which bring software engineers (broadly termed to include expert system developers) in contact with students of those other disciplines. While the computer science students refine their knowledge about particular issues in computer science, they also reap the benefits of exposure to other fields such as, psyschology, sociology, or any of the humanitits. They will extend their rational capabilities and will have increased sympathy for other fields of study. Likewise, the students of the domain field will improve their command of that study, and at the same time they gain appreciation of computer science. Learning intensifies. In Socrates, even the expert claimed to have benefited through the conflicts that she found in DSM-III.

CITATIONS

Bobrow, Daniel G., Sanjay Mittal, and Mark J. Stefik. Expert Systems: Perils and Promise," in Communications of the ACM. Volume 29,9 (September, 1986.)

Buchanan, Bruce G., David Barstow, Robert Bechtal, et al "constructing an Expert System," in Building Expert Systems. Hayes-Roth, Waterman, Lenat eds. Reading, Mass: Wesley Publishing Company, Inc. (1983) 127-67.

Diagnostic and Statistical Manual of Mental Disorders, Third Edition. Washington, DC: American Psychiatric Association, (1980).

Fairley, Richard. Software Engineering Concepts. New York: McGraw-Hill Book Company, (1985).

Fellers, Jack W. "Key Factors in Knowledge Acquisition," in Computer Personnel. A quarterly publication of the Special Interest Group on Computer Personnel Research: ACM Press. Volume II, 1 (May, 1987).

Frank, Edwina D., Phd.D., Professor of Psychology, Loyola University, New Orleans, LA: informal interviews and project reviews. (January, 1987 -- August, 1987)

Harmon, Paul, and David King. Expert Systems: Artificial Intelligence in Business. New York: John Wiley & Sons. (1985).

Hayes-Roth, Frederick, Donald A. Waterman, and Douglas B. Lenat. "An Overview of Expert Systems," in Building Expert Systems. Hayes-Roth, Waterman, Lenat eds. Reading, Mass: Wesley Publishing Company, Inc. (1983) 3-29.

Page-Jones, Meilir. The Practical Guide to Structured Systems Design. Englewood Cliffs, NJ: Yourdon Press. (1980).

Sagalowicz, Daniel. Quoted by Edith Meyers in "Expert Systems: Not for Everyone," in Datamation. (May 15, 1987).

Welburn, Tyler. Advanced Structured Cobol: Batch, On-line, and Data-Base Concepts. Palo Alto, CA: Mayfield Publishing Company, 1983.

Zuckerman, Edward, Ph.D., Professor of Psychology, Wellness Resource Center, University of Pittsburg. Pittsburg, PA: correspondence and telephone interviews. (January 1987).

AN EXPERT SYSTEM FOR AN IDIOSYNCRATIC DOMAIN: LOVE, INTIMACY, AND FRIENDSHIP

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Expert systems conceived and developed thus far have dealt with problems, such as medical diagnosis, circuit design, and mineral exploration, which have objective solutions. Humans, however, are also experts in reasoning about domains where the key concepts are not objectively fixed. We do form subjective, but sound, judgments about idiosyncratic--i.e., person-specific-- domains. One such domain is that of love, intimacy, and friendship. Despite the fact that our notions of love, intimacy, and friendship vary greatly and that these relationships have been the subject of poets, novelists, biographers, psychologists, and other students of human nature for centuries, there is enough of a common consensus to make communication and, very frequently, common judgments about this domain possible.

We present a rule-based expert system, currently being implemented in PROLOG, which provides a general mechanism for handling idiosyncratic domains. Our system also provides a thorough example of how the attainment of cognitive-affective states and resulting relationships between people can be modelled using a rule-based system. Thus this work should interest cognitive scientists as well as computer scientists seeking to endow computers with truly human-like thought.

The key to our design is, as might be expected, to abstract out whatever is common to most people's understanding of the nature of a particular class of relationships. Nevertheless, there will be a substantial failure rate if idiosyncratic criteria for the attainment or blocking of relationships are simply ignored. Therefore, we adopt the following formalism:

Iff X (a)
Y (b)
Then Z (c).

This bidirectional rule is to be understood as follows: If X & Y then Z with probability c; If Z then X with probability a; If Z then Y with probability b. (Of course, "If Z then X" is identical to "Only if X then Z.") Thus a, b, and c are what have been called certainty factors or, more gracefully, attenuation factors (1). (Note that we are not associating certainty factors with the antecedent conditions of the rules in either direction, though it is trivial to add these.) The concept of attenuation factors was developed for the MYCIN system, a rule-based expert system for medical diagnosis (2). This formalism using bidirectional rules with attenuation factors oerative in both directions (cf. 3, 4) neatly handles the problems inherent in reasoning about an idiosyncratic domain. These are two: somesone may have idiosyncratic requirements for the attainment or

blocking of relationship Z or he may idiosyncratically ignore some of the elements that most do use in deciding whether to enter relationship Z.

Thus, in the example above, if c is .7 this means that 30% of the instances where X and Y, nevertheless not Z because of idiosyncratic requirements for the attainment or blocking or the relationship. Likewise, if a is .8, then in 20% of the instances where the parties have relationship Z, they do so despite the prevalent view that X ought to hold for Z to obtain but does not.

We deal here, intentionally, with a small number of rules and relationships; nuances of these are not treated, since they are far too idiosyncratic for general agreement, even broadly considered. The relationships considered are, in order of increasing commitment and initial intensity, companionship, friendship, confidant(e)s, intimacy, love, marriage, and family.

Before presenting the rules themselves, which are the ultimate test of the merit of the idea, some perfatory remarks on the system as a whole are in order.

First, we have designed the system with two purposes in mind: ease of implementation and testing and naturalness of representation, with the latter easily the more important desideratum. Thus, except for companionship, each level of interpersonal closeness includes and subsumes the previous (and therefore all prior) level(s). Thus if X and Y have a family together, they are married, they love each other, they are intimates, they are confidants, and they are friends (subject to the usual idiosyncratic exceptions). This seems natural enough for the attainment of relationships. However, relationships are dynamic and when they degrade, as they so often do, they do not do so nicely and monotonically. So while it may be true that apart from the idiosyncratic exception friendship always precedes marriage, after many years it is certainly possible for X and Y to love each other and miss each other when apart; but not to like each other or take any pleasure in each other's company: An odd, but common, state of affairs. So the system presented here should be see either as a relationship-attainment model or as an ideal.

Second, the specific attenuation factors selected were not obtained by empirical research. They are simply left-brain estimates of frequency or right-brain estimates of probability. They do seem to conform to our (limited) experience and our intuition, but a methodological cognitive scientist might wish to use other numbers, more rigorously obtained. Tant mieux. Since we are, after all, dealing with and presenting a methodology for idiosyncratic domains, the author's own person-specific biases or insights may occasionally be visible.

COMPANIONSHIP.

Iff X and Y: like each other[1] (.7)
X and Y: willing to share time with each other (1)
X and Y: lonely (.8)
Then X and Y: companions (.5)

In the forward direction, there are three antecedent conditions which are representative of the three classes of conditions on which relationships may be contingent. First, there is the "engine," the emotional impetus for the relationship, here loneliness. Second, there is the defining condition, a condition which holds universally when the relationship exists, here "willing to share free time with each other." Third, there is a precondition, here simple affection, without which the relationship is blocked (5).

To the computer scientist interested in the formalism introduced and the framework provided for idiosyncratic domains, there is no distinction of importance between these three classes of conditions. To the cognitive scientist, the specialist imparting his knowledge to the expert system and the knowledge engineer assisting him, the user applying the expert system, and the general reader, on the other hand, these distinctions are pregnant with meaning. In presenting the rules, therefore, we shall continue to draw them.

A rule must have one or more engines, for there is no relationship which begins with no emotional impetus of any sort; usually, but as we shall see not always, there is just one. When the attenuation factors of the engine conditions sum to less than one, as is the case here, with companionship, it is an indication that the emotional impetus for the relationship class is sometimes idiosyncratic.

A rule may or may not have a defining condition, but if it has more than one, it is an indication of sloppy design-- in particular, failure to generalize. Note that a defining condition does not guarantee a relationship (as here), although the relationship guarantees it. As we shall see, however, most antecedent conditions are preconditions.

The low attenuation factor for companionship reflects the fact that, unlike more committed relationships, it arises from a generalized loneliness on the part of, to use the system's names, X and Y, and many other random or idiosyncratic factors help decide whether the two will become companions. As we ascend the hierarchy of relationships, random influences will become increasingly negligible and idiosyncratic factors increasingly visible.

FRIENDSHIP.

Iff X and Y: like each other[2] (.8)
X and Y: respect each other. (.7)
X and Y: want to share free time with each other (1)
Then X and Y: friends (.9)

For friendship, wanting to share free time with each other is both the engine and the defining condition. Note that the preconditions are still necessary to ensure that the motivation for wanting each other's company is friendship and not (say) business. Those who attain the cognitive-affective state common to friends without liking or respecting each other are, of course, accounted for by the attenuation factors. For some people, all important business associates may be friends.

Many will find the preconditions given here inadequate; their notion of friendship is probably akin to our notion of confidants, which will be presented next and amounts to classical, true friendship ("friendship with a capital 'F'"). As the word is normally used today, however, "friend" means (at most) what is given above.

Notice the difference between the defining conditions for companionship and friendship: "willing" vs. "want" to

[1] A rule elaborating this will be presented later.

[2] A rule elaborating this will be presented later.

share free time with each other. A person-specific need has replaced a generalized loneliness.

CONFIDANTS.

Iff X and Y: friends (.85)
X and Y: respect each other highly (.7)
X and Y: willing/want to share their thoughts and feelings with each other (1)
X and Y: miss each other when apart (.5)
X and Y: trust each other[3] (.8)
Then X and Y: confidant(e)s (.7)

Once again, the engine and the defining condition are the same: sharing thoughts and feelings. This is *friendship* on a more intimate level (it subsumes friendship with idiosyncratic exceptions) than sharing time alone can even reach. It is also the lowest level of the hierarchy of the relationship classes we consider at which missing each other, a cognitive-affective state central to strong relationships, comes into play. For some, it is a precondition to being a confidant (or a very quick result); for some, it may also be an engine condition. One might suppose that "trusting each other" and being "willing to share their thoughts and feelings with each other" would be coincident. Experience teaches that this is not always so, as the need to confide, in many so often overpowers doubts about the other's trustworthiness. It is also a reflection of the mechanism of trust buildup, which is not unlike the buildup of band credit. One trusts a little; if it works out, one trusts a little more. Of course, however natural this system may be and however prevalent, it leaves the confidant (or bank) open to disaster in unfortunate instances. Perhaps that's why another method--formal and informal references--has evolved for the resolution of the trust issue (by potential creditors and potential friends alike).

INTIMATES.

Iff X and Y: confidants(e)s (.95)
X and Y: know each other for some time (.5)
X and Y: emotionally compatible even in close quarters (.5)
X and Y: find each other attractive (.8)
Then X and Y: intimates (.5)

Intimacy, as we are considering it, is a serious relationship one step shy of romantic love, not mere physical intimacy without a very powerful emotional component. Obviously, mere physical intimacy is possible when X and Y are strangers, hardly intimates as we are using the term. The intimacy to which we refer is a state of heart and mind, a cognitive-affective state, joined to a state of affairs (in the philosopher's sense of the phrase) which can be reached without a confidant-type relationship idiosyncratically only one time in twenty. For the forward-chaining antecedent "X and Y: physically intimate" the consequents would have very different attenuation factors, say, .05, .25, .02, .6, respectively.

Another issue that must eventually be addressed here is that of same-sex relationships. For heterosexuals, the fourth antecedent condition rules out same-sex relationships. For others, it does not, nor does anything else in the rule. Studies show that one-one relationships are much more common among heterosexuals, but it is not to be supposed that this creates a serious overstatement of the chances of an intimate relationship developing (50%) given all the stated antecedent conditions.

Having dealt with these two side issues, we return to an exposition of the rule. The engine here is mutual attraction and as anyone will admit under persistent questioning it is not a sure thing; technically, that is, it does not give "X and Y: intimates" an attenuation factor of 1. What will make two people decide to upgrade a confidant relationship to an intimate relationship is highly idiosyncratic, so much so that fully half the time that the antecedents are true, intimacy will nevertheless not result. If it seems to the reader that this is surely a gross exaggeration, it is likely that he is unwittingly using intimacy in a weaker sense by not being sensible of the full range of antecedent conditions for a confidant-type relationship, which relationship is, in all but a handful of idiosyncratic cases, prerequisite to intimacy as here defined. (And there are of course the requirements of the engine condition and the two preconditions.)

ROMANTIC LOVE.

Iff X and Y: intimates (.95)
X and Y: willing/want mutual emotional commitment(.75)
X and Y: willing/want absorption in each other's life(.7)
X and Y: miss each other quite intensely when apart (1)
Then X and Y: love each other (romantically) (.9)

The engines here are the mutual desire for emotional commitment, one-one loyalty, and the mutual desire for total involvement in each other's life (involvement does not mean domination, unwanted interference, etc.) and the defining condition for this cognitive-affective state is given by the final antecedent condition. It will be istructive to compare loving and liking (the latter is required for compaionship and friendship (and, as explained early in this paper, by inclusion in all more intense relationships)):

Iff X and Y: enjoy each other's company (.95)
X and Y: emotionally compatible (.8)
Then X and Y: like each other (1)

Thus the emphasis in loving is on a longing when apart, while the emphasis in liking is on an agreeableness when together. Of course, except for idiosyncratic cases, love includes intimacy which includes....friendship and, therefore, liking. Nevertheless, this negative emphasis helps explain why love without affection as may occur when a relationship degrades can be a clearly destructive force and why lectures entitled "How to Fall out of Love" draw large audiences.

MARIAGE.

Iff X and Y: love each other (.65)
X and Y: culturally compatible (.7)
X and Y: know each other for a considerable time (.75)
X and Y: willing/want mutual instrumental commitment
X and Y: find each other's idiosyncratic behaviors tolerable to pleasing (.5)
X and Y: lonely (.7)/X and Y: want kids (.9)
Then X and Y: married (.7)/X and Y: married (.75)

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[3] A rule elaborating this will be presented later.

Marriage conditions are fairly idiosyncratic; hence only 70-75% of the time that the antecedent conditions are satisfied is the consequent realized. Since no condition as to gender is imposed, if a same-sex relationship meets all the antecedent conditions, it is among the 30% (forget about wanting kids as an antecedent!) of such cases where the rule is idiosyncratically not triggered. Also low are the attenuation factors in the other direction. This may indicate why so many marriages sour. In other words, if the consequent were "X and Y: happily married" the attenuation factors would be far higher, perhaps .98, .95, .8, .7, .9, .7/.9 respectively.

There are two or possibly three engines here which overlap; wanting instrumental commitment, wanting kids, and being lonely. As the attenuation factors for marriage show, wanting kids is a stronger spur to marriage than loneliness, which can more easily be satisfied by means short of marriage. As implemented, the rules for marriage in the system number three. One with "X and Y: want kids (.9)" leading to "X and Y: "married (.75)"; one with "X and Y: lonely (.7)" leading to "X and Y: married (.7)"; and one with both "X and Y: lonely (.7)" and "X and Y: want kids (.9)" leading to "X and Y: married (.75)." There is no redundancy in the presence of the third rule, since all rules are bidirectional. Furthermore, that two rules say that 75% of couples will end up married does not guarantee that they will be the same 75%, so from an intellectual point of view, it is well to include it, even if it makes no different probabilistic prediction.

There are three degrees of emotional compatibility required by the system: finding each other's idiosyncratic behaviors tolerable to pleasing--for marriage, emotional compatibility even in close quarters--for intimacy, and (basic) emotional compatibility--for companionship (via liking). The levels of compatibility required may vary on a person-specific basis and that, of course, is dealt with by the attenuation factors.

A word about loneliness, a requirement for companionship and marriage--but nothing in between, is in order. The system reflects the idea that either companionship will satisfy loneliness or if it does not, neither will friendship, a confidant, or even intimacy and love. These in-between relationships satisfy person-specific and type-specific (to confide, to be intimate, etc.) needs, rather than loneliness in general. Marriage, on the other hand, adds to love (with its satisfaction of a wide variety of person-specific and type-specific needs) constant companionship.

FAMILY

Iff X and Y: married (1)
X and Y: want kids (.9)
X and Y: sufficient means and space (.5)
Then X and Y: have a family together (.95)

The engine here, obviously, is wanting kids. Virtually all married couples who want kids do have or adopt them. The only somewhat general constraint seems to be sufficiency of means and space and, as the attenuation factor shows (50% of families don't have sufficient means and space), it is not terribly constraining.

It is instructive to compare the final three rules of the hierarchy: family given marriage, marriage given love, love given intimacy. The comparison suggests that the conditions for marriage are far more idiosyncratic than are those for a family given marriage and love given intimacy. People who are married do almost always have families; people who are intimate and meet the remaining conditions do fall in love. But even if love is tried and true, marriage is often not the result. (By often, we mean, of course, 25-30% of the time.) The non-idiosyncratic conditions for marriage are also a good deal more demanding than those for love given intimacy and family given marriage. Thus with such a model of relationship attainment, it is no surprise that marriages are hard to maintain. That conclusion follows from the single premise that the harder a relationship is to form, the easier it is to damage. While we could see an intellectual case either way on the premise, empirical evidence supports both the premise and the conclusion. This is only one of many domain- specific comments made in this work. It is natural when designing a system to be an expert and discussing one's ideas with colleagues and associates to learn a considerable amount about the domain as well as about expert system design for idiosyncratic domains in general.

Returning to the latter, an attempt was made throughout the system to restrict consideration to conditions with attenuation factors that would make at least .5. Thus, in the case of the familial relationship, the 5% of couples who don't have or adopt children despite that desire, their being married to each other, and their having sufficient means and space have "reasons of their own "--idiosyncratic or person-specific factors which influence the relationships they form. Likewise, the 10% of couples who have a family but do not want children must also have "reasons of their own" --perhaps religious beliefs or concern with what the neighbors think, etc. It is important in an expert system designed for an idiosyncratic domain not to try to discover every idiosyncrasy and assign it an appropriate attenuation factor (less than .5), or the system will rapidly be transformed from one which handles idiosyncrasies in its domain to one which merely reflects the idiosyncrasies of its author. The latter is to some extent impossible to avoid in any domain where the key concepts are not objectively fixed; we hope we have done a credible job.

REFERENCES

1. Winston, P.H., Artificial Intelligence, 1984, Reading, MA; Addison Wesley.
2. Shortliffe, E. H. and Buchanan, B.G., "A Model of Inexact Reasoning in Medicine," Mathematical Biosciences 23(1975): 351-379.
3. Duda, R.O., et al., "Development of the Prospector Consultation System for Mineral Exploration," September 1978, Menlo Park, CA: SRI.
4. Duda, R.O, et al., "A Computer-Based Consultant for Mineral Exploration," September 1979, Menlo Park, CA: SRI.
5. Vere, S.A., "Relational Production Systems," Artificial Intelligence 8(1977): 47-68.

APPENDIX

A. DEFAULT RULE.

Iff true (1) Then X and Y: nothing (.8)

The system's universe of discourse is all couples, X and Y, who know each other, however slightly. This rule states that 80% of such couples are neither companions nor friends (nor anything closer); it serves as a default.

B. ADOPTION RULES (UNDIRECTIONAL).

1. If X and Y: married
   Y and Z: friends (or more)
   Then X and Z: companions (.6)

2. If X and Y: married
Y and Z: confidants (more would probably lead to divorce)
Then X and Z: friends (.4)

3. If X and Y: married
Y and Z: confidants
Then X and Z: companions (.7)

There is little point in writing rules for X and Y: less than married, since the attenuation factors would be very low (very few such "adoptions"). It is possible that for X and Y: have a family together, the attenuation factors would be lower, since people with families have less time. Finally, subject to idiosyncratic exceptions, adoptions never result in more than a friend or, if they do, they cease being an adoption and meet the standard antecedent conditions.

Note that the antecedents of (2) and (3) overlap as do those of (1) and (2)/(3) to some extent (because, with idiosyncratic exceptions, confidants are friends). One might try to rigorously use available methods (see refs. 2,3,4) to obtain better numbers. But the above will do.

C. TRUST RULE.

IFF X and Y: believe they can repose their thoughts and feelings in each other without facing ridicule, rejection, etc. (.85)
X and Y: believe they can repose their thoughts and feelings in each other without facing exposure leading to interpersonal and/or instrumental harm (.85)
X and Y: believe they can repose their thoughts and feelings in each other without fearing that their confidences will eventually be used against them emotionally i.e., thrown up at them, etc. (.7)
X and Y: trust each other (1)

The difference in attenuation factors reflects the fact that nearly everyone would sooner risk long-term emotional hurt (condition 3) than short-term emotional hurt (condition 1) or exposure (condition 2).

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ABRAMS, DAVID HOWARD. Georgia Institute of Technology D.B. 1987, 220 pages. A REFERENCE MODEL FOR HETEROGENEOUS DATA BASE MANIPULATION AND AN EXPERT SYSTEM PROTOTYPE FOR HOMOGENEOUS DATA BASE MANIPULATION. DAI V48(09), SecB. University Microfilms Order Number ADG87-27184. Computer Science.