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Sharing Accounting Expertise

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ABSTRACT

One problem of eliciting knowledge from several experts is that experts may share only parts of their terminologies and conceptual systems. Experts may use the same term for different concepts, use different terms for the same concept, use the same term for the same concept, or use different terms and have different concepts. Moreover, clients who use an expert system have even less likelihood of sharing terms and concepts with the experts who produced it. This paper outlines a methodology for eliciting and recognizing such individual differences. KSS0 is a knowledge support system providing an integrated set of tools for knowledge acquisition and the rapid prototyping of knowledge-based systems. *Socio* is a tool in KSS0 that compares the conceptual systems of multiple experts in the same domain. It can be used to focus discussion between experts on those differences between them which require resolution, enabling them to classify them in terms of differing terminologies, levels of abstraction, disagreements, and so on. Socio promotes the full exploration of the conceptual framework of a domain of expertise by encouraging experts to operate in a "brain-storming" mode as a group, using differing viewpoints to develop a rich framework. It avoids social pressures forcing an invalid consensus by providing objective analysis of separately elicited conceptual systems. Experiments on validating the system by using it to re-construct the Business Information Analysis and Integration Technique (BIAIT) are reported.

INTRODUCTION

The elicitation of knowledge from one expert presents enough problems that elicitation from many might seem an unnecessary complication. However, a major reason for practical interest in expert systems is that in many domains, such as quality control, expertise is essentially distributed over many experts, and the purpose of the system is to bring it together (Hayes-Roth 1984). More fundamentally, the use of multiple experts in 'brain-storming' or synectics sessions has been found valuable in problem-solving, and is an attractive technique to prevent individuals experts 'blocking' and failing fully to explore and express their conceptual domains.

It is important to note in dealing with multiple experts that consensual agreement upon domain concepts is only one of many significant possibilities. Experts may legitimately have different terminologies for the same domain concept. They may describe it at different levels of abstraction. One expert may describe a concept in operational terms and another in descriptive terms. They may also legitimately use the same terminology for different domain concepts. They may be using the same term distinguished by different contexts. One expert may have a very different conceptual framework or strategy from another. These differences may be carried through to an expert system design that allows users to obtain advice based on different and mixed sources of expertise, and to ask for dissenting opinions (Boose & Bradshaw 1987).

Thus, in a knowledge acquisition system, it is important not to attempt to force a false consensus on a group of experts on the assumption that there is some 'correct' terminology and conceptual framework. However, it is also important to bring to light differences among the experts and make these clearly available for discussion. Some of them may reflect errors in elicitation, others differences in terminology, others differences in conceptual frameworks. In any event, the discussion of these differences is in itself a significant stage in the knowledge elicitation process.

The next section establishes a theoretical framework for knowledge elicitation from multiple experts. The following sections describe a practical methodology based on this framework, a computer tool implementing this methodology, and results of using this tool to apply the methodology to practical knowledge elicitation.

CONCEPTUAL SYSTEMS IN A DOMAIN COMMUNITY

Figure 1 shows a domain in which an expert system could be constructed from the knowledge of existing experts. The two "experts" shown, Expert 1 and Expert 2, are best thought of as *roles* in the individuals involved. These expert roles are distinguished by involving conceptual systems which, when applied to problem solving in the domain, lead to recognition of the individuals playing the roles as beings "experts" in the domain. The individuals will also have other roles involving other conceptual systems appropriate to other domains in which they may, or may not, be experts.

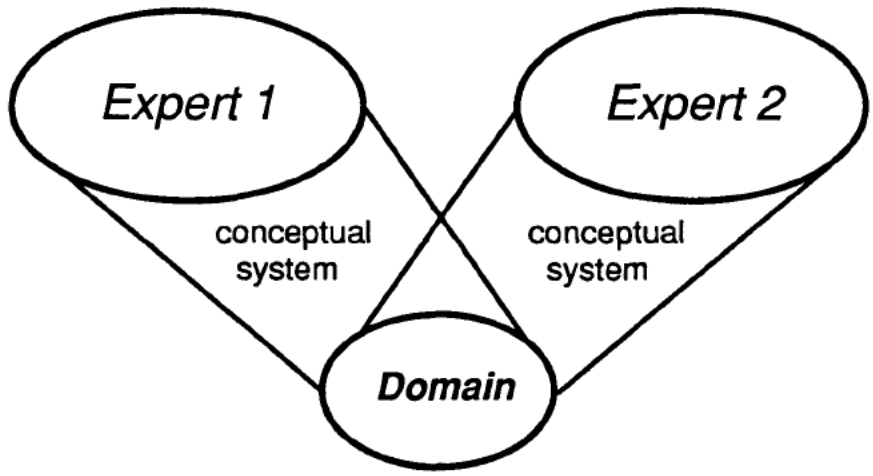

Fig.1 Experts acting in the same domain

The figure shows an overlap in the two conceptual systems indicating corresponding concepts. The experts will each have terminologies for expressing the concepts involved. The possible overlaps between concepts and terminologies leads to four relations which can occur between parts of the conceptual systems as shown in Figure 2:

- *Consensus* occurs when there is agreement in both the concepts and terminology used;
- *Correspondence* occurs when different terms are used for the same concepts;
- *Conflict* occurs when the the same terms are used for different concepts;
- *Contrast* occurs when different terms are used for different concepts.

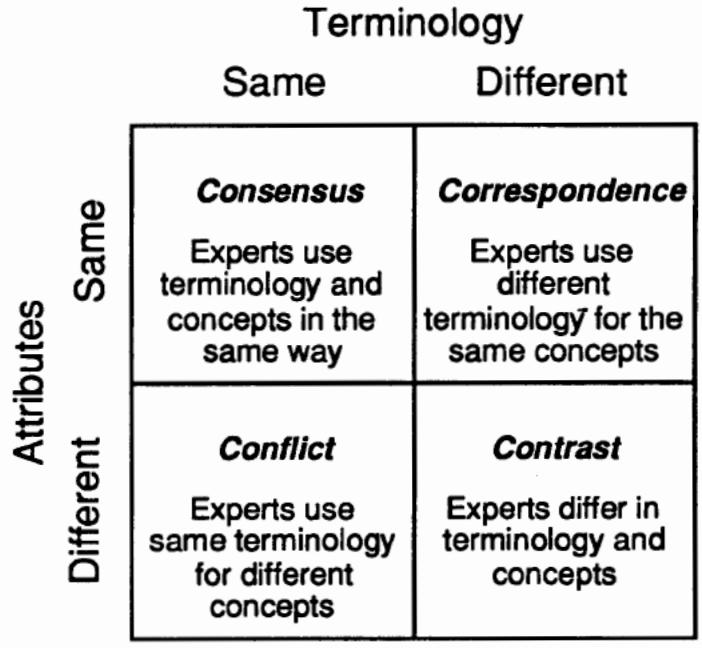

Fig.2 Consensus, correspondence, conflict and contrast among experts

The recognition of consensual concepts is important because it establishes a basis for communication using shared concepts and terminologies.

The recognition of corresponding concepts is important because it establishes a basis for mutual understanding of differing terms through the availability of common concepts.

The recognition of conflicting concepts is important because it establishes a basis for avoiding confusion over the labeling of differing concepts with same term.

The recognition of contrasting concepts is important because it establishes that there are aspects of the differing expertise about which communication and understanding may be very difficult, even though this should not lead to confusion. Such contrasts are more common than is generally realized. For example, it is possible to derive the same theorem in mathematics either by using an algebraic perspective, or a geometric one. There is nothing in common in these two approaches except the final result. It may still be possible to discuss the same domain using consensual and corresponding concepts that were not fundamental to the problem solving activities.

These considerations also apply to clients of the experts whose concepts and terminologies may be evaluated along these four dimensions in relation to those of the expert. The recognition of possible conflicts between the experts' and clients' use of terminology, and the provision of a variety of corresponding concepts, are major factors in the usability of an expert system.

In Figure 3, Client 1 is shown as having overlap only with Expert 1. He or she has no overlap whatsoever with any other individual in the figure, expert or user. Client 2 has overlap both with Client 3 and with the two experts. He or she is able to understand the concepts of Expert 2 and to a lesser extent those of Expert 1. Client 3 has no overlap with either expert, but has sufficient overlap with Client 2 that Client 2 can explain to him the advice given. In the development of an expert system, Client 1 may choose not to take advantage of Expert 2's expertise in the system. It would be particularly important to develop additional concepts and terminology to enable Client 3 to have adequate communication with, and understanding of, the system.

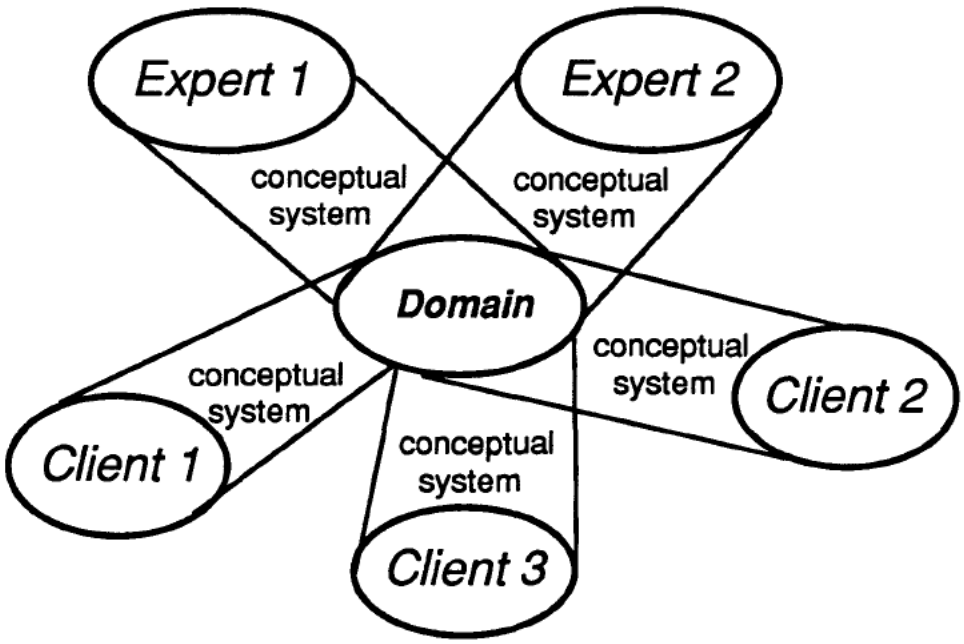

Fig.3 Experts and clients operating in the same domain

These are some of the possible relations which may occur between the conceptual systems of users and experts. The model is one of *roles* within an individual using a particular *conceptual system* and expressing it in a particular way to enter into an externally perceived and valued *domain community*. This model of coherent intellectual processes, each with its own individuality, each using its own conceptual system and its own terminology to enter into the domain community provides a cogent picture of the rationale behind, and the conflicts involved in, the development of communication and understanding in the community and in expert systems playing a role in that community.

DERIVING CONCEPTUAL SYSTEMS

Personal Construct Psychology (Kelly 1955, Shaw 1980) has been widely used as a basis for developing methods of knowledge acquisition from experts in a given domain (Shaw & Gaines 1983, Boose 1984, Diederich, Ruhmann & May 1987). Personal Construct Psychology is a psychology of the individual and many of its applications emphasize the idiosyncratic nature of conceptual systems (Mancuso & Shaw 1988). However, it is also a psychology of the individual interacting with the world and embedded in society (Shaw 1985). It encompasses shared concepts and conceptual systems, and their generation through experience. In particular it encompasses those systems that are so widely shared and so significant that they are construed as *knowledge*, and treated as having an existence virtually independent of their carriers.

Entity-attribute, or repertory grid, methodologies based on Personal Construct Psychology allow a significant part of the conceptual systems of experts to be elicited through interactive interviewing techniques such as those of KSS0 (Gaines 1987) and Aquinas (Boose and Bradshaw 1987). The resultant data structure is one in which the terms for entities and attributes in a domain have been specified by the expert, together with the values of those entities along the dimensions of the attributes. The entities are usually concrete items in the domain whose nature, definition and names can be agreed by experts and clients. The attributes reflect individual conceptual systems and may be used, and labeled, idiosynchratically.

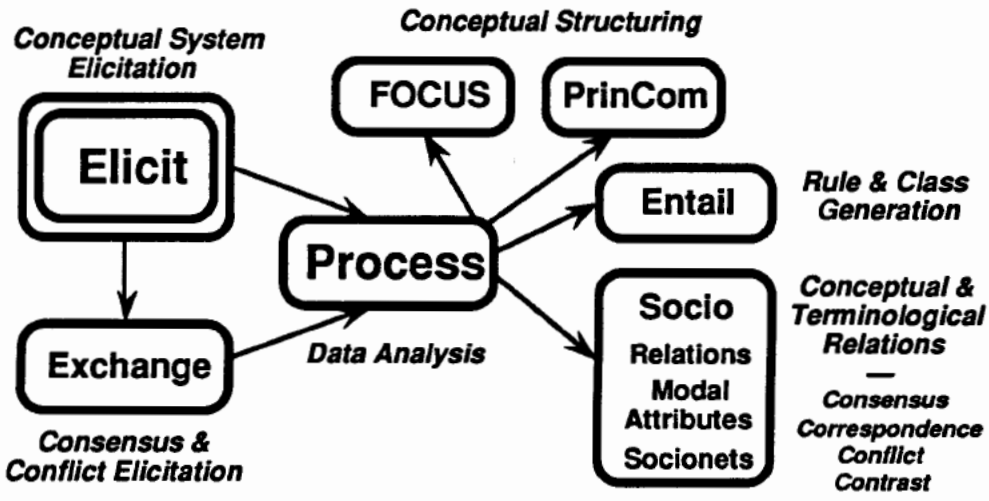

Fig.4 Some tools in Knowledge Support System Zero

Figure 4 shows the main tools in KSS0 relevant to the issues discussed in this paper:

- *Elicit* accepts specifications of entities within a domain and provides an interactive graphical elicitation environment within which the experts can distinguish entities to derive their attributes. The resultant conceptual system is continuously analyzed to provide feedback prompting the expert to enter further entities and attributes.
- *Exchange* allows the terms in the conceptual system derived from one expert to be used by another in order to determine whether the two experts have consensus or conflict in their use of terminology and concepts.
- *Process* gives access to various cluster analytic methods for the analysis and display of the conceptual systems elicited: FOCUS shows the system as a hierarchical structure; PrinCom as a spatial map; and Entail as a logical structure of classes and rules.
- *Socio* compares elicited and exchanged grids in a variety of ways to determine consensus, correspondence, conflict and contrast, and its methodology is described in detail in the next section.

One of the problems of evaluating any methodology for knowledge engineering is to have some clear-cut test cases where the conceptual framework of experts has been both elicited and validated. Sowa (1984) describes one such case where the record keeping needs of a business can be prescribed through the BIAIT analysis technique (Carlson 1979) based on seven features:

1. Does the supplier bill the customer, or does the customer pay cash?
2. Does the supplier deliver the product at some time in the future, or does the customer take the order with him?
3. Does the supplier keep a profile of the customer, or is every transaction a surprise?
4. Is the price negotiated or fixed?
5. Is the product rented or purchased?
6. Does the supplier keep track of the product after it is sold or not?
7. Is the product made to order or provided from stock?

Sowa notes that these features "seem almost obvious once they are presented, but finding the right features and categories may take months or years of analysis. The proper set of categories provides a structural framework that helps us organize the detailed facts and general principles of a system. Without them, nothing seems to fit, and the resulting system is far too complex or unwieldy."

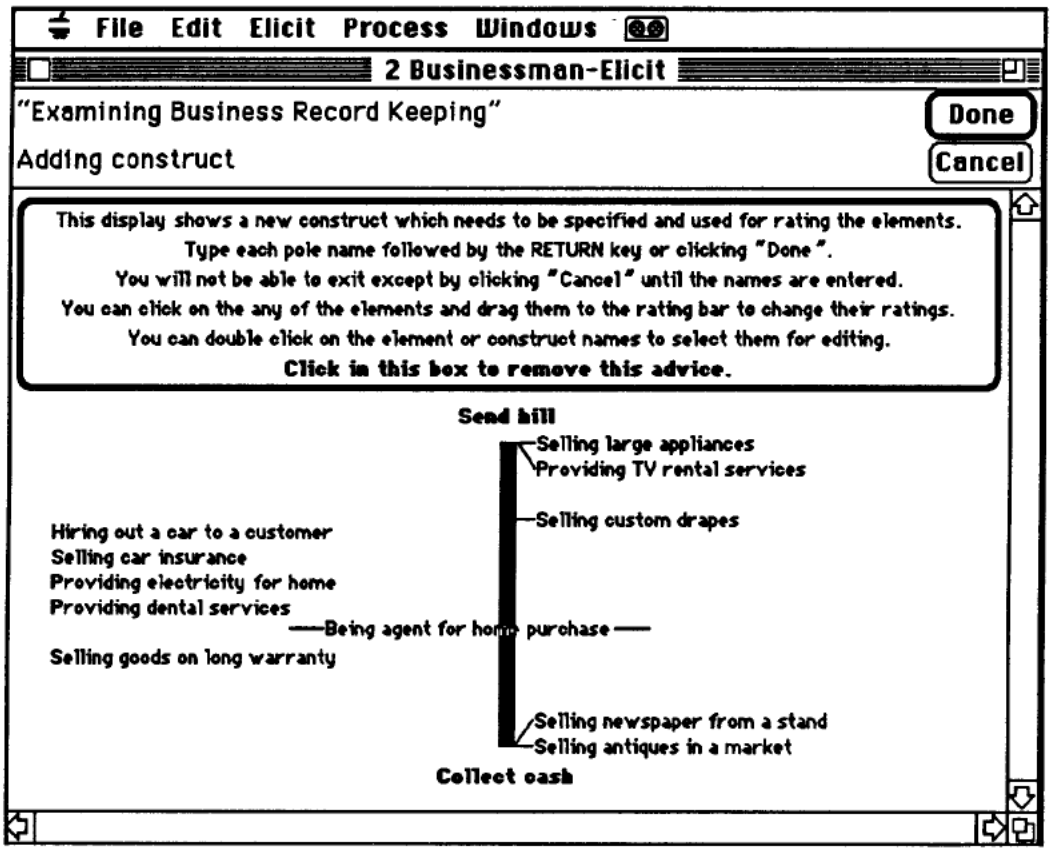

Fig.5 KSS0 attribute elicitation screen showing entities being rated

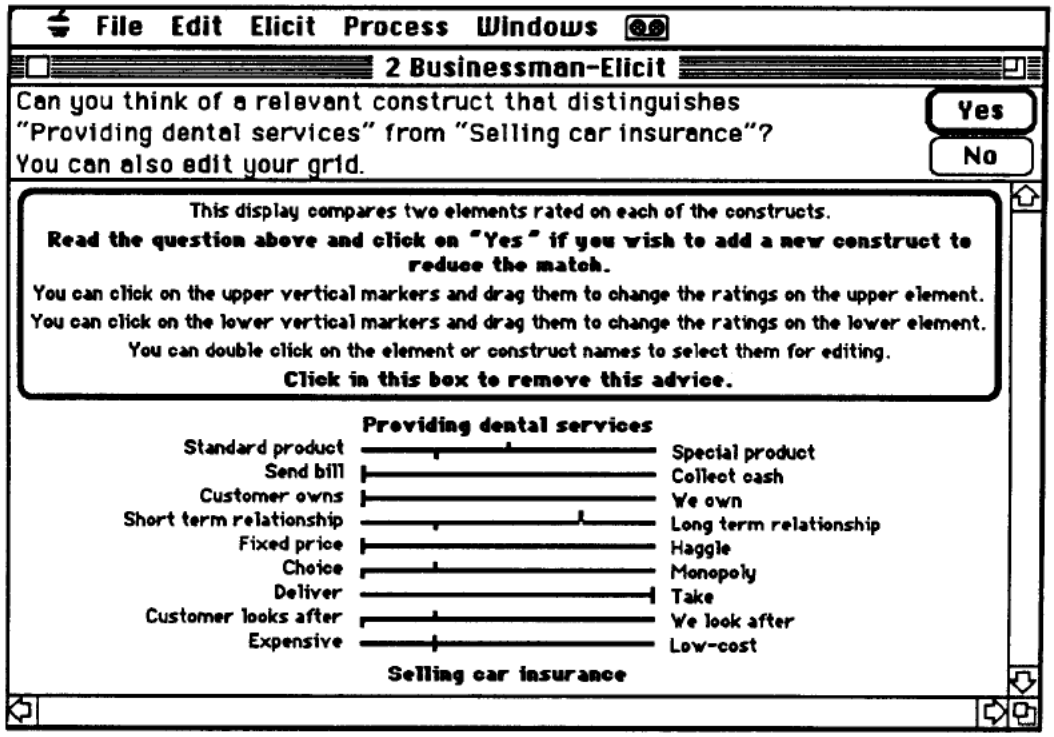

Fig.6 KSS0 entity match screen showing ratings on attributes

The BIAIT features are examples of constructs applied to orders placed between a customer and supplier. They provide a useful test case with which to evaluate the personal construct elicitation methodology provided in KSS0. An empirical study was carried out to determine whether KSS0 could be used to elicit the BIAIT distinctions from those with some accounting or business knowledge. Ten subjects with an assumed range of expertise in business record keeping was taken, from businessmen and accountants, to accounting students at various stages of their education, and KSS) used to elicit their attributes relating to business transactions. In the interests of an initial open-ended approach, the construing was not tightly constrained to relate to the record-keeping aspects of the transactions. It has been interesting to determine what distinctions are made that do not relate to record-keeping, or relate to it in ways different from BIAIT.

Figures 5 and 6 give examples of the interactive graphical elicitation of attributes using KSS0 in this study. Figure 5 shows some of the services used as entities through a rating screen from the program, *Elicit*, in which a businessman is rating the entity, *being agent for home purchase*, on the attribute, *send bill—collect cash*. Figure 6 shows some of the characteristics derived as attributes through a match screen also from *Elicit* in which the same businessman is being asked to distinguish *providing dental services* from *selling car insurance*. Figure 7 shows an elicited entity-attribute grid.

Exchange methodologies were developed for the measurement of understanding and agreement between either two individuals, two roles or on two occasions (Shaw 1980). To do this two people, possibly experts with differing points of view, each elicit a grid in an area of common knowledge or experience. Each may choose his own entities independently of the other, and elicit and rate his or her attributes quite separately. Each then can *Exchange* his or her grid, that is use the other's entities and attributes but fill in his or her own the rating values. For example, in terms of Figure 5, the exchanging expert would see the terms *send bill—collect cash*, but the entities would all be to the left and have to be dragged to the scale with no knowledge of where the other expert had previously placed them.

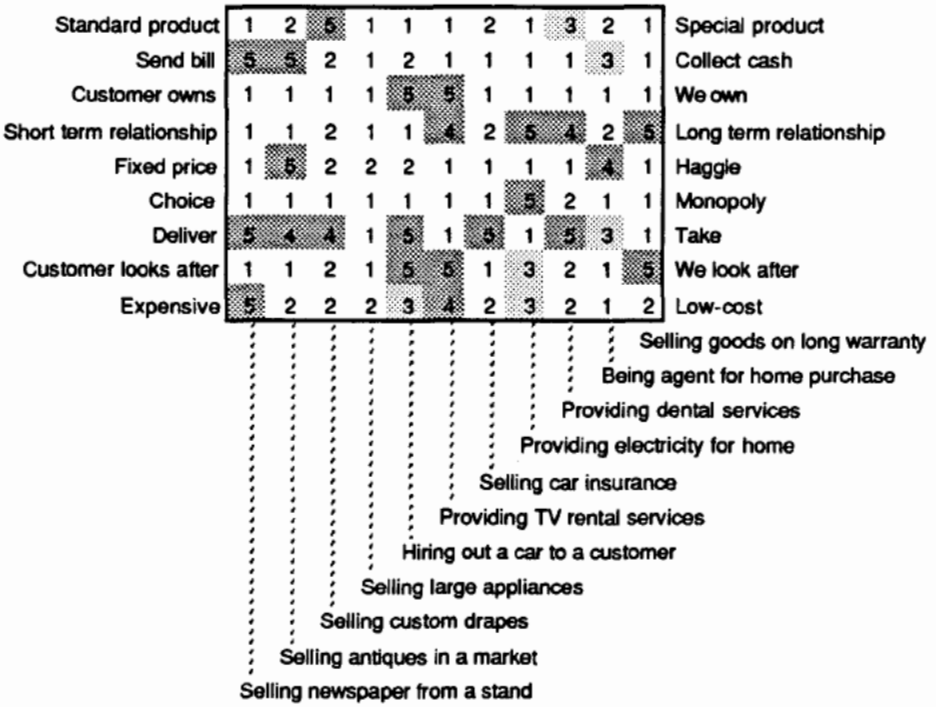

Fig.7 Conceptual system in entity-attribute grid

DERIVING RELATIONS BETWEEN CONCEPTUAL SYSTEMS

The *Socio* analysis in KSS0 allows members of a community to explore their agreement and understanding with other members, and to make overt the knowledge network involved (Shaw 1980, 1981, 1988). It is an extension of techniques such as SOCIOGRIDS (Shaw 1980) for deriving socionets and mode constructs from groups of individuals construing the same class of entities. The objective of Socio is to take different conceptual systems in the same domain and compare them for their structure, showing the similarities and differences. It may be regarded as the implementation of a simple form of analogical reasoning. Figure 8 shows the basis of operation of Socio—consider one set of data as being the base class defined by its entities, their attributes and values, and consider variant classes:

- *Entity-Attribute Compare*: The conceptual system at the upper left has the same entities and attributes but possibly differing values. Socio analyzes the matches between the entities and the attributes in this and the base class according to the values, and shows those entities and attributes that are similar and those which are different. A typical application is to see whether experts agree on the definitions of attributes by asking them to separately fill in the values for a grid exchanged between them.
- *Entity Compare*: The conceptual system at the upper right has different entities but the same attributes. Socio analyzes the matches between the entities in this and the base class, and for each entity in the base class shows the closest matching entity in the other class. A typical application is to see whether experts are using different terminologies for the same entities by asking them separately to define entities and fill in the values for a domain defined through a class with agreed attributes.

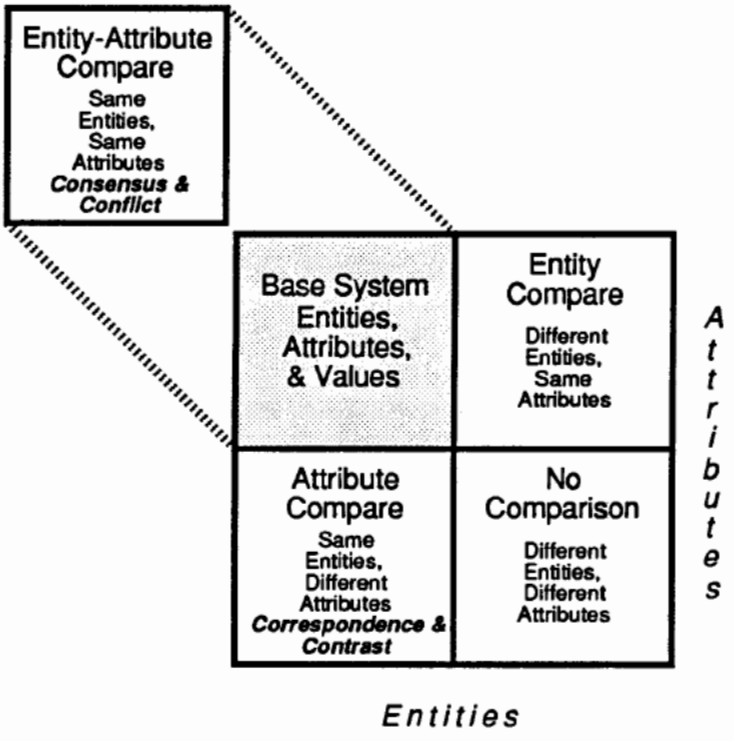

Fig.8 Possible comparisons between base and related systems

- *Attribute Compare*: The conceptual system at the lower left has different attributes but the same entities. Socio analyzes the matches between the attributes in this and the base class, and for each attribute in the base class shows the closest matching attribute in the other class. A typical application is to see whether experts are using different terminologies for the same attributes by asking them to separately define attributes and fill in the values for a sub-domain defined through a class with agreed entities.

If, as in the lower right, neither entities nor attributes are common then no comparison is possible. When a number of classes representing the same sub-domain are available, Socio also provides two other forms of analysis:

- *Mode Entities and Attributes*: Socio attempts to derive "modal" entities or attributes that reflect a consensus among the experts. It does this by extracting those which occur as highly matched entities or attributes across the majority of conceptual systems. A typical application is to reach consensus on critical concepts that are associated with a rich vocabulary at differing levels of abstraction.
- *Socionets*: Socio derives a socionet showing the degree to which each expert is able to make the same distinctions as another expert, even if they use different terminology. A typical application is to validate the knowledge acquisition process by determining whether the structure derived conforms with known relations between the experts.

CONSENSUS, CORRESPONDENCE, CONFLICT AND CONTRAST

Using the concepts developed above it is possible to develop a complete methodology for eliciting and analyzing consensus, correspondence, conflict and contrast in a group of experts or others, and implement this as an automatic process using the tools in KSS0. The methodology has three phases shown in Figures 9 through 11.

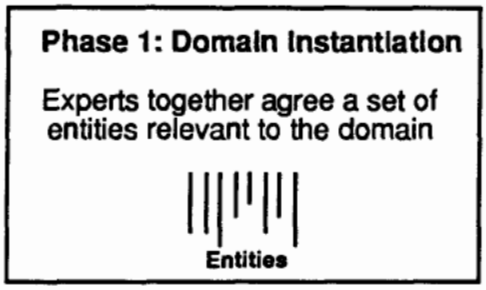

Fig.9 Phase 1 Methodology

Phase 1: Domain Discussion and Instantiation

In phase 1 a group of people comes to an agreement over a set of entities which instantiate the relevant domain. This is the initial phase of any entity-attribute methodology, whether used with individuals or groups. However, with individuals the elicitation techniques may be used to elicit more entities as the exploration of the conceptual domain proceeds. When comparing multiple experts it is important that a set of entities is established at the start of the comparative study, and that the experts mutually agree on the definitions of these.

A convenient way to generate this set of entities is have each person individually use Elicit to enter his or her conceptual system for a domain, and then extract the elicited entities from all the grids for discussion and consolidation by the group. This has the advantage that the people gain some experience in the use of the KSS0 tools and can take advantage of the full elicitation facilities.

Phase 2: Conceptualization and Feedback

In phase 2 each person individually elicits attributes and values for the agreed entities. The resultant conceptual systems will have the same entities but different attributes and can be analyzed by the *Attribute Compare* component of Socio as shown in Figure 8. This takes each attribute in one grid and determines the best matching attribute in the other grid, if there is one. The result is a mapping from the attributes in one person's grid to those in another's as shown in Figure 10.

In evaluating this mapping we are not particularly interested in the terminology used but rather whether one person has an attribute that can be used to make the same distinctions between the entities as does the other person, regardless of whether these distinctions are called by the same terms. If such a *correspondence* occurs then the experts have a basis for mutual understanding of the underlying concept.

If an attribute in one system has no matching attribute in the other then it stands in *contrast* to all the other person's attributes, and it may be very difficult for the other person to understand the use of this term.

Note that the arrows in Figure 10 need not be symmetric. Attribute A in G1 may be best matched by attribute B in G2, but attribute B in G2 may be best matched by attribute C in G1. The only constraint is that if an attribute has an incoming arrow then it will have an outgoing arrow.

Thus, the second phase provides the basis for analysis of correspondence and contrast as already discussed.

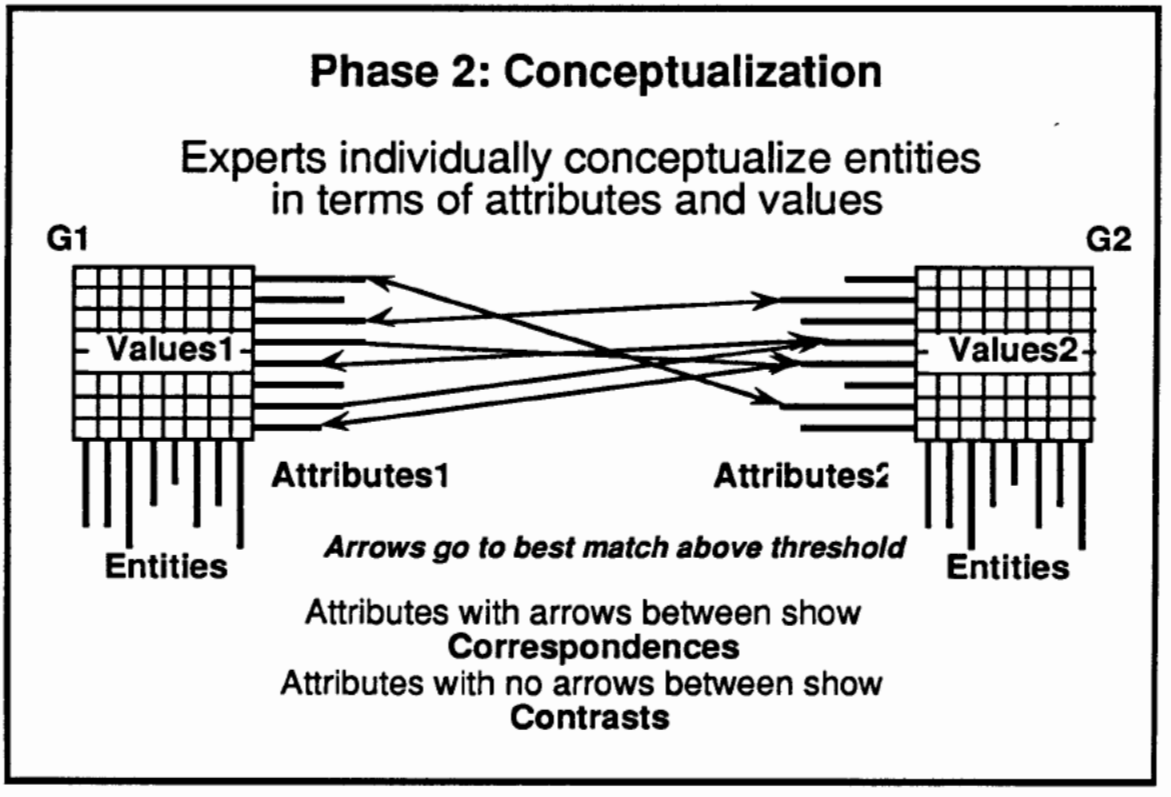

Fig.10 Phase 2 Methodology

Phase 3: Exchange and Compare

In phase 3 each person individually exchanges elicited conceptual systems with every other person, and fills in the values for the agreed entities on the attributes used by the other people. The resultant conceptual systems will have the same entities and attributes and can be analyzed by the *Entity-Attribute Compare* component of Socio as shown in Figure 8. This takes each attribute in one grid and determines whether it matches the corresponding attribute in the other grid.

The result is a map showing *consensus* when attributes with the same labels are used in the same way and *conflict* when they are not as shown in Figure 11. Thus, the third phase provides the basis for analysis of consensus and conflict as already discussed.

Figure 11 also shows the correspondence and contrast relations analyzed in phase 2 as a relations between two of the grids used in phase 3. Thus, for two people, four grids obtained by one elicitation and one exchange each, are sufficient to classify the relations between attributes in terms of consensus, correspondence, conflict and contrast. The methodology scales up linearly for each expert, so that n people will be involved in n elicitations, one base elicitation and n-1 exchanges.

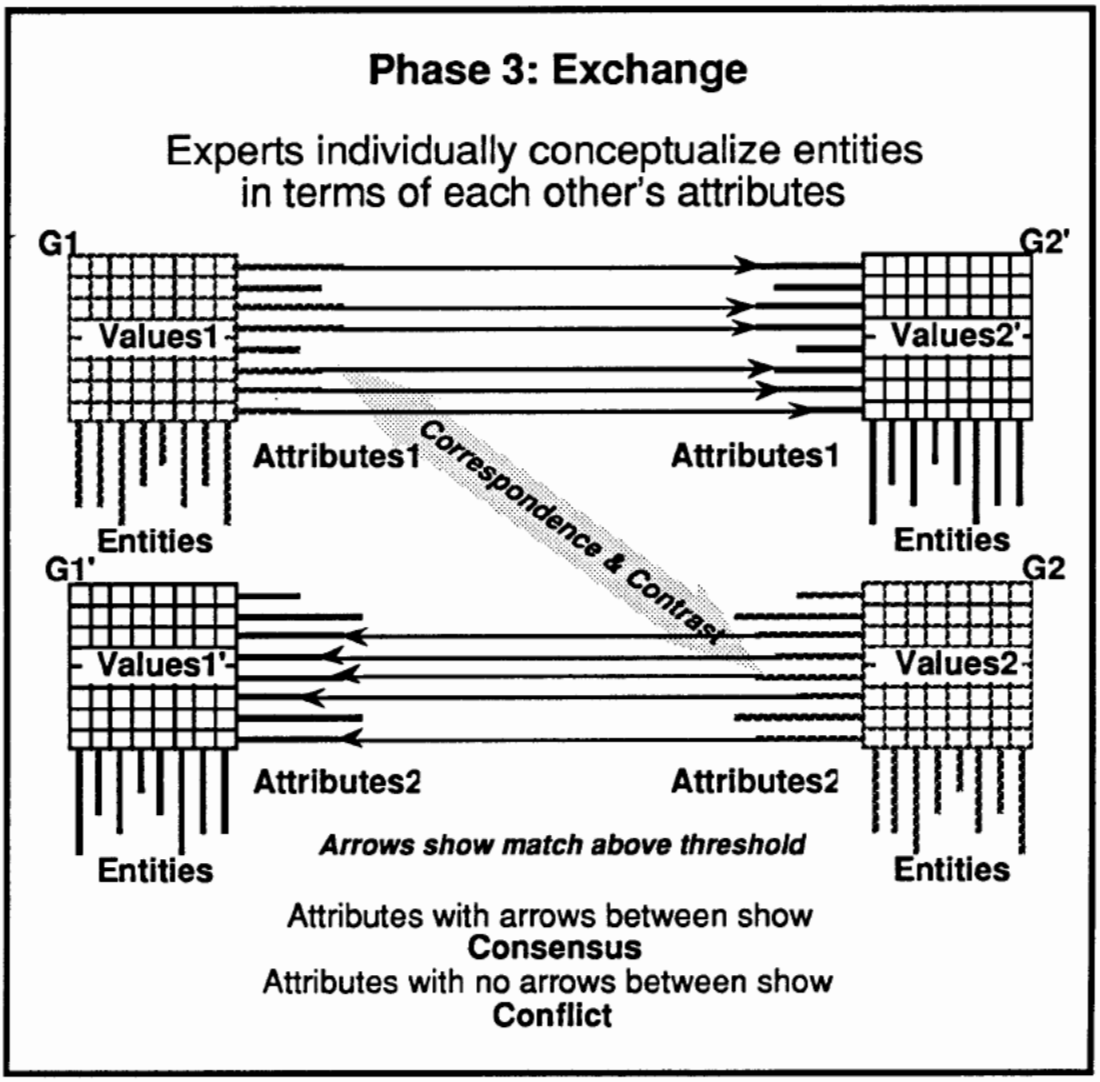

Fig.11 Phase 3 Methodology

These three phases result in the people's conceptual systems having become overt and inter-related. They lead naturally to later phases in which classes, objects and rules can be developed incorporating consensual, corresponding, and some of the contrasting attributes as kernel knowledge and, possibly, the conflicting and remaining contrasting attributes as 'other opinions.'

EXAMPLES OF THE METHODOLOGY IN ACTION

This section gives an example of the methodology in action using data from the study of re-constructing the basic distinctions used in the Business Information Analysis and Integration Technique (BIAIT) used to determine the accounting needs of a company (Carlson 1979, Sowa 1984 pp.301-302). As described in a previous section, the study involved ten subjects with an assumed range of expertise in business record keeping, including businessmen and accountants, and students in an introductory accounting course, at various stages of their education. KSS0 used to elicit their attributes relating to business transactions.

Figure 12 shows an entity-attribute comparison from the study in which a businessman (3) has filled in the values for a class defined by entities and attributes elicited from another businessman (2). The print out shows the matches sorted with best first. The cumulative percentage is given of the number of attributes with matches greater than the value shown. In the list of attributes at the top, it can be seen that there is consensus on *return after use—ownership transfers* but conflict on *many different bookkeeping entries—one (or few) entries*. There is clear consensus on the top seven attributes, clear conflict on the lower five, and uncertainty about the remaining one.

In the list of entities at the bottom, it can be seen that there is close agreement on *hiring out a car to a customer*, but high disagreement on *providing TV rental services*. This output can be used to focus a discussion between the experts on why they differ in their views of *providing TV rental services* and the classification of services in terms of *many* or *few different bookkeeping entries*.

```
G1:G2 53.8% over 80.0 (3+2 construct-consensus-with 3 Businessman)
  1:   7.7% ≥ 92.5  C12: Return after use - Ownership transfers
  2:  15.4% ≥ 90.0   C2: Quantity/price recording - Professional fee system
  3:  23.1% ≥ 87.5   C3: Customer selling required - Provides service to customer
  4:  30.8% ≥ 82.5   C9: Nonpersonal delivery - 'Hands-on' delivery
  5:          80.0   C4: Impersonal interaction - Close personal interaction
  6:          80.0   C5: Direct delivery - Supplied one at a time
  7:  53.8% ≥ 80.0  C11: Record customer - No record
  8:  61.5% ≥ 75.0   C6: Low $/unit price - High $/unit price
  9:          67.5   C1: No. of different objects - Same object in quantity
 10:  76.9% ≥ 67.5   C8: Requires "professional demeanor" - Requires "selling personality"
 11:  84.6% ≥ 65.0  C13: Semi-professional training required - Casual training required
 12:  92.3% ≥ 62.5   C7: Many similar items - Many different items
 13: 100.0% ≥ 37.5  C10: Many different bookkeeping entries - One (or few) entries

G1:G2 20.0% over 80.0 (3+2 Element-consensus-with 3 Businessman)
  1:  10.0% ≥ 82.7   E5: Hiring out a car to a customer
  2:  20.0% ≥ 80.8   E8: Providing electricity for home
  3:  30.0% ≥ 78.8   E2: Selling antiques in a market
  4:  40.0% ≥ 76.9   E1: Selling newspaper from a stand
  5:  50.0% ≥ 75.0   E4: Selling large appliances
  6:  60.0% ≥ 73.1  E10: Being agent for home purchase
  7:  70.0% ≥ 71.2   E9: Providing dental services
  8:          69.2   E3: Selling custom drapes
  9:  90.0% ≥ 69.2   E7: Selling car insurance
 10: 100.0% ≥ 67.3   E6: Providing TV rental services
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Fig.12 Entity-attribute comparison of businessman 3 with businessman 2

KSS0 can present figure 12 graphically as a *difference grid* where rating values (in this case 1 to 5) for businessman 3's ratings of businessman 2's entities on his attributes are subtracted from businessman 2's similar rating values respectively. Figure 13 shows this with the entities and attributes about which they agree the most in the top right corner, shown by no difference or a difference of only 1; and those with most disagreement towards the bottom left, shown by the maximum difference of 4 or a large difference of 3. Hence from this difference grid, the consensus and conflicts can easily be identified and discussed by the experts.

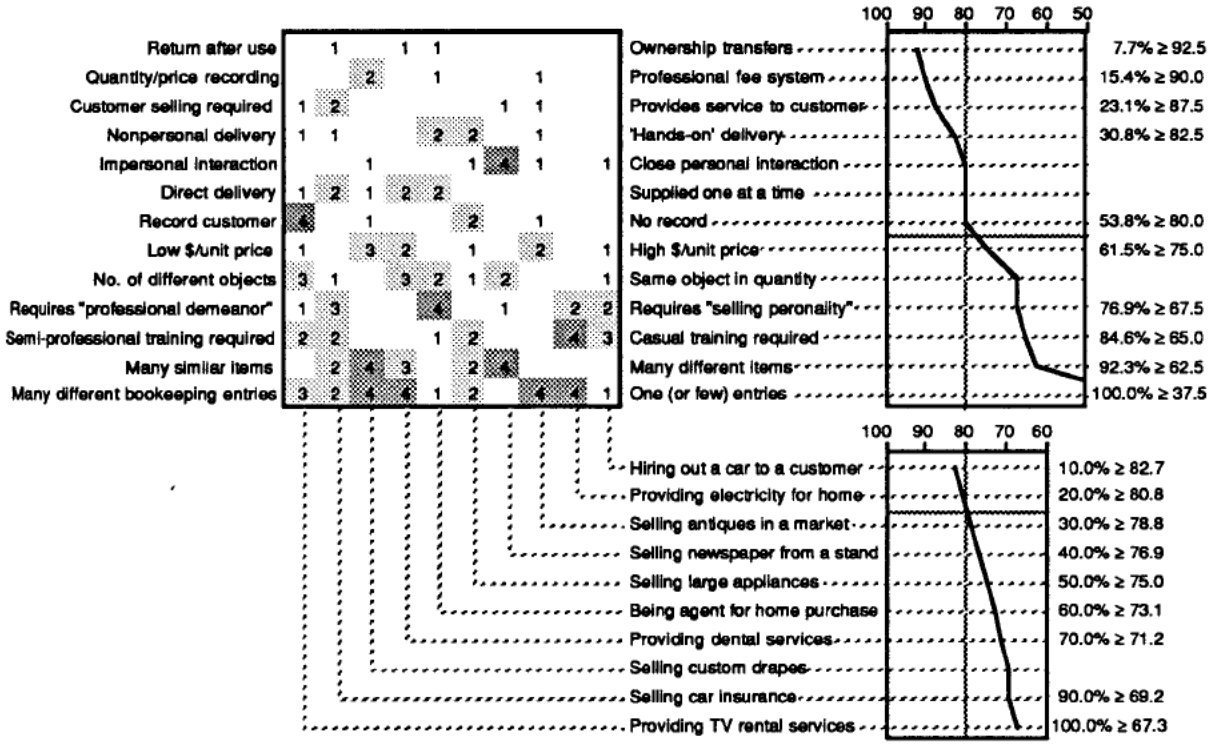

Fig.13 The difference grid for businessmen 2 and 3

Figure 14 shows an attribute comparison from the study in which businessman 3 has specified attributes and filled in the values for a class defined by entities elicited from businessman 2. The print out shows the matches sorted with best first. The cumulative percentage is given of those with matches greater than the value shown, and the attribute from 3 which best matches each from 2 is shown beneath it. It can be seen that:

- The first or highest match which accounts for 7.7% of the attributes has a level of 95.0 out of a possible 100 if they were identical. That is, when businessman 3 is using the attribute *return after use—ownership transfers* businessman 2 is using the attribute *we own—customer owns* in the same way. This is an example of *correspondence.*
- The second and third matches together account for 23.1% of all attributes, and they are matched over the level of 87.5. For the second attribute, when businessman 2 uses the term *impersonal interaction—close personal interaction,* businessman 3 is using the term *low cost—expensive.* This shows a difference in terminology which can be interpreted as their *levels of attribution* being different in their construing of this topic. This illustrates the two businessmen having attributes in *correspondence.*
- The third match again shows a *correspondence* with businessman 3 using the attribute *direct delivery—supplied one at a time* in the same way as businessman 2 using *long term relationship—short term relationship.*

```
G1<:G2 38.5% over 80.0 (3 Businessman construct-correspondence-from 2 Businessman)
  1:   7.7% ≥ 95.0    G1A12: Return after use - Ownership transfers
                       G2A3:           We own - Customer owns
  2:          87.5     G1A4: Impersonal interaction - Close personal interaction
                       G2A9:                Low-cost - Expensive
  3:  23.1% ≥ 87.5     G1A5:        Direct delivery - Supplied one at a time
                       G2A4: Long term relationship - Short term relationship
  4:          80.0     G1A2: Quantity/price recording - Professional fee system
                       G2A1:         Standard product - Special product
  5:  38.5% ≥ 80.0    G1A13: Semi-professional training required - Casual training required
                       G2A1:                        Special product - Standard product
  6:  46.2% ≥ 77.5     G1A9: Nonpersonal delivery - 'Hands-on' delivery
                       G2A9:              Low-cost - Expensive
  7:          75.0     G1A3: Customer selling required - Provides service to customer
                       G2A1:           Special product - Standard product
  8:          75.0     G1A8: Requires "professional demeanor" - Requires "selling personality"
                       G2A4:           Long term relationship - Short term relationship
  9:          75.0    G1A10: Many different bookkeeping entries - One (or few) entries
                       G2A1:                      Special product - Standard product
 10:  76.9% ≥ 75.0    G1A11: Record customer - No record
                       G2A2:       Send bill - Collect cash
 11:          72.5     G1A1: No. of different objects - Same object in quantity
                       G2A6:                      Choice - Monopoly
 12:          72.5     G1A6: Low $/unit price - High $/unit price
                       G2A5:      Fixed price - Haggle
 13: 100.0% ≥ 72.5     G1A7: Many similar items - Many different items
                       G2A5:        Fixed price - Haggle
```

Fig.14 Attribute comparison of businessman 2 with businessman 3

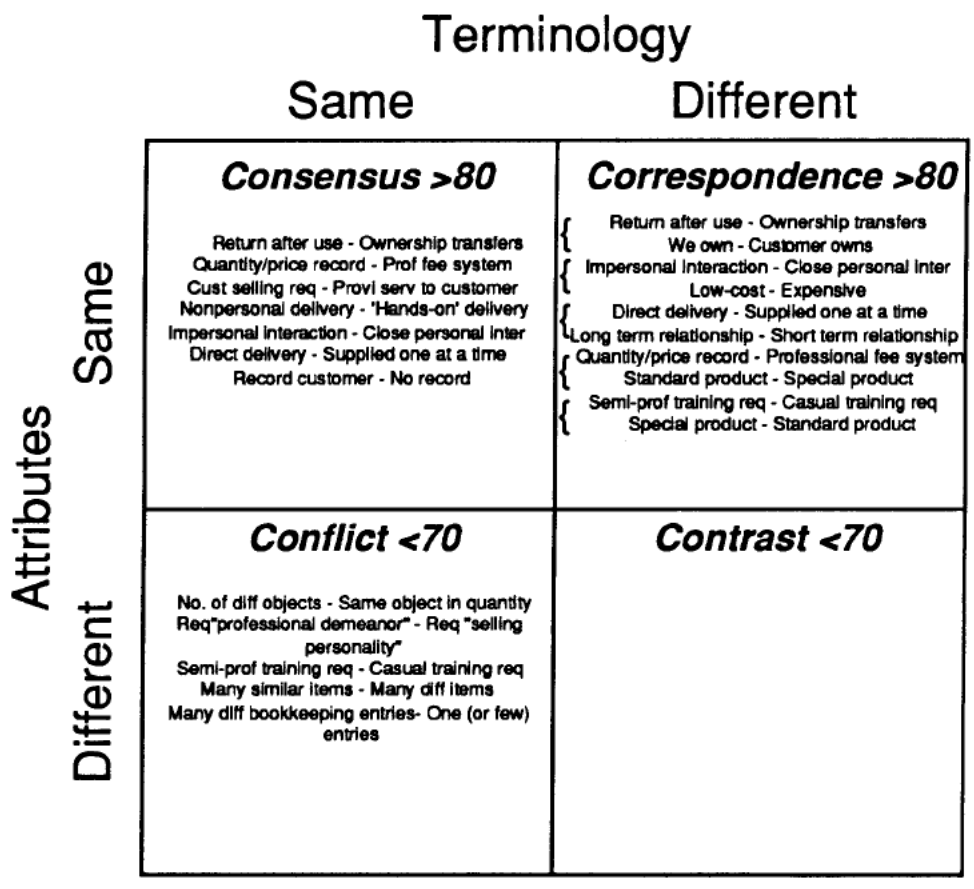

Fig.15 Consensus, correspondence, conflict and contrast from Figs. 12 and 14

- The fourth match shows a *correspondence* between *quantity/price recording—professional fee system* and *standard product—special product.*
- The fifth match, still over the level of 80, again shows *correspondence*. It shows the attribute *special product—standard product* is being used by businessman 3 to correspond to *semi-professional training required—casual training required* used by businessman 2. We can interpret this as a difference in attribution corresponding to a correlation in the real-world. Notice that *special product—standard product* used by businessman 3 was also used in the fourth match indicating that businessman 2 has two attributes *professional fee system—quantity/price recording* and *semi-professional training required—casual training required* which are used similarly to each other but with different terminology, whereas businessman 3 has only one. This shows a differences in richness of concepts not necessarily making new distinctions in the class so far defined by the entities.

Figure 15 shows each of the attributes from Figures 12 and 14 put into the appropriate quadrant of Figure 2. There is no significant example of *contrast* in this data. Such examples do arise in a full analysis of the all the subjects in the original study.

```
Mode Construct 1: 8 constructs in 6 grids at 90.0
  G2A3:      Being hired - Being sold
  G2A4:          Service - Sales
  G4A8:         Property - Sales representative
  G6A4:           Rental - Sales
 G9A12: Return after use - Ownership transfers
 G10A3:          We own - Customer owns
 G10A8:    We look after - Customer looks after
 G11A5:   Product rented - Product purchased

Mode Construct 2: 4 constructs in 4 grids at 90.0
 G1A10:                Investment - Personal use
  G2A6: Agent looks for customers - Customer goes to salesman
 G10A5:                   Haggle - Fixed price
 G11A4:          Price negotiated - Price fixed

Mode Construct 3: 2 constructs in 2 grids at 90.0
  G1A5: Tangible - Intangible
  G2A2: Tangible - Intangibles

Mode Construct 4: 2 constructs in 2 grids at 90.0
  G2A7: Salesman not required - Salesman required
 G10A6:             Monopoly - Choice

Mode Construct 5: 2 constructs in 2 grids at 90.0
  G3A3:             Less contacts - Customer contacts
  G9A3: Customer selling required - Provides service to customer

Mode Construct 6: 2 constructs in 2 grids at 90.0
  G5A1: Expensive for customer - Affordable for public
 G10A9:              Expensive - Low-cost

Mode Construct 7: 2 constructs in 2 grids at 90.0
  G5A7: No direct contact with customer - Direct contact with customer
  G8A9:                 Less experience - Experience of seller

Mode Construct 8: 2 constructs in 2 grids at 90.0
  G5A8:     Luxury - Necessity
  G6A9: Low supply - Supply
```

Fig.16 Mode attributes from eleven subjects

Figure 16 shows a *mode attributes* analysis of data from the ten subjects which extends the clusters noted above. These mode attributes are essentially inter-conceptual-system clusters of corresponding attributes from the three experts. The first may be interpreted as centering around who owns the property encompassing a variety of concepts related to this; the second as around fixed or negotiated sales and their consequences; the third as around *tangible—intangible* products.

These mode attributes can be interpreted as indicating stereotypical lines of reasoning most used by these subjects. This output can be used as a basis for discussion among them on whether these conceptual clusters should be retained as being the same concept expressed in different terminologies. Once this form of analysis has been discussed by the group it is readily edited and extended.

Figure 17 shows a *socionets* analysis of the same data based on a set of comparisons like that shown in full in Figure 14, but each with the BIAIT data. It can be seen from the first link that the conceptual system of businessman 2 encompasses the majority of attributes used by BIAIT. This indicates that he has a deeper knowledge of the topic than any of the others. Those of the economics students 9 and 11 encompass the majority of the attributes of BIAIT, shown in the second and third links, and that of the computing student just below half. However, those of the others do not encompass many of those of BIAIT.

```
Attribute Links between Grids
 G1<:G11   85.7% over  80.0 (1 BIAIT construct-correspondence-from 2 Businessman)
 G1<:G2    57.1% over  80.0 (1 BIAIT construct-correspondence-from 9 Economics)
 G1<:G9    57.1% over  80.0 (1 BIAIT construct-correspondence-from 11 Economics)
 G1<:G6    42.9% over  80.0 (1 BIAIT construct-correspondence-from 5 Computing)
 G1<:G3    28.6% over  80.0 (1 BIAIT construct-correspondence-from 7 Visual Arts)
 G1<:G4    28.6% over  80.0 (1 BIAIT construct-correspondence-from 4 Economics)
 G1<:G5    28.6% over  80.0 (1 BIAIT construct-correspondence-from 6 Chemistry)
 G1<:G7    28.6% over  80.0 (1 BIAIT construct-correspondence-from 8 Economics)
 G1<:G10   28.6% over  80.0 (1 BIAIT construct-correspondence-from 3 Businessman)
 G1<:G8    14.3% over  80.0 (1 BIAIT construct-correspondence-from 10 Accounting)
```

Fig.17 Socionet analysis of three experts

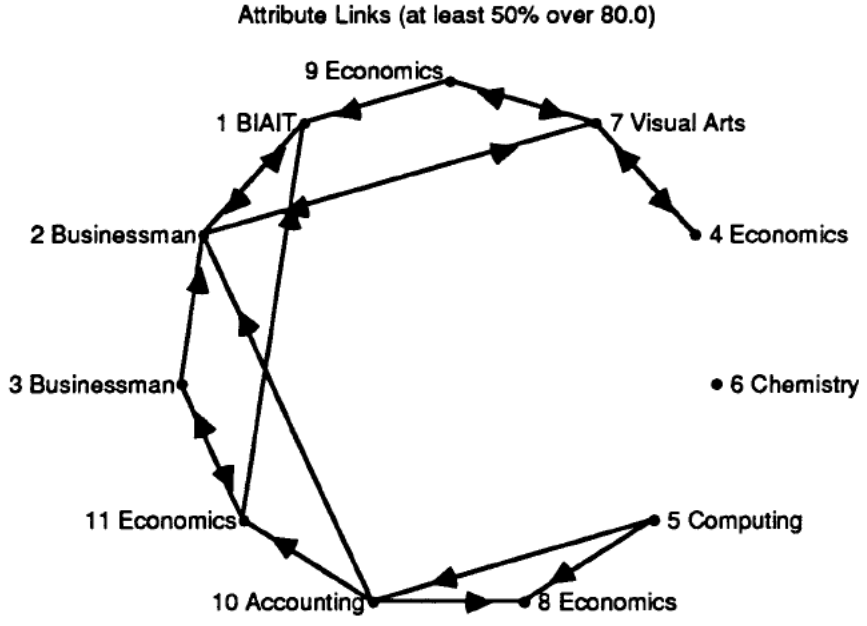

Fig.18 Socionet of relations between experts' conceptual systems

Figure 18 shows the full set of links between all subjects showing at least 50% overlap expressed in the socionet links of relations between the subjects' conceptual systems for the domain.

SUMMARY OF METHODOLOGY

Phase 1: Domain Discussion and Instantiation

1. The problem is discussed with the subjects and a domain identified.
2. The subjects are introduced to the use of KSS0. At this time a specific task is agreed upon and a purpose for the grid elicitation developed.
3. The first elicitation consists of the elicitation of a grid by each subject individually. This gives each person experience in using KSS0 and provides an initial set of entities and attributes particular to each.
4. These grids are processed using FOCUS and PrinCom, and the results reported and explained to each subject respectively.
5. The subjects meet together to discuss each set of entities, review and revise the purpose or context of the elicitations, and agree on a common set of entities which all understand.

Phase 2: Conceptualization and Feedback

6. This common entity set provides the basis for the next phase of data collection which consists of the elicitation of a grid by each subject using the set of common entities and a common rating scale. This elicitation is done separately for each subject.
7. These grids are also processed on FOCUS and PrinCom, and the results reported and explained to each subject respectively.
8. This data is then processed on Socio, and attributes of correspondence and contrast identified.

Phase 3: Exchange and Compare

9. The next phase of data collection consists of the subject exchanging their grids elicited in phase 2 with each other subject in the group to produce other grids.
10. This data is then processed on Socio, and attributes of consensus and conflict identified.
11. From the Socio results a mode grid is produced to identify the content of the shared lines of thought emanating from the distinctions made by all the subjects together.
12. From the Socio results the socionet sequence is produced to identify the subgroups of subjects who think and act in similar ways, and any who are different in their thinking from the main lines of thought in the group.

CONCLUSIONS

The methodology described in this paper provides facilities for revealing the similarities and differences in the concept systems of different people, or the same person at different times, construing a domain defined through common entities or attributes. It can be used to focus discussion between subjects on those differences between them which require resolution, enabling them to classify them in terms of differing terminologies, levels of abstraction, disagreements, and so on.

Note that the derivation of consensual, corresponding, conflicting and contrasting attributes is completely algorithmic, based solely on the data in the grids. This derivation is done by a computer program, not a knowledge engineer, and its basis can be demonstrated clearly to the subjects through computer output such as the difference grid of Figure 13. Thus, there are no opinions being expressed about the correctness of the use of the attributes and terminology, that the differences highlighted are 'right' or 'wrong.' It is open to the subjects to consider, discuss and explain these differences, changing or retaining them as they wish.

The methodology promotes the full exploration of the conceptual framework of a domain of expertise by encouraging subjects to operate in a "brain-storming" mode as a group, using differing viewpoints to develop a rich framework. It avoids social pressures forcing an invalid consensus by providing objective analysis of separately elicited conceptual systems.

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