Towards Solving the Interdisciplinary Language Barrier Problem

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February 1, 2008

There are two great secrets to success in life. The first is to not tell everything you know.
Anonymous

Everybody laughs in the same language.
Anonymous

0.1 Abstract
This work aims to make it easier for a specialist in one field to find and explore ideas from another field which may be useful in solving a new problem arising in his practice. It presents a methodology which serves to represent the relationships that exist between concepts, problems, and solution patterns from different fields of human activity in the form of a graph. Our approach is based upon generalization and specialization relationships and problem solving. It is simple enough to be understood quite easily, and general enough to enable coherent integration of concepts and problems from virtually any field. We have built an implementation which uses the World Wide Web as a support to allow navigation between graph nodes and collaborative development of the graph.

1 Introduction

1.1 The Ills of Specialization
The problem we are concerned with in this work is extremely common in today’s world. Anyone who has consulted medical doctors without having himself or herself a good grasp of medicine
has encountered a language barrier first-hand: whereas the doctor (usually) knows what he is doing and will be able to discuss it with other experts in the same field, his patient will understand very little of what is going on in such a dialogue, because it will be replete with terms that mean nothing to him. Moreover, frequently the doctor will not be able to fully convey his understanding to the patient. This can be a frustrating predicament, especially as the issues under discussion may greatly matter to patient.

To specialize is to concentrate on a particular, necessarily restricted activity or field of study. Observing the contemporary world, it is not difficult to discern a massive trend towards the specialization of humans, which translates into an explosive growth in the number of fields of human activity. Specialization is a way of increasing overall efficiency; one of the better known examples is Henry Ford’s introduction of the assembly line for manufacturing cars. By assigning to each member of the production team a single task to be performed on the cars as they passed by slowly down the assembly line, Ford realized a tremendous gain in efficiency compared to traditional assembly methods.

While specialization is desirable from that particular point of view, it also has a downside: the more a person becomes specialized, the less he can meaningfully discuss problems that matter to him with other people. In effect, the specialist is very often restricted to collaboration with other specialists in the same area. As one gets more and more specialized, pools of colleagues grow ever smaller. This is unfortunate because discussions with specialists in another area often prove to be fertile ground, as ideas and strategies which were first developed in one field often turn out to be adaptable to a problem in a different field. Indeed, breakthroughs often result from interdisciplinary collaboration: it is not unusual that effective tools for tackling a long-standing problem in an area are found in another area. For instance, the recent scientific successes of genome sequencing owe much to the collaboration between biologists and computer scientists. Another adverse consequence of the isolation arising from specialization is that many people reinvent the wheel for themselves because they are unaware of similar work that has been done elsewhere.

Interdisciplinary communication is thus desirable from the point of view of progress; that is, it is helpful in solving problems, especially the more important and challenging ones. Consequently, finding efficient ways of communicating with outsiders is becoming an increasingly pressing problem for people who are not content with speaking only with an inner circle of colleagues. A way to alleviate the problem is to learn another specialty, which will provide opportunities for discussion with a larger circle of people. However, learning a specialty usually involves a considerable time investment; moreover, there are so many different specialties that even selecting a promising one can be a difficult problem in itself.

### 1.2 A Language Issue

Human communication is an activity whose goal is to convey meaning from one person to another. Language is a set of signals (such as words, images or gestures) which serves to conduct it. In order for two people to communicate, it is necessary that they agree on signals and their meanings. A language barrier exists whenever the signals one person uses are not recognized or have different meanings.

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1. This text uses the masculine to include the feminine.
2. Crane and Small reported that there were 8530 definable knowledge fields in 1987. It is reasonable to presume that the figure has grown significantly since then.
meaning for the other person.

Since different specialties are concerned with different things, specialists develop different languages that enable them to communicate efficiently amongst themselves. The advantage in developing a specialized language is that of conciseness. Expressing a complex, multi-faceted construct in a single word is preferable to always using everyday (commonly used) language. This is because the unequivocal description of the construct in everyday language is usually much longer. As a case in point, consider the fact that mathematical equations used to be expressed in words. Following the development of a symbol system providing shorthand representations for recurring expressions (i.e. $x$ being substituted for the phrase “the unknown”), it became easier to think about complicated mathematical problems. However, at the same time an additional requirement was imposed unto whoever wanted to understand what mathematicians were doing: it became necessary to learn their specialized language.

In the time of Leonardo da Vinci, it was possible for a dedicated individual to become reasonably versed in most existing disciplines, providing ample occasion for cross-fertilization between fields. Sadly, nowadays this is no longer possible. The interdisciplinary language barrier problem is universal, because one can be trained in no more than a few specialties, and consequently cannot easily understand the languages that are used in the other specialties.

### 1.3 Connections Between Languages

How does one convey the meaning of words\footnote{In what follows, we use “word” to mean any kind of signal.} belonging to a language which they understand to someone who has never heard of them before? (This is a central problem in teaching.) A well-known strategy consists in using words known to both teacher and student to explain what a new words means. Those will either be words taken from everyday language, or specialized words which are known to be understood because an area of overlap exists between the teacher’s and the student’s backgrounds.

We wish to stress the point that this overlap, the common ground between teacher and student, can be a major determinant of the efficiency of this process. For instance, if both master the language of mathematics at a sufficiently advanced level, the teaching of elementary physics should be greatly facilitated. This is because numerous and deep connections have been established between those two fields. Thus a learner acquainted with the concept of derivative will most likely quickly understand that of velocity, seeing it as a special case of a derivative of a spatial variable with respect to a temporal variable. This specialization relationship between concepts can be seen as a shortcut from one field to the other, since understanding one of the concepts enables one to understand the other quickly, without building it from the ground up. A similar argument could be made concerning the situation of someone familiar with the concept of velocity who wishes to understand that of derivative. If we abstract out the labels of space and time from the concept of velocity we get that of derivative. In that direction, the shortcut is rather a generalization relationship. Specialization and generalizations are two sides of the same coin: the former consists in putting particular things in as-yet-empty boxes, while the latter consists in removing them.

The last example referred to recognizing something new as a particular form of something that is already understood, and vice versa. Sometimes connections between concepts are not as obvious. For instance, a physicist who is introduced to the concept of chemical reaction speed
might perceive a similarity between it and the concept of velocity, which might help him grasp
the former concept. What happens here is that both concepts may be seen as special cases of a
common, more general concept: that of a derivative with respect to time. In this case the shortcut
is an indirect, two-link path from the particular to the general and back to the particular. Note
that even though the learner may perceive the similarity between two concepts, he may not readily
express the common abstraction in words.

Shortcuts of the three types mentioned above (specialization, generalization, and similarity)
have much value because they enable learners to quickly learn about a new topic, capitalizing on
their mastery of a specialty. Having access to a large, organized body of such shortcuts, would
provide specialists with a quick and rather painless way of learning about new topics. It would
consequently enable them to discuss meaningfully with specialists from other fields, thereby giving
them a chance to overcome the interdisciplinary language barrier with much less effort than is
currently required.

The natural question which arises from the previous discussion is the following one: are there
really that many shortcuts between the concepts belonging to different fields of human activity? If
so, are there ways of identifying them, organizing them, and sharing them? The goal of the present
work is to examine those questions and provide elements of answers to them.

1.4 Mathematics as “Shortcut Science”?  

The previous examples, as well as simple observation of the methods used in several sciences,
point to the discipline of mathematics as a kind of substrate underlying many specialized concepts.
Indeed, mathematics does provide a kind of integrative unity to a very large body of knowledge
comprising most of physics and chemistry, parts of engineering, computer science and economics,
etc. One could think of it as a well-organized, useful network of passageways between those fields.
A mastery of mathematics will definitely help someone learn any of those fields.

However, the network is far from completely connecting every concept in every field and sub-
field. If such were the case, able mathematicians would likely rule the world. What is missing?
What kinds of knowledge have not been abstracted out and organized by mathematicians?

Insofar as it can be considered as knowledge, know-how or problem solving knowledge, which
relates to the actions that enable one to accomplish a particular task or to reach a particular goal,
is an obvious and glaring omission. Among other disciplines, computer science has made a few
forays into this area, especially as regards the specification of know-how, but a proper and general
organization of know-how is nowhere to be found at present. Many problem solving strategies
have been identified, a few relationships have been identified between them, but for most problems
that appear for the first time there is currently nowhere to look for potentially appropriate strategies.

Problem solving is a central human activity. Most occupations are defined by the set of prob-
lems they are concerned with. Problem solving knowledge that is specific to an occupation is often
referred to as the “tricks of the trade”, and (sadly) is seldom well documented. Acquiring it quite
often involves a sometimes costly process of trial-and-error which is called “experience”. More
often than not, success in an occupation depends on achieving mastery of those tricks. The useful-
ness of properly documenting problem solving processes lies, among other things, in the potential
it has for reducing the amount of trial-and-error that is necessary to learn a trade.
1.5 Scope of this work

This work makes the (admittedly audacious) suggestion that a simple approach laid upon the foundation of specialization and generalization relationships and problem solving strategies may enable concepts, problems and solution strategies from all fields of human endeavour which are describable by language to be structured together in a coherent, usable manner. This structure may be seen as a large graph linking these entities together. Moreover, it proposes a practical means of building and providing access to such an organized body of knowledge which is based on currently available technology.

Of course, our conjecture cannot be proved true without exhaustively organizing all (symbolic) human knowledge, a task which is beyond the reach of any individual. However, demonstrating it to be false would require identifying something which demonstrably does not relate to anything. The mere act of defining such a thing would put it in relationship with something, which would create a contradiction.

Having put aside questions of absolute truth or falsity regarding our claim, one might still legitimately attempt to evaluate the practicality of the methodology presented here. In order to address this question, we have applied the methodology to produce a small-scale prototypical structure comprising concepts from diverse fields of activity, to test the practicality and the general applicability of our approach.

1.6 Citation Warning

Texts such as this one are usually replete with references to related work by other researchers. As the topic under discussion here is quite broad, every reader will undoubtedly find relationships between this work and other work, perhaps even his own. Without the shadow of a doubt, the present work reinvents several wheels which have already been invented in other fields of study.

However, the reader will find a remarkable paucity of citations in this document. There are two reasons for this state of affairs, one benign, the other more serious. The first is that the author will never have time to read and understand everything in every discipline which could be related to this work. The second is that, because the problem considered here is intrinsically interdisciplinary, the author doesn’t have at his disposition proper means of finding everything which could be related to this work. This unfortunate predicament actually constitutes the original motivation for this work.

1.7 Structure of the Document

The remainder of this document further explains and provides support for what has been suggested in this introduction.

Section 2 explains our approach to the problem. It is divided in two. Subsection 2.1 explains the basics of graphs, which we subsequently use to explain our approach. Other ways of describing the same approach are possible, but the idea of a graph is intuitive and allows for easy-to-grasp visual representations.

Subsection 2.2 argues that any concept that is expressible in a language is defined by way of its relationships to other concepts. It describes the basic structure of a type of graph node which may serve to represent a concept, and types of links which may originate from such a node.
Three particular kinds of concepts are central to our work and are explained in Subsection 2.3. They are: problems, solution patterns, and strategies. Another useful concept is that of domain, which is explained last.

Section 3 describes our prototypical implementation of a concrete example of a product of our approach. We conclude in section 4 by summarizing this work and providing directions for future research.

2 A General Approach to Organizing Concepts and Problems

2.1 Graphs, Nodes and Links

A graph is a set of abstract entities called nodes that are connected by abstract entities called edges. The word “edge” has a geometrical connotation which may be confusing in the context of this work; we use the word “link” instead. Links represent relationships that exist between nodal entities. A link which represents an asymmetrical relationship (for instance, the relationship between parent and child) has a direction, that is, one of its endpoints is labelled as the origin node and the other is labelled as the destination node. Sample visual representations of graphs are found in figure 1.

Figure 1: Examples of graphs. Nodes are represented as circles and links as line segments (indicating symmetrical relationships) or arrows (indicating asymmetrical relationships).

The concept of a graph is useful in a multitude of contexts, for instance for representing transportation or communication networks. It has also been extensively used to represent relationships between concepts. Our approach uses nodes to represent concepts, and links to represent specific kinds of relationships that exist between them.

2.2 Concepts

Dictionaries define the meaning of words using other words. Teachers do the same with students who are learning new ideas. This suggests the general statement that a concept that is expressible in a language is defined by way of its relationships with other concepts. This is not something which can be proved. The only way to go further in this work is to temporarily accept that it may be true and see where this leads.

We have said that we want to define a type of graph node which may serve to represent any concept. We have already explained what we mean by definition, generalization and specialization. Our proposition is the following. A concept node features:
1. a name, which is a signal which may be used to refer to the concept among people who understand it;

2. a definition which contains links to the concepts which are involved in it;

3. a set of links to concepts that are generalizations of the concept;

4. a set of links to concepts that are specializations of the concept;

5. a set of links to other concepts whose definition directly involves the concept;

6. a set of links to problems in which the concept is directly involved; and

7. a link to a domain which this concept primarily relates to.

We give an example of a concept node which could describe the concept of an ordinary quadratic function.

1. The name is the expression “real-valued quadratic function of a real variable”.

2. The definition is the phrase “A real-valued polynomial function of a real variable involving terms of the second degree at most.” Italicized words indicate that links to the corresponding concept nodes exist.

3. Generalizations could include, but are not limited to: “polynomial function solvable by radicals”, “function having a global extremum”, and “high school level mathematical concept”. Note that the first generalization classifies the concept from the standpoint of algebra, the second one highlights a property that could be useful in an optimization context, and the third indicates a property that could be useful in an educational context. The three are quite different; their relevance depends on what one is looking for.

4. Specializations could include: “real-valued quadratic function of a real variable having no real root”, “real-valued quadratic function of a real variable having one real root”, “real-valued quadratic function of a real variable having two real roots”, “real-valued quadratic function of time”, “real-valued quadratic function of a spatial variable”. Here the first three specializations have a mathematical flavour while the latter two have a physical flavour.

Let us recall at this point that the overall goal is to obtain a graph that is easy for humans to use. This implies that someone who is creating a node must strive to ensure that none of the above two lists grow to become unmanageably large. In order to achieve this, a guiding principle needs to be applied. Our prescription is the following: systematically hide complexity by introducing new, meaningful nodes wherever possible. What this means for instance is that instead of listing “real-valued quadratic function of straight-line distance”, “real-valued quadratic function of geodesic distance”, etc. as specializations, one should instead bundle them together into

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4We remark that words often have multiple meanings. This means that one particular expression may appear as a name in a number of distinct concept nodes. Obviously, the rest of the node contents disambiguates the name.

5We explain what we mean by a problem in section 2.3.1.

6We explain what we mean by a domain in section 2.3.4.
“real-valued quadratic function of a spatial variable”. The same principle should be applied for
generalizations. A similar principle is often applied successfully in the context of writing, where
explicit structure serves to help the reader deal with the overall complexity of the text.

5. An example of a concept whose definition directly involves this concept is that of a paraboloid.

6. Problems could include links to the following problem nodes: “Obtain the roots of a real-
valued quadratic function of a real variable”, “Find the extremum of a real-valued quadratic
function of a real variable”, “Teach the concept of quadratic function”.

7. Finally, the domain link could connect the concept node to the domain of mathematics.

2.3 Special Concepts

In the last subsection, we defined the structure of nodes which represent concepts. Here we define
slightly different structures for nodes which describe problems, solution patterns, strategies, and
domains.

Subsection 2.3.1 explains what we mean by a problem. It describes the basic structure of a type
of graph node which may serve to represent a problem, and types of links which may originate from
such a node.

Subsection 2.3.2 explains what we mean by a solution pattern to a problem. It describes the
basic structure of a type of graph node which may serve to represent a solution pattern, and types
of links which may originate from such a node.

Subsection 2.3.3 explains what we mean by a strategy. It describes the basic structure of a type
of graph node which may serve to represent a strategy, and types of links which may originate from
such a node.

Subsection 2.3.4 explains what we mean by a specialized domain of activity and argues that a
domain can be approximately defined by the set of concepts, problems and solution patterns which
it is concerned with. It describes the basic structure of a type of graph node which may serve to
represent a domain, and types of links which may originate from such a node.

At this point in our exposition, we would suggest that the reader take a look around our pro-
totype implementation, which is described in section 3. This should make it easier to understand
what follows.

2.3.1 Problems

Up until now we have talked about problems without defining more precisely what we meant by
that term, hoping that the reader has encountered enough problems in his life to have an intuitive
grasp on that concept.

Our conception of a problem is similar to that proposed by Polya[1]: a goal in a context which
we can express clearly, but that is not immediately accessible. This is a very broad definition.
Examples of common problems are: to find something to eat in a cluttered refrigerator, to obtain
recognition from others, and to understand something.

What constitutes a problem for a person is not necessarily a problem for another. For instance,
for most people getting out of bed is an immediately accessible goal, while this is far from being
the case for a baby. Thus a possible line of action for someone who does not know how to solve a problem is to collaborate with someone who does. (This may be a problem in itself.)

A problem is fully specified when both goal and context are unequivocally specified in terms of concepts. We propose to represent problems in nodes which feature:

1. a (possibly empty) set of names used for referring to the problem;
2. a description of the problem, comprising goal and context;
3. a set of links to generalizations of the problem; that is, instances of the problem with a generalized form of the goal, a generalized form of the context, or both;
4. a set of links to specializations of the problem; that is, instances of the problem with a specialized form of the goal, a specialized form of the context, or both;
5. a set of links to solution patterns to more complex problems which require, as a substep, that this problem be solved, providing motivation for solving the problem;
6. a set of links to solution patterns that apply to the problem;
7. a link to a domain which this problem primarily relates to.

We give an example of a problem node which could describe the problem of solving an ordinary quadratic equation, given that we know the quadratic formula \( \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \). We ought to warn readers who are used to solving this problem without even thinking about it that seeing the problem from the perspective of someone who is tackling it for the first time will likely require some effort.

1. A name could be “Solve an ordinary quadratic equation”. Note that it is easier for a specialist to refer to the problem by its name, while it is easier for a non-expert to refer to the problem by its longer but more explicit description.
2. The description of the problem could be the following: “Obtain the roots of a real-valued quadratic function of a real variable, using the quadratic formula”. Links to the relevant concepts, i.e. that of a root, that of a real-valued quadratic function of a real variable, and that of the quadratic formula are provided.
3. An example of a generalization of the problem could be: “Obtain the roots of a polynomial function solvable by radicals, using an appropriate formula.”
4. A (perhaps a little contrived) example of a specialization of the problem could be: “Obtain the roots of a real-valued quadratic function of a real variable of the form \( ax^2 + c \), using the quadratic formula.”
5. An example of a solution pattern which involves solving this problem could be that consisting in finding the intersection of a line with a parabola by (1) finding the corresponding quadratic equation; and (2) solving it.
6. A solution pattern that is applicable to the problem could be that consisting in computing the solution by feeding the polynomial coefficients into the quadratic formula.
7. Finally, the domain link could connect the problem node to the domain of mathematics.
2.3.2 Solution Patterns

Solving a problem amounts to finding a precise line of action which will enable one to attain the goal. The line of action is made up of a series of subproblems to be solved. This is what we mean by the term solution pattern. Finding (and remembering) a solution pattern is interesting because it is reusable once found: if the same problem arises again, it suffices to apply the same pattern again to solve it. For instance, once the standard solution pattern to ordinary quadratic equations has been remembered, any such equation can be solved without hesitation. The more general the solution pattern, the wider its applicability. Of course, a very general solution pattern can hide much of the actual complexity because the subproblems it features can be complex problems in themselves. By contrast, a very specialized solution pattern is quite straightforward to put into application, but has a correspondingly restricted applicability.

A solution pattern is fully specified when all the subproblems which compose it are identified. The solution pattern is guaranteed to be usable if every one of its subproblems has a known solution pattern. If such is not the case, the solution pattern may be usable, but this is conditional upon finding solution patterns to every subproblem.

We propose to represent solution patterns in nodes which feature:

1. a link to the associated problem;
2. a link to a strategy which generalizes the solution pattern (strategies are defined in the next section);
3. a specification of the solution pattern, containing links to the subproblems that it entails;
4. a link to a domain which this solution pattern primarily relates to.

We give an example of a solution pattern node which could describe a way of solving an ordinary quadratic function.

1. A link to the problem “Obtain the roots of a real-valued quadratic function of a real variable, using the quadratic formula” could be provided.
2. A link to the strategy “Obtain a result from an appropriate input and a procedure” (explained next) could be provided.
3. The solution pattern consists of a single subproblem: “Evaluate the quadratic formula on the polynomial coefficients”.
4. Finally, the domain link could connect the problem node to the domain of mathematics.

The equivalent term in computer science is algorithm. Procedure is another word which refers to the same concept.
2.3.3 Strategies

This work makes the (perhaps controversial) assumption that every problem solving process can be modelled as a sequence of two steps: (1) putting the problem in relationship with a very general, abstract form of problem for which the (abstract) solution is known; (2) translating the abstract solution into terms that are specific to the problem. We call *strategy* an abstract problem form accompanied by its associated solution which has wide enough applicability to be used in almost any domain. A strategy captures the essential aspects of a solution pattern. Strategies are interesting because they suggest reusable forms of solution for wide classes of problems.

We illustrate the process of going from solution pattern to strategy by considering the following simple problem. Suppose a friend has secretly chosen a number between 1 and 10 and asks you to repeatedly guess what it is. Each time you make a guess he will tell you whether your guess is indeed the secret number. The problem is to find the secret number. You choose a simple solution pattern: you try every number in order, from 1 to 10, until your friend confirms that you have found the secret number. This is an appropriate solution pattern, in the sense that you are guaranteed to find that number.

What would be the strategy in such a case? It is often hard to tell what is going on in one’s head; we can only make conjectures as to what really happened. Our point of view is that strategies can be identified, which may or may not correspond to the actual mental process. Although knowing more about that process would certainly be interesting, the only goal we are concerned with here is finding an abstract form of the problem for which a valid solution is known. The important thing to recognize is that once we have found a potentially appropriate strategy, it is easy to check whether it is indeed qualifies as a generalization of the solution pattern at hand.

What can be abstracted out of our problem without essentially changing it? First, note that the concept of number is not essential, for we could have replaced numbers with letters of the alphabet or billiard balls. The important thing is that we had a finite set of possible objects to choose from. Second, what is essential in your interaction with your friend? Surely your friend could be replaced by a machine which tells you whether you have found the right object. The essential thing here is that you have a way of checking whether a given object satisfies the property of being the secret object. Finally, what was the use of counting to ten? It was to provide a way of selecting an untested object at each guess.

Thus the abstract version of our problem is the following: “Find an object satisfying a particular property in a finite set of objects, given a way to check an object for the property and a way to find an untested object”. The strategy solution pattern is the following: “As long as an object satisfying the property is not found, find an untested object and test it”. People seem to use such a strategy everyday; finding something to eat in a cluttered refrigerator, shopping for clothes or selecting an appropriate screwdriver from a toolbox are examples of problems where this strategy applies.

In a sense, strategies are even more useful than domain-specific solution patterns in the sense that they are relatively easy to grasp and apply to large sets of problems. They are also very useful from an interdisciplinary standpoint because they provide clear connections between methods that are used in different fields.

We propose to represent strategies in nodes which have a structure similar to that of problems:

1. a (possibly empty) set of *names* used for referring to the problem;

2. a *description* of the problem, comprising goal and context;
3. a set of links to strategic generalizations of the problem; that is, strategies that apply to problems involving a generalized form of the goal, a generalized form of the context, or both;

4. a set of links to strategic specializations of the problem; that is, strategies that apply to problems involving a specialized form of the goal, a specialized form of the context, or both;

5. a specification of the solution pattern to the problem, containing links to the strategic sub-problems that it entails;

6. a set of links to domain-specific specializations of the strategy; that is, domain-specific solution patterns which are specializations of the strategy;

7. a link to a domain named “strategies”.

In the example of the applying the quadratic solution formula, the associated strategy node could take the following form:

1. Possible names could include “Apply a recipe”, “Do it by the book”.

2. The description of the problem is “Obtain a result from an appropriate input and a procedure”.

3. A possible generalization could be the strategy “Obtain a result from a procedure and an input”, the precise nature of the input (for instance, as being appropriate versus almost appropriate) being abstracted out.

4. A specialization could be the problem “Effortlessly obtain a result from an appropriate input, a procedure, and a helper”.

5. There would be a single strategic subproblem in this case: “Apply the procedure to the input”.

6. A domain-specific solution pattern could be the one described in the previous subsection;

7. Finally, the domain link would connect to the domain of strategies.

2.3.4 Domains

The concept of domain provides a convenient way of classifying specialized concepts, problems and solution patterns which are somehow related together. Almost everyone today thinks of himself as a specialist in a particular domain. Thus we have quantum cosmologists who are physicists who are specialized in quantum cosmology; neurosurgeons who are medical doctors who are chiefly concerned with brain surgery; hitmen who are criminals that specialize in murder; and so on.

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8 We characterize an input as almost appropriate with respect to a procedure if we have a way of converting it to an input that is appropriate for that procedure.

9 Calling upon a computer or a graduate student to perform the work should come to the minds of experienced researchers.
Being able to label people is useful. Upon learning that someone has expertise in a particular domain, we know that this person masters the concepts and problems of the domain. If we need to solve a problem which we know to be related to that domain, we know that this person may be able to help.

We propose to represent domains in nodes which have the following structure:

1. A name which people who are specialized in the domain use to recognize each other;

2. A set of generalizations which are disciplines which may be considered to be the roots of the domain; usually this is the domain in which specialists of the domain are first trained.

3. A set of specializations which are disciplines which may be considered to be the branches of the domain;

4. A set of prominent concepts which are the central concepts used in the domain;

5. Finally, a set of prominent problems which are the central problems that a specialist in the domain knows how to solve.

In the case of mathematics, the domain node could read as follows:

1. The name is “mathematics”.

2. A possible generalization could be “science”.

3. Possible specializations could include: “fundamental mathematics”, “algebra”, “number theory”, “geometry”, “topology”, and “mathematical analysis”.

4. Possible prominent concepts could include: “set”, “number”, “function”, “axiom”, “proof”, and “definition”.

5. Possible prominent problems could include: “prove a proposition” and “find an unknown from data”.

Domain boundaries are quite fuzzy and constantly evolving. New domains pop up ever more quickly as the trend towards specialization accentuates. On the other hand, some domains become obsolete. Thus we see less and less blacksmiths, alchemists and carriage makers as time goes by. An unfortunate aspect of this kind of natural selection among specialties is that interesting solution patterns may die along with their trade unless those processes are documented before their complete extinction. We remark that a graph such as the one described in this work could obviously represent the forgotten specialties alongside the current ones.

3 An Implementation

The previous section described a basic architecture for organizing concepts and methods. Here we describe a simplistic but concrete form which this architecture may take. We have built a prototypical knowledge base which uses this basic design. We are certain that many improvements could be made to further facilitate navigation among concepts.
The World Wide Web (WWW) consists of documents that are available on the Internet. These documents (“web pages”) are written in hypertext, which means that they may contain links to other documents. There is no restriction on what documents a given document may link to, as long as the target documents are themselves available somewhere on the Internet. Users of the Web use WWW browsing software to view documents and can move over to linked documents with a simple mouse click.

Our implementation uses this technology in a very straightforward manner. Each concept, problem, solution pattern or strategy is explained on a single web page, and the relevant links are provided in that page. Every page follows the template corresponding to the kind of concept it describes. This homogeneity enables one to explore the knowledge base confidently once the nature of the basic kinds of links have been understood.

Thanks to the way the WWW is designed, the pages which constitute the knowledge base need not all be in the same physical location. This allows different parts to be developed by people working in different locations. Of course, communication is necessary in order to establish links between parts that are developed separately. The prototype is accessible on the Web at the address http://www.iro.umontreal.ca/~paquetse/knoweb/000_INTRODUCTION.html.

This design has the following strengths:

- The architecture is simple and easy to understand.
- Consulting the knowledge base is easy. All one needs is a WWW browser and access to the Internet. Large numbers of people nowadays have such access.
- Contributing to the knowledge base is easy. All one needs is the ability to write Web pages and means of making them available. Large numbers of people nowadays have such means.
- The architecture allows contributors to work together to strengthen their respective contributions by linking them.
- While restrictions exist on the format that is used to represent ideas, there is complete freedom in regard to the contents itself.

It shares the following shortcomings with the basic WWW architecture:

- Changing or refining existing parts of the knowledge base may result in large numbers of links coming from other parts of the base being invalidated. Work is then needed to fix those links.
- In order to maximize their usefulness, new contributions must be properly linked to the existing base. This may require a lot of communication between contributors.
- There is no way of ascertaining the quality of contents that has been contributed.

We believe that despite the limitations of this initial design, such a concrete way of organizing ideas has the potential to win the favour of dedicated individuals who not only like to learn but wish to share their understanding with others in an efficient manner.
4 Conclusion

We have proposed a simple methodology which aims at integrating knowledge and know-how across disciplines in a coherent, usable manner. This methodology is centered around generalization/specialization relationships and a problem solving perspective. We have provided a sample implementation of that methodology which builds on the strengths of World Wide Web technology.

We hope that the reader feels the importance of the interdisciplinary language barrier problem and sees this work as an interesting first step towards solving it. He is currently actively seeking feedback and help to improve this work. He can be reached by email at the address paquetse@iro.umontreal.ca.

References

[1] George Polya. How to solve it. Princeton University Press, 1973.