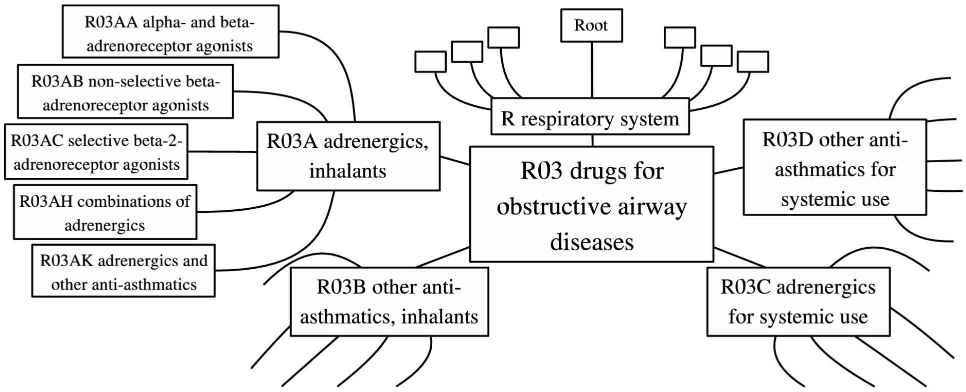

Figure 3: Part of the ATC classification displayed on an hyperbolic tree.

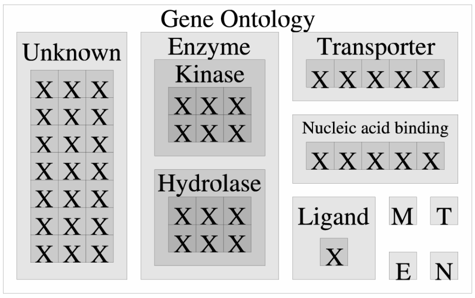

Figure 4: Genes (marked by 'X') classified according to ontology, inspired from [12].

3.4 Trees and networks : medical classifications

Medicine is full of hierarchical structures, such as medical classifications and ontologies. I. Herman *et al.* [11] reviewed tree visualization methods , but few IV methods deal with networks. Most focus on simplified forms of the network and try to turn them into trees. Two methods seem to be particularly interesting:

Hyperbolic trees are highly suitable for navigation, for medical classifications in particular. A hyperbolic tree is a radial tree in a hyperbolic plane. The hyperbolic geometry generates a deforming Fisheye, so more details are visible near the center than at the periphery. The user can navigate through the tree by deplacing the center (figure 3).

Tree-maps provides an overview of a tree, making it possible to discover recurrent patterns; B. Ketan [12] applied this method to the gene ontology. Tree-maps use all the available space; this space is divided horizontally or vertically into several rectangles, one for each node at the first level of the tree. The rectangle for each node is then divided into subrectanges corresponding to the daughter nodes, and so on (figure 4).

3.5 Similarity indices

This method is applied to a set of objects (often texts). A similarity index is then defined for each pair of objects within the set. Objects with high similarity indices are located close together on the screen, forming clusters. This makes it very easy to identify similar objects. In medicine, similarity indices could represent medical documents in a searching tool, or drugs in prescribing software. This would help physicians to find similar drugs when unable to prescribe their first-choice drug due to contraindications, for example. This method could also be used to find clusters of similar patients.

4. Discussion and conclusion

Many methods have been proposed for the graphical representation of knowledge. These methods have already been applied to medical knowledge, but most applications have been evaluated sufficiently and follow an 'intuitive approach' rather than a rational approach.

Graphical language design should take into account semiotics and the abilities of human visual perception. The standardization of medical graphical languages, as has been done for traffic signs, would help to create new languages by re-using some pictograms or some grammatical structures, and would reduce the time required to learn the new language.

It is difficult to choose the right IV method, and the structure-based classification presented above is of little help in practice. For example, drugs can be treated as texts (SPC), a tree (ATC classification), an object-attribute matrix (drug-drug property matrix) or similarity indices (extracted from SPC). It is therefore possible to use any of the methods described above. Methods should therefore not be selected on the basis of the structure of the information to be displayed. Instead, they should be chosen such that the method is appropriate for the intended use. Ideally, several methods should be combined and applied to the same knowledge, allowing the physician to choose the most appropriate method for a particular situation. For example, hyperbolic tree could be used to navigate to beta-blocking anti-hypertensive drugs; a table lens could then be used to compare these drugs, and finally a graphical langage could be used to obtain an overview of the SPC of the most interesting drugs.

In conclusion, there is a clear need for rigorous methodology based on semiotics and information vizualisation. We are currently far from the achievements in other domains, such as information retrieval, but this study has provided convincing evidence that graphical approaches are of value for the presentation of medical knowledge.

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