What are Kinship Terminologies, and Why do we Care?: A Computational Approach to Analysing Symbolic Domains

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Abstract

Kinship is a fundamental feature and basis of human societies. We describe a set of computational tools and services, the Kinship Algebra Modeler, and the logic that underlies these. These were developed to improve how we understand both the fundamental facts of kinship, and how people use kinship as a resource in their lives. Mathematical formalism applied to cultural concepts is more than an exercise in model building, as it provides a way to represent and explore logical consistency and implications. The logic underlying kinship is explored here through the kin term computations made by users of a terminology when computing the kinship relation one person has to another by referring to a third person for whom each has a kin term relationship. Kinship Algebra Modeler provides a set of tools, services and an architecture to explore kinship terminologies and their properties in an accessible manner.

Keywords

Kinship, Algebra, Semantic Domains, Kinship Terminology, Theory Building

1. Introduction

The Kinship Algebra Modeller (KAM) is a suite of open source software tools and services u nder development to support the elicitation and analysis of kinship terminologies, building al gebraic models of the relations structuring terminologies, and instantiating these models in lar ger contexts to better understand how people pragmatically interpret and employ the logic of kinship relations as a resource in their individual and collective lives. KAM is the latest versi on of a computational framework based on over 40 years of research by Murray Leaf, Dwight Read and, more recently, Michael Fischer.

Kinship, and particularly kinship terminologies and algebraic and computational tools, may a ppear to non-anthropologists (and to many anthropologists these days) as a rather exotic topic for which to develop specialised software to mount research. Kinship is, however, a fundame ntal feature and basis of human societies. We know this even though we do not yet have a cle ar understanding of what it is. But all societies have something we can see as comparable to whatever we recognize as kinship in our own, although never exactly the same. Likewise, the relationships that are forged by kinship shape everyone's life in important ways, and although everyone's kinship experience is unique to themselves, at the same time there is a basis for co mmon understanding. This understanding is perhaps most significant when used to understan d the kinship experience and perspective of others, rather than one's own situation.

It is also true that all societies also have other kinds of relationships beyond kinship. But few, if any, of these other kinds of relations are clearly universal. Some have government; some ar guably do not even though every community in the world is now at least nominally within so me national jurisdiction. Some have hunting organizations; some do not. Some have age-gra des; some do not. Some have business firms, some have caste, some have courts, and so on.

The fact that there are multiple kinds of organizations presents the problem of distinguishing one from another. This involves language, in the sense that all organizations have named and defined values, roles, and relations. Distinct organizations have roles and relations with distin ct names and descriptions; related organizations have roles and relations with related roles an d descriptions. Kinship organizations are no exception. Kinship, as a sphere of organization a nd activity, is distinguished from other spheres by distinct terms for kinship roles and relation s, and as a matter of fact—plain fact—at the center of this terminology, or language, is a disti nct set or system of terms for the basic relationships that define kinship as such. All kinship s ystems are marked by a kinship terminology.

Kinship was for a very long time one of the key drivers for anthropological theory in the conv entional sense. However, many anthropologists have reached a kind of hiatus with respect to kinship theory, with origins in Schneider's repudiation of kinship theory and practice as being a reflection of western conceptions of relatedness through blood (1987). While this rightly be gan a raft of critical considerations of kinship, what Schneider and other anthropologists did n ot acknowledge was that Schneider's complaint was directed at problems in the margins of ki nship theory, not the core, which despite its weaknesses by and large had been a progressive p latform for describing one particular domain of human agency, activity and diversity and the i ntereractions between this domain and many many others. In any case many anthropologists a ppear to have accepted Schneider's criticism and the study of kinship diminished rapidly in th e 1980s and beyond.

Just as there was something to Schneider and his concerns about ethnocentric treatment and a ssumptions in kinship theory and analysis, there was something remaining in the study of kin ship relationships. Carsten (2000) focused more broadly on relationships, of which kinship w as just one. This was a useful idea, indeed one that Buchler and Fischer (1984) initially used i

n an argument in response to Read's 1984 paper describing an algebraic structure for Americ an kin terms (AKT). Buchler and Fischer were a bit too quick off the blocks with this point as Read had demonstrated something very specific and important in showing that the structure o f AKT conformed to an algebra -- this could only be constructed for kinship terms, not the ent ire set of American relationship terms. In particular, there was the question of why kinship ter ms should conform to such s tight set of constraints? This was, with a bit of reflection, quite a dramatic outcome, with far more motivation than the componential grammars and structural a nalyses in play at the time.

Based on this result we developed KAM (Kinship Algebra Modeler) with an aim to expand th e range of, and clarity in, accounting for the structure and regularity we find in kinship-relate d phenomena, including kinship terminologies, genealogies, and kinship associated behaviou r, such as marriage, inheritance and social organization. KAM as a software project originated in a project originally developed by Dwight Read and Cliff Behrens (1990) as the Kinship Al gebra Expert System (KAES) and rewritten from 1999 by Dwight Read and Michael Fischer, culminating in KAM. KAM is presently a suite of java applications that run standalone or as services to assist development of a formal, generative model, in the form of an abstract algebr a, to identify the underlying logic of any specific kinship terminology, and to support models and simulations of social processes based on instantiating the logical properties of a kinship t erminology. Further development of the components of KAES was a key basis for KAM, tog ether with other software under development that utilizes the products of KAES components.

KAM provides services for eliciting kinship terminologies in a form that is complete, for mod elling relations between the elicited terms by constructing a custom algebra for each terminol ogy based on structural properties of the terminology, and for pragmatically instantiating thes e algebraic representations to create models that reflect some of the many applications people

have that are informed by terminological relations. These applications might take the form of merging different personal viewpoints onto a common structural model such as a genealogy o r pedigree, or a more dynamic representation such as terminological relations within a simulat ed population that maintains the more individuated viewpoint on their own relationships that each person has.

The underlying ideas and theory that have shaped the development of KAM's elicitation serv ice began over 40 years ago with Leaf's (1972) development of methods for eliciting and repr esenting relationships between ideas, resulting in what he called "semantic maps" of these rel ationships based on local judgements by members of the community. Although we will focus in this article on applications to kinship terminologies, this work is by no means limited to ki nship terminologies, and we envisage eventually a more general Semantic Domain Modeller suite to work within and between a range of cultural domains.

Following is a commentary by Murray Leaf describing the logic and elicitation methods unde rlying KAMs basic data structure, the kin term map, the instantiation of Leaf's more conceptu al kinship maps. In particular Leaf demonstrates how we know a kinship terminology when w e see one, and provides the only published solution to how we know when we have elicited th e entire terminology.

2. What kinship terminologies are, and how we know it.

Murray Leaf:

There is a great deal of confusion over what a kinship terminology is, and how we know it. T he confusion is largely generated by an underlying referential conception of meaning deriving from sociological and logical positivism, especially from Mill (1950). The alternative I will d

emonstrate here is pragmatic (Leaf 1979; 2009). Referential theories are set up in terms of w ords and their referents. Pragmatic theories are set up in terms of ideas and their uses

It may seem that it is more "objective" and hence "scientific" to speak of words or lexemes an d their referents rather than ideas and their uses. We can regard both of words (in a linguistic sense) and referents as physical in some sense, and hence "objective" (cf. Wallace and Atkin s, 1960. Ideas, on the other hand, seem more "subjective," hence either less scientific or not s cientific at all. In fact, however, the referential theory, and the associated supposed objectivit y, is infected with an inherent and unavoidable circularity. If, indeed, we strictly adhere to the notion that that a word is simply a sound or some other objective symbol, then how do we kn ow any given word is a kinship term? The usual answer is that we can see that they designate or refer to a kinsman (as though it were tied to kinsman by a kind of conceptual string). Davi d Schneider long ago pointed out the circularity in this as it had been argued in componential analysis (1969), although he eventually abandoned kinship analysis entirely because he could not find an alternative (Schneider 1987).

In reality, kinship terminologies are not like sets of labels but like geometries. They are not c ollections of lexemes but systems of ideas. Moreover, like geometry, they are generative syst ems.

We do not learn geometry by seeing how people refer to shapes, collecting the "geometrical t erms" and arranging them in some systematic formal way. We learn geometry by learning w hat its premises and corollaries are, and how to use them. In the process, of course, we also l earn the more basic ideas of what a premise is in general, what a corollary is, and what logica l computation is. Only after we have done this can we know how to apply these ideas to actua l shapes. It is exactly the same for kinship, only the premises and corollaries are different.

Once we realize that kinship terminologies are generative systems, we can see how to elicit th em. Basically, this requires developing an elicitation method that shows what the premises ar e are and how they are used. As the premises of geometry are built into systems of geometry, so the premises of kinship terminologies are built into the terminologies. But of course the pr emises are not the same. The fundamental idea of a formal, generative, system is the same bu t the specific premises and computational rules are different.

The premises of kinship terminologies are the basic concept of a "self" or "my," the positions defined around that self as its direct, rather than indirect relations, and the relationships that in terconnect them. The relationships include the basic computational concept: recursive concat enation to produce relations that are transitive and reciprocal.

To avoid the methodological misdirection built into the term "kinship terminology" I will hen ceforth revert to the more accurately descriptive term I have used previously: kinship map. A kinship map is a map quite literally, but in a topological rather than geographical sense: it is a record and portrait of the logical relationships among positions in logically defined kinship sp ace. Under the title "Experimental Analysis of Kinship" (Leaf 2006), I have previously provid ed a detailed description of how such kinship maps can be systematically elicited, how they a re used, and how they resemble one another and differ from one another. The following is a s hortened version that account.

The Kinship Map

Kinship maps always utilize a spatial imagery. People around the world commonly speak of " sides," "lines," "distant" or "close" relatives, and reckoning "upward" or "downward." Becau se of this, the best way to capture the conceptual structure of systems of kinship definitions w ithout using one's own cultural conceptions as an obscuring filter is usually to ask for diagram s, not lists. Systems of kinship definitions are always ego-centered. This means two things. F

irst and most simply, the positions are generally defined only with reference to a specific user. There is not a definition for father or mother against all comers in the way a temple priest, vill age headman, or the President of the United is defined against all comers. The primary defini tion is only for "my" father, a father in relation to a specific person who is a son or daughter. Moreover, such definitions always occur in fixed reciprocal pairs, in the sense that if you are my father then I must be your son and vice versa. I cannot be your uncle or cousin. By contra st, if you are "my" village priest I might be your supporter, opponent, acolyte, or any number of other things, and none of these will define your position in what most people consider to be the most important sense.

Elicitation

In kinship maps, there is always a very restricted set of *direct* relations arrayed immediately a round ego. All other relations are connected as concatenations of these direct relations. Thes e direct relations are not only the core in a pictorial and logical sense but also in a developme ntal sense: beginnings as infants, we learn them from the center out, deepening our sense of t he logic of kinship idea systems as we expand the range of positions we come to recognize.

The direct relations are not identical from culture to culture but by and large they are very sim ilar. For present purposes, I will deal only with American English and Punjabi. The configur ation of core positions is given in figure 1 with their standard English and Punjabi names. No n-standard names are recognized as being defined in terms of the standard names, like "Pop is another word for father"—although in fact such seemingly casual or informal forms often app ear to be very ancient and might very well be survivals of earlier formal terms. In the end, ho wever, it is not the terms that matter but the ideas that they evoke.

[Figure 1 about here]

The English and Punjabi definitions seem the same in terms of the other positions within the c ore, but as we will see they are not the same in terms of their implications for the positions be yond it. In both of these systems, ego may be male or female, here symbolized by a square. The definitions of relatives do not change with sex of ego.

Kinship relations are reciprocal. In the diagram, the reciprocity this reciprocity can be seen b y recognizing that each relation is "other" to ego as a "self." It follows that the reciprocal of e ach

other" to ego can be found by tracing the relation from ego to alternative other in the opposite direction. That is, the positions one link up from ego are the reciprocals of the positions one li nk down. The positions one link to the side are reciprocals of each other, allowing for sex an d other represented attributes. If you are my brother and I am male, I am your brother. If I a m female, I am your sister. If you are my father (one link up, male) then I am your son or dau ghter (one link down, differentiated by sex). More generally, reversing the path from ego to a ny position yields the relation from that position to its reciprocal.

Since any person occupying any of the direct kin relations to ego is also, necessarily a "self" i n relation to themselves, the core terminology can be used as an eliciting frame to obtain the r est of the system of definitions. We simply apply it outward to every direct relation in turn by asking what each of the direct relations to the first set of direct relations is to ego. What is fat her of father to self? What is mother of father to self? What is brother of father to self, and so on.

As elicitations proceed outward we usually find that multiple paths of links lead to each name d position. In English, father's father is the same relation as mother's father: "grandfather." If we ask whether these relations that all have the same name actually *are* the same, it is logicall y possible that we could be told either that they are or that they are not. In my experience, ho

wever, the actual answer has consistently been that they are. The general rule is one term, on e position. When it is, we need to draw the graph to show it by making all the different links converge on that graphic element. The one symbol then corresponds to the one relational con cept (such as grandfather) and the various paths to it correspond to different parts of its final, complete, definition. Figures 2 through 5 illustrate the process with part of the Punjabi kinshi p map.

Figure 2 takes ego's *ma* as the reference other, and asks what the core positions to *ma* are to t he original ego. What is *baap of ma* to you? What is *ma of ma* to you? And so on around. Thi s then yields names for these positions. The names of the new positions are indicated in regul ar type, the original remain in italics.

[Figure 2 about here]

I then query the new positions in the same way. Figure 3 is the responses from taking *ma* of *ma* (*nani)* as the new reference other and asking what her *bap, ma, bhai, bhain, putar, and pu tri* are to ego. As with the first step, this gives some positions that are wholly new, and some t hat have the same names as those already elicited. I then ask if the new positions with the sa me names are "the same" positions as the early positions with that name. If they are, I then m erge the drawings (by erasing and redrawing). This has to be done as the elicitation proceeds; otherwise the responses to keep the overlaps manageable. Figure 3 is the merged result for *m a of ma of ma*. So far, they have always been the same. If they were not, we would have a ser ious conceptual puzzle: how can a terminology exist and be passed on through the generation s in which conceptually different positions are not distinguished by their names? The questio n probes what can be described as the economy of thought. I cannot think of a way this can b e done without confusion. Where the positions are described as "the same," the new graphic f orm now represents the same position arrived at by additional conceptual pathways—it adds

additional definitions. The meaning of the position *nana*, for example, is now either a *putar of parnana*, a *bhai of nana*, a *bhai of nani*, a *bap of ma*, a *bap of masar*, or a *bap of masi*.

[Figure 3 about here]

New positions are again queried in the same way. Figure 4 is the result from asking what the direct relations of parnana are to ego, which illustrates one way of arriving at an endpoint or rule for logical closure.

[Figure 4 about here]

The new positions are again represented by bolder descent lines and regular typefaces. Here again we have some new terms and some repetitions of terms already elicited, and again for those that are the same we have to ask if the relations or positions they designate are actually also the same relations. In this case, all the new positions are either "the same" as positions already elicited or not kin at all. This procedure continues until it finds the endpoints of the system, the conceptual boundaries. In Punjabi, this happens when the parnana position is queried. The result is that all the new relations are either new paths to positions already defined, or not relations at all. The bhai and bhain of parnana, for example, are parnana and parnani, respectively. The putar of parnani is nana, the putri of parnani is nani, and the bap and ma of parnana are *not relations*. They are ancestors, but not relations. The reason, when I asked, was that they were dead; one does not have relationships with them, so they are not relations. And this of course reveals a different basic understanding of what a relative or relation is than, for example, that which we would obtain using the same procedure for English speakers. In English, by contrast, the endpoints in the vertical direction are not statements of this sort but rather rules for indefinite continuation—"just keep adding "great.""

After reaching one end point, elicitation has to return to a different intermediate point and tra ce it out—all the relates from the nana position, for example, or all the relations from *bhai* an d *bhain*, and then all the relations from *putar and putri*. The order does not matter; what matt ers is that all possible paths must be explored until no query yields new positions.

When all the end points are reached and all the graphic symbols used in the elicitation are gat hered so that there is just one graphic representation of each recognized position, the result is an experimental trace of the system of kinship concepts that exactly parallels a photographic exposure or an instrument reading in a physical experiment. It is a trace that will let us see ho w each positional idea is related to all the others, and, thereby, to predict its use. Figure 5, bel ow, is the same as the diagram I drew in the village during my first field work to summarize t he Punjabi analysis.

The only difference between this and the final map I drew in the village to check with those w ho had been in the interviews is that in that one the names were written in Gurumukhi script. Below ego's generation, the terms noted are stems which take four different endings for each position in the group that they appear in. The endings "a" and "i" indicate a female descenda nt. "Joai" indicates a male who has come in by marriage, and "nuh" indicates a woman conne cted by marriage. So, for example, *patija* is *putar of bhai*. *Patiji* is *putri of bhai*. *Patij-joai* i s husband of *patiji*, and *patij-nuh* is wife of *patija*.

This is not an "interpretation" of what I observed or any sort of inference from it. It is what I elicited. There is an unbroken chain of experimentally collected observation from the conver sation in the village to the final representation on the printed page that is every bit as clean an d definite as the results from an experimental process in a physical laboratory.

[Figure 5 about here]

Comparison

When the same procedure is applied to English, the results are as in figure 6. I have simplified this diagram slightly in the same way as I did the Punjabi, by not including additional positions for relations acquired by marriage relatively late in life—terms for relatives of spouses of relatives. In both of these systems, however, the basic rule is that you treat them like actual relatives, and take the connection from the relative they are connected through, allowing for the difference in gender.

[Figure 6 about here]

Since readers are probably familiar with this system in practice, even though they would normally have no reason to elicit it in its entirety in the manner described here, there is no need to review the details.

The most evident point of contrast is the most important. The shapes are not the same. English looks like a Christmas tree and Punjabi looks like a butterfly. This immediately tells us that the ways the definitions are interconnected differ in the two systems. Note first that in the Punjabi case the positions below ego's generation fall into groups of four, each marked by a unique stem and common set of four endings. The endings indicate sex and marital status. The ending for a consanguine male is *-a*. For a consanguine female it is *-i*. For affinal male it is *-joai* (the term for husband of daughter) and for affinal female it is *-nuh* (the term for wife of son). The stem indicates the descent-relation to ego, in which relational distance is suggested by similarity of sound. It is actually a kind of kinship poetry, which can be readily heard reading down the groups, the phonetic combinations mirroring the graphic pattern. In the American/English case, because of the ways collaterals are distinguished from lineal relatives, it is particularly important to remember to read the definitions as developing in the direction of the arrows, from ego out but not the reverse. A great uncle is anyone who is the brother of a gran

dfather but a grandfather is not anyone who is the brother of a great uncle. The configuration including uncle and aunt relations on the superior generations, which connects them by both a line indicating common "blood" and an equal mark indicating marriage, is to be read that an uncle is *either* the brother of an aunt *or* the husband of an aunt, and an aunt is *either* a sister of an uncle *or* a wife of an uncle, *but not both* because there is a rule that one does not marry a sibling. For the same reason, father is understood as not being brother to mother and a grandfather must be *either* the father of mother *or* the father of father, *but not both*, and so on. There is no reason to draw the two sets of uncles and aunts or grandparents as separate any more than there is a reason to draw each brother as separate. *The drawing represents the relationships, not the people who take them.*

The second major difference is that boundary concepts are not the same. In Punjabi, as noted, beyond the positions pictured as the top and bottom of the map, a person can be an ancestor but not a relative. The system is limited in the vertical dimension but relations can be indefinitely extended in the horizontal dimension. English is the opposite. The conceptual outer boundaries of the system are indicated in the horizontal dimension by the cousin line and in the vertical dimension by Rules 1, 2, and 3. Cousin is a boundary because it is a conceptual outer limit beyond which a person is defined as either yet another cousin or not a relative. Rules 1, 2, and 3 are limits because they are rules for indefinite extension. Ascendant and descendant relations go on forever according to the rule, but there is nothing beyond the rule. Rule 1 is that for each succeeding ancestor beyond great grandfather one simply adds a *great*, and the same is true for the reciprocal—each successively more remote descendant beyond great grandson or great granddaughter. Rule 2 is the comparable rule for collaterals, the uncle and aunt positions and their nephew and niece reciprocals: "add great." And Rule 3 is that any descendant of a cousin is a cousin. With these rules, the system is complete and logically closed, with

every term defined in relation to every other term. For any person, it will be possible to know if they are a relative or are not, and if they are their relation to oneself and all other relatives will be specified consistently.

The different shapes and boundary conceptions reflect different basic notions of what a relation is and what kinds of relationships are permissible. In the American system the idea of a brother and a sister is restricted only to children of one's own parents. In Punjabi, they are all children of one's own parents or their siblings, and those parents' siblings in turn are all children of *their* parents' siblings, a class that is ultimately infinitely large. The American idea is thus very strongly an idea of common descent, common "blood." The Punjabi idea is much more an idea of mutual interrelations. The American ideas define those who can be recruited as relatives as a very small set out of a much larger world of strangers, and define kinship relations substantially as something that comes down from ancestors. The Punjabi ideas allow recruitment of an indefinitely large set with the only ultimate distinctions being between different types of relatives rather than between relatives and non-relatives, and define kin relations as something that one builds outward from oneself.

Kinship and social organization

These kinship maps, like all kinship maps, can be used to generate an indefinitely large number of implications. These implications, when instantiated in behavior, are the map's uses. By tracing generative links as defined in the core among a set of actual people, any two people can decide whether they are or are not related, and precisely what that relation is—reciprocally. One can generate ideas of specific kinds of groups or organizations: a lineage, a "side," a family, a generation, or a category like "my female cousins" or "his *nanke*" (the people of his *nana*'s household).

Group definitions generated from kinship maps may be actual organizations but they need not be. With English, for example, there is a persistent belief in America (especially among sociologists) that the core relations also define a quintessential or "typical" family—the "nuclear family." In fact, in the United States according to the 2000 census, only 22 % of households of households had a householder, spouse, and at least one natural child. But we can be sure that in 100% of households, if people were related they had a common way to compute what their relationships were.

As can be seen above, Punjabi has essentially same core relations, but there is no such idea of a nuclear family as an ideal or typical household. Rather, there is an idea of a "joint family" or *parivar*, which is a group of brothers and a father who share rights in ancestral property, along with their female dependants. The nearest thing to the idea of a "household" is a "hearth," meaning those who store and take their food together. A hearth may be a joint family in this sense, but a joint family may also involve several hearths.

Czech Compared to English and Punjabi

Probably one of the most important barriers to seeing kinship terminologies as coherent idea-systems that not only name kin relations but actually constitute conceptual universes of kinship is that fact that when we learn a second language we also learn accepted translations for kin terms we already know. This necessarily allows English speakers who talk to Punjabi speakers in English about kinship to think that they are talking about the same things. Similarly, every Czech who speaks English knows English names for his relations, which allows the same impression. Such impressions must be tested, and the method of elicitation I have described provides the way to do so.

To close the argument by showing that the elicitation process is entirely natural from the point of view of the informant, imposing no ideas alien to the idea-system itself, I offered to elicit

the Czech terminology from the audience, using a large paper easel. I had no prior knowledge of Czech or of Czech kin terms. Daniel Sosna took the lead in responding. We started with th e direct terms and proceeded outward as in figures 1 through 4. Figure 6 is a photograph of th e drawing at that point. The triangle in a circle represents the concept of self, and positions i mmediately around self are the direct kin.

[Figure 7 about here]

At or just after the point captured in the photograph, it seemed clear to me that the pattern tha t was emerging corresponded to English as represented in figure 6. I said so, and those prese nt agreed. More precisely, since Czech distinguishes *syn* of *stryc* and *teta* from *dcera* of *stryc* and *teta*, it is exactly like Spanish, French, and German. It is very clearly unlike Punjabi. H owever, since the elicitation could not be carried out to far enough to encounter the boundary conditions within the time allotted in the meeting, this impression remained as a hypothesis to be tested. The most crucial test is to ask if Czech has rules for indefinite upward and downwa rd generation of the line from *otec* and *matka* to *d de ek* and *babí ka*. The answer can be obt ained in a dictionary: it does. The Czech equivalent of the English rule 1, to "add a *great-*," is "add a *velký*". It follows that the basic concept of kinship itself in the Czech terminology, as i n English but unlike Punjabi, is tightly linked to the idea of biological descent. It would mak e no more sense to a user of the Czech terminology to say a given person is an ancestor but n ot a relative than it would for an English speaker. Similarly, the ethnological distinction betw een lineals and collaterals will make the sense to a Czech speaker as it does to an English spe aker. English, French, German, Spanish, and Czech demonstrably share a common metaphysi cs of kinship that contrasts with the metaphysics of kinship of the Indo-European languages o f South Asia.

Commentary

Kinship maps are as real as pots and houses. They are also objective, but not in the way that pots and houses are. They are objective in the way systems of mathematics are, in a very stri ct sense as Dwight Read has shown repeatedly (1974; 1984; 2002). Systems of mathematics, like geometry, are bases of objectification. Geometry lets us objectify physical space as som ething we are in, that we move through, and that is the same for all of us. Calculus lets us obj ectify orbits and trajectories within space—among many other things. So, in precisely the sa me way, kinship maps lets us objectify kinship and kinship space as a system of relations that we move through and that is the same for all of us. What is truly constant about kinship map s, staying the same across all the cultural variation, is not anything about what the terms "refe r" to or designate, how kinship is conceived or how specific relations are conceived. Nor are t hey what is universal about kinship, what is truly constant rather than what varies from cultur e to culture. That, clearly, is in its logical structure. It is first of all in their use of a core set of relational definitions as premises, and in the computational rules for concatenation, embodyin g the ideas of recursiveness, transitivity and reciprocity, that allow these premises to entail the rest of the system.

Of course I am not saying that kinship in a biological sense is not real, or not "there." There c learly is something (or more exactly some things) that this objectification captures, something that ideas of descent, marriage, and the like take hold of and make available socially and conc eptually, and we can say a great deal about what it is. But many species reproduce sexually, h ave some sort of bonding between parents and offspring, and have means by which mature in dividuals assure the survival of offspring until they can grow enough and learn enough to pro vide for themselves. But only human beings organize all of this, and more, with a consciously held conceptual system associated with grammatical language. This is what kinship idea-syst ems are the foundation for. The most fundamental explanation of kinship terminologies is no

t to be found outside them either in the sense of what they refer to or in the sense of arbitrary analytic schemes we impose upon them for purposes of "comparison." It is, rather, to be fou nd within them, in the principles and concepts that give them their generative power. Seeing h ow this happens brings us face to face with the cultural and social basis of thought itself.

3. KAM: Kin Term Maps to Algebra

KAM has services that support establishing a *kin term map* following Leaf's more conceptual Kinship Map (see Figures 5 and 8), a complete set of terms and their relationships to each oth er without reference to a genealogical structure or other external relationships. In KAM a kin term map can either be based on a set of existing terms elicited using conventional methods, or can serve as a means for eliciting terms and the products of the terms; e.g., for American ki nship terms, the product of the kin term *father* with itself is *grandfather*: *father* of *father* is *gr andfather*. This follows from the fact that if speaker (properly) refers to a male as *father* and that person (properly) refers to another person as *father*, then speaker (properly) refers to that third person as *grandfather*. The kin term map is based on kin terms products of kin terms wit h the primary kin terms of the kinship terminology. Once it is formed, the kin term map is a d escription of the structure of a terminological system and kin term maps for different terminol ogies can be compared directly as a way to determine structural differences between kinship t erminologies.

It can then be genealogically instantiated (if one wishes to do this) by mapping the kin terms t o a standard genealogical diagram, starting with the mapping of the primary kin terms to the genealogical space and doing the composition of relations in the kin term space. Thus given t he genealogical path, ego's *ffs* (father's father's son), then for English speakers the primary kin terms *father* → {*f*}, and reciprocal primary term son → {*s*}, so *ffs* → *son* o *father* o *father* (ki n term products are written from right to left so that "*son* o *father* o *father*" can be read "*son*

of *father* of *father*") = *uncle* (from the kin term map) and so *ffs* is one of the genealogical path s mapped to the kin term *uncle*. In this way, we generate (and therefore predict) the categoriza tion of genealogical relations for a given kinship terminology rather than induce meanings for the terms based on genealogical relations.

Having represented the data as a kin term map, KAM provides additional services to identify the structural logic of the terms, and to produce an algebra consistent with the structural logi c. The approach employed originates with Read's demonstration of an algebraic structure for AKT (1984), This was, however, based on mathematical reasoning and methods which are m ostly not available to anthropologists. Read saw this as a barrier to further development of his remarkable result in the discipline as a whole, and in 1990 published with Behrens (Read & B ehrens, 1990) a description of a software program, Kinship Algebra Expert System (KAES), t hat was intended to take a relatively non-technical anthropologist step by step through the alg ebra creation and visualisation process. Although this was an interesting early example of usi ng a software tool as a part of the theory building process itself, in the end it was still not acce ssible enough for most anthropologists, and relatively difficult to update as new structural feat ures and consequent requirements emerged from treatments of new terminologies.

In 1999 Read and Fischer began work on a joint research grant to develop the framework furt her to investigate the use of the algebraic models for further descriptive and analytic research. This required a redesign of KAES. Initially KAES was intended to be an 'expert system' for al gebra-based structural analysis of kinship terminologies as a means for involving the larger a nthropological community which could otherwise be excluded. However, Read had found it was rather more than this: "... the software program became the idiom through which the theo ry was developed..." (Read, 2002: 411)

In developing a theory of kinship terminology in concert with implementing the theory with F ischer in computer software, they had the unexpected result that the the algebraic analysis per formed by KAES was almost algorithmatic - the 'expert system' aspect was redundant as ther e were very few choices to be made. The information and relationships used by the KAES pr ogram are drawn entirely from indigenous judgments relating to the terms themselves, withou t reference to the genealogical information anthropologists conventionally used in analyzing a nd interpreting kinship terminologies (and which was the basis of Schneider's (1987) rejectio n). It is therefore unnecessary to regard terminologies as a labeling system for kin categories which are distinguished for reasons external (such as a genealogy). KAES made it evident tha t the structural properties of kinship terminologies arise from logical constraints on the genera tion of structure and differences among terminologies relate to places in the generation of a st ructure where alternative ways to develop the full terminology structure are logically possibl e.

KAM includes services derived from the earlier work on KAES to elicit and represent a kin te rm map, identify the logical relations in the kin term map and to identify an algebra consisten t with these logical relations. Following is a description by Dwight Read of the logic and orga nization underlying these services as they are implemented in KAM.

4. What kinship terminologies are: the logical foundations

Dwight Read

Leaf states in the previous segment that kinship terminologies are "… systems of ideas. Mor eover, like geometry, they are generative systems." That kinship terminologies are generative systems of ideas and what this entails can be seen from the analogy made with geometry. In t he case of geometry, being a generative system implies that we begin with intuitive ideas, or axioms, such as the idea of a point or a line, from which we define other geometric ideas that

then become part of a logically generated system of ideas and their meaning. Similarly, as we will see, kinship concepts are generated from primary concepts such as motherhood, fatherhood and spousehood -- the equivalent for kinship terminologies of points and lines in geometry -- whose meaning is intuitively understood by culture bearers. These primary concepts are associated with culturally specified behaviors that are the marker for when these statuses are realized, such as the status of motherhood being associated with a woman engaging in supportive behaviors directed towards her infant, including feeding, caring, nurturing and comforting.

This implies that the conditions under which primary kinship concepts are recognized as being satisfied are culturally specified and not simply determined by biological facts. This is especially evident for spousehood with its dependence on marriage since the latter, due to the multiple ways it is culturally specified and recognized, does not have a biological counterpart. Even though motherhood, in particular, and fatherhood, to a lesser extent, are often associated with behaviors that are initiated and implemented as part of procreation, the criteria by which these statuses are recognized as being satisfied cannot be reduced to biological facts. The status of motherhood (or fatherhood) may be realized even when, for example, the recipient of a female's behavior is an infant who is not her biological offspring. Though procreation and the behaviors it activates can lead to the status of motherhood being realized, procreation is not a necessary condition for this to happen and so procreation is not a prerequisite for kinship relations to be recognized as has often been assumed. While no kinship system ignores procreation, the biological facts of procreation alone are not sufficient for recognizing when kinship statuses are realized.

As with geometry, a kinship terminology is a system of interconnected concepts with properties derived from its premises. The premises for a kinship terminology are the kin terms -- referred to here as primary kin terms -- that correspond to the culturally recognized primary kinsh

ip statuses and their reciprocal statuses. For English speakers these are the kin terms *parent*, *child* and *spouse* that take on the cultural meaning of the primary kinship concepts of parenthood, childhood and spousehood. The meaning of the kin terms making up a kinship terminology is then determined through interconnections involving the primary kin terms and not by genealogical denotata (Read 2001). Genealogical denotata may be identified when kin terms are instantiated as categories of genealogical relations, but these categorizations are derived from the meaning kin terms have as a system of interconnected terms (Read 2001, 2007) in the same way that meaning of geometric concepts is derived from the system of interconnected concepts of which they are a part and not from their physical world denotata.

The interconnections that give meaning to kin terms can be made explicit through the elicitation procedure discussed by Leaf (2006). The procedure builds on the fact as a child becomes a user of a terminology, s(he) does not first learn genealogical denotata of kin terms, but instead initially learns the interconnections among terms and only later their genealogical denotata. Studies of the way children learn to use kin terms (e.g., Luong 1986 for Vietnamese children, Price-Williams 1978 for Hawaiian children, Benson and Aglin 1987 for Canadian children, Milicic 2010 for Bosnian and Quechuan children, among others) show that they understand the proper usage of kin terms long before they can formulate genealogical definitions of kin terms, which implies that there is a logic or "grammar" for kin terms that children learn. If this were not the case and a child learned each term individually through its supposed denotata, then we would expect that a language with complex terms (at least for English speakers) such as sibling terms dependent on sex of speaker, sex of referent and relative age of speaker and referent would be harder for a child to learn than sibling terms in a language where the sibling terms only distinguish the sex of referent, but this is not the case (Milicic 2010). If there is a logic or grammar through which the meaning of kin terms is determined, then we want to wor

k out the logic for the system of kin terms making up a kinship terminology from its premises in the same way that we work out geometry as a system of concepts derived from its premise s. To do this, we will begin by representing formally the information about a kinship termino logy obtained through the elicitation procedure so that we can determine how kinship concept s are generated from the primary concepts underlying kinship terminology systems.

Due to limitations of space, we will only work out the formal representation of some of the ba sic properties of kinship terminologies and then exemplify how these relate to the important d istinction between descriptive and classificatory terminologies introduced by Lewis Henry M organ (1871). A more complete presentation of the formal generation of kinship terminologie s from basic concepts is given in Read (1984, 2001, 2007), Read and Behrens (1990), Bennar do and Read (2007) and Leaf and Read (2012).

Elicitation of Kinship Terminology Structure

We want the formalism to express the properties and relations obtained for a kinship terminol ogy through the elicitation procedure. Consequently, we will focus here on the properties exp ressed in Leaf's elicitation diagram (Figure 1) for eliciting a kinship terminology. The elicitati on procedure determines the conceptual interconnections among kin terms obtained through r epeatedly asking questions of the form "If you properly refer to a person by the kin term, *L*, a nd that person properly refers to another person by one of the primary kin terms, *K*, then what kin term, *M*, (if any) do you use to properly refer to that latter person?" (see Figures 8 and 9). We will refer to the relationship between *K* and *L* as the product of these two kin terms and n otationally we will express their product by *K* o *L* (read "K of L"), where "o" is a symbol repr esenting a binary operator. By *K* o *L* is meant the kin term (if any) that would be used by spe aker when speaker refers to $alter_1$ by the kin term *L* and $alter_1$ refers to $alter_2$ by the kin term *K*. If speaker uses the kin term *M* to refer to $alter_2$, then *K* o *L* = *M* (read "K of L is M"). In P

unjabi, the terms *bap*, *ma* and *masar* are connected in this manner by the kin term product eq uation, *bap* o *ma* = *masar*, meaning that if ego (properly) refers to a woman as *ma* (*L*) and tha t woman refers to a man as *bap* (*K*), then ego refers to that man as *masar* (*M*). For English sp eakers, a comparable statement would be that *father* of *mother* is *grandfather.*

We can formally express the idea of a kin term product of a pair of kin terms as follows (Read 1984):

> *Kin Term Product*: Let *K* and *L* be kin terms in a kinship terminology, T. Let ego, alte r_1 and $alter_2$ refer to three persons each of whose cultural repertoire includes the kinshi p terminology, T. The kin term product of *K* and *L*, denoted *K* o *L*, is a kin term, *M*, in T, if any, that ego may (properly) use to refer to $alter_2$ when ego (properly) uses the ki n term *L* to refer to $alter_1$ and $alter_1$ (properly) uses the kin term *K* to refer to $alter_2$.

For example, if *K* = *father* and *L* = *mother*, then *father* o *mother* = *grandfather* for English sp eakers and so *K* o *L* = *M*, where *M* is the kin term *grandfather*.

While we can work out the genealogical relations involved in a kin term product, the critical point is that we do not need to do so as we are using the idea of a kin term product to determi ne the relations among the kin terms directly in accordance with the cultural knowledge of inf ormants. The elicitation question asks, for example, about the product of the kin terms *bap* an d *ma* and we are informed through the elicitation procedure that the product of the kin terms *bap* and *ma* is the kin term *masar* without reference to genealogical relations. We continue in this manner, using the primary kin terms, to elicit the interconnections among the kin terms in a kinship terminology.

Structural Relations Among Kin Terms

The elicitation procedure uses a conventional kinship diagram to display the relations among the the core, or primary, positions linked directly to the *self* position where ego is located (see Figure 1). We can read off from the physical form of the diagram the kind of relation expressed by a kin term. For example, we know that the Punjabi kin term, *bap*, expresses a fatherhood status given the position of the term *bap* in the kinship diagram (Figure 1). In our formal representation, however, we want the defining properties of a term such as *bap* to be expressed through the structural relations among the kin terms, not through the physical shape of the diagram and the meaning of iconic symbols. For this reason, we will use a modified diagram, called a *kin term map* (Read 1984), which has one node for each kin term and arrows connecting nodes according to the consequence of taking a kin term product with a primary term. The form of the arrow (shape of arrowhead, type of line used for the shaft) will be specific to the primary term used in the kin term product represented by the arrow. An arrow shows the result of taking a kin term product by connecting a pair of nodes where the kin term at the head of the arrow is obtained from the kin term at the tail of the arrow by taking a kin term product of the latter kin term with the primary kin term corresponding to the form of the arrow. In this way the kin term map expresses directly the cultural knowledge we have elicited about interconnections among kin terms.

A kin term map of the American kinship terminology, based on the *parent*, *child* and *spouse* primary terms, is shown in Figure 8. Compare with the kinship map in Figure 6 that shows the relationship among the elicited kin terms. The structures represented in the two diagrams are isomorphic and differ only by the kinship map showing the way the elicitation procedure leads to a structure of interconnections among the kin terms while the kin term map displays the same structure through kin term products with the primary kin terms.

[Figure 8 about here]

If we think of a kinship terminology as a natural language, then the kinship map and the kin t erm map for a terminology make visually evident structural properties that are embedded in t hat language. The structure we see in Figure 8 or Figure 6 is not a model of a theory we have about the structure of kinship terminologies (that is, it is not a theory model) but a model expr essing the relations that are part of the cultural knowledge English speaking culture bearers h ave about their terminology (that is, it is a data model for the kinship terminology of English speakers). The structure shown in Figure 8 displays properties of the natural language of kins hip terms.

Formal Properties of Kinship Terminology Structure

We want to determine from the structure shown in the kin term map its formal, generative pro perties. In particular, we want to know if this is a structure that can be generated from its pri mary kin terms by using the kin term product and a few, structural equations that involve cult urally salient properties of a kinship terminology. The answer is "yes" for all kinship termino logies considered to date, including terminologies as disparate as the American (Read and Be hrens 1990), the Shipibo (Read and Behrens 1990), the Trobriand (Read and Behrens 1990), t he Tongan (Bennardo and Read 2007), the Kariera (Leaf and Read 2012), the Dravidian proto type (Read 2010), the Punjabi (Leaf and Read 2012), and the !Kung San (Read 2012) termino logies. Differences in the primary terms (e.g., Is a sibling term a primary term or is it derived from a kin term product such as *child* of *parent* = *sibling* as is the case for English speakers? Are the primary terms sex marked? and so on) and in structural equations used to generate a t erminology then become a way to account for differences among kinship terminologies at a g enerative, structural level and this can be the basis for a more meaningful typology of kinship terminologies (Read n.d.). We will only illustrate some of these structural results here, in part icular differences in terminologies for primary terms for the ascending relations, the sibling re

lations and the spouse relations as well as the structural basis for reciprocity of kin terms and the structural difference that provides a generative basis for Morgan's seminal distinction between descriptive and classificatory terminologies.

Because the properties we derive are obtained from a kin term map that displays the structure embedded in a kinship terminology viewed as a natural language, it follows that these are properties of the corresponding natural language. Unlike other analytical methods such as rewrite rules and componential analysis that impose formalisms rather than deriving the formalism from the structural properties embedded in a kinship terminology, the formalism developed here uncovers the structural properties of the natural language of kin terms. We begin the formal representation with ascendant kin terms.

Ascendant Terms

We first structurally distinguish ascendant parental terms based on fatherhood and motherhood such as Punjabi *bap* and English *father* from related, but structurally different kin terms, such as the Punjabi and English sibling terms, *bhai* and *brother*, respectively, and then all of these from spouse terms by identifying different kin term product equations that distinguish the structural differences among these kin terms. To distinguish the ascendant terms, we note that only ascendant terms have the property that they traverse across generations in their genealogical instantiation of the terms determined from kin term products of ascendant terms with themselves. For example, Punjabi terms *bap* and the kin term product, *bap* o *bap* = *nana* ('grandfather'), (or for English terms, *father* and *father* o *father* = *grandfather*) refer, respectively, to first and second generation relations with speaker when they are genealogically instantiated.

The property of traversing generations is captured by the fact that in virtually all terminologies the kin term product of an ascendant kin term with itself will lead to a new kin term; e.g., *mother* o *mother* = *grandmother* in English. There are exceptions such as the terminology for t

he !Kung san hunter-gatherer group in Botswana where a product of the form, *ascendant ter m* o *ascendant term*, is not genealogically defined without first referring to the naming relatio nship activated when a child is born (Marshall 1976).

In most terminologies, though, if *K* is an ascendant kin term, then *K* o *K* will be a new kin ter m *M* *K*. Thus for the Punjabi ascendant primary kin term *bap* ('father'), *bap* o *bap* = *nana*, where *nana* ('grandfather') is a new, elicited kin term. To take into account sex marking of as cendant kin terms in Punjabi (and many other terminologies), we also include the equations *b ap* o *ma* = *nana*, *ma* o *bap* = *dadi*, and *ma* o *ma* = *nani* for the female marked ascendant terms *ma* ('mother') and *nani* ('grandmother'). (The corresponding equations in English are *father* o *father* = *grandfather*, *father* o *mother* = *grandfather*, *mother* o *father* = *grandmother*, and *mot her* o *mother* = *grandmother*.)

Additional products using the primary ascendant kin term will either (1) yield new terms inde finitely (e.g., in the English terminology, products of *father* and/or *mother* always yield new k in terms labeled by adding *great* to the initial kin term name), (2) stop after several products (e.g., in the Punjabi terminology, *bap* o *bap* o *bap* o *bap* o *bap* does not yield a kin term), or (3) become reflexive (e.g., in the terminology for the Shipibo, a horticulture group in the east ern part of Peru, products of *papa* ('father') and/or *tita* ('mother') eventually always yield the t erms *papaisi shoko* ('great grandfather') or *yoshan shoko* ('great grandmother') [Behrens 198 4]). Thus the way new kin term concepts are generated in an ascending direction across gene rations may be expressed formally through kin term products of the primary ascendant kin ter ms.

Reciprocal Kin Terms

A critical kinship property of terminologies is the reciprocity of kin terms. The descendant Pu njabi kin terms *putar* ('son') and *putri* ('daughter') are the reciprocal terms for the ascendant te

rms *bap* and *ma* (taking into account the sex of speaker and sex of alter), meaning that if female speaker refers to alter as *bap*, for example, then alter refers to that female speaker as *putri*. The eliciting kinship diagram (Figure 1 in Leaf, this volume) reflects the reciprocity between *putar*/*putri* and *bap*/*ma* by their symmetric positions in the upper and lower parts of the diagram. In the formal representation, we need to express reciprocity without referring either to the usage of kin terms or to their physical location in a diagram. To do this, we need to determine what kin term product equation holds between a kin term, *K*, and its reciprocal kin term, *L*. Consider reciprocal ascendant and descendant primary kin terms. Observe that if *K* is a primary ascendant kin term and *L* its reciprocal descendant term, then the term, *L*, leads us, through kin term reference, from ego to alter and the term, *K*, takes us back to ego from alter. Thus, according to the definition of a kin term product, *K* o *L* will be a kin term ego uses to refer to ego. Since ego refers to ego by the *self* concept, it follows that *K* o *L* = *self* is the desired kin term product equation. This leads to the following definition.

> *Definition of Reciprocal Primary Terms*: The primary ascendant kin term *K* and the primary descendant kin term *L* are reciprocal kin terms when *K* o *L* = *self*, taking into account the sex marking of speaker and of the terms *K* and *L*, as appropriate.

Note that a primary kin term, *K*, will be self-reciprocal when *K* o *K* = *self*. We may extend the concept of reciprocity to kin term products as follows.

> *Definition of Reciprocal Kin Term Products*: The reciprocal for the kin term product K_1 o K_2 o ... o K_n of the primary kin terms K_1, K_2, ..., K_n is the kin term product K_n^r o K_{n-1}^r o ... o K_1^r, where K_i^r is the reciprocal of the primary kin term K_i, $1 \quad i \quad n$, taking into account the sex marking of speaker and of the primary kin terms as appropriate.

For example, in English the reciprocal of *child* o *parent* o *parent* is *child* o *child* o *parent*; that is, the reciprocal of *child* o *parent* o *parent* = [*uncle*, *aunt*] is *child* o *child* o *parent* = [*nephe*

w, *niece*], where the square brackets denote an unnamed, neutral cover term for the pair of ter ms enclosed by the square brackets.

Descriptive Terminologies

The kin term product in the reverse direction, namely L o K, will not reduce to *self* when a ter minology distinguishes collateral genealogical relations through kin terms. In English, *child* o *parent* = [*brother*, *sister*] and not *self*. More formally, if a terminology distinguishes collate ral genealogical relations, then L o K will be a kin term, M, other than the *self* concept: L o $K = M \neq self$.

We can now stipulate a formal criterion for Lewis Henry Morgan's (1871) idea that descriptiv e terminologies are those in which collateral genealogical relations are distinguished by kin te rms.

> *Definition of a Descriptive Terminology*: A terminology will be called a *descriptive ter minology* when the terminology has a primary ascendant term, K, and a reciprocal des cendant term, L, for which L o $K = M \neq self$.

Sibling Terms

Just as we define new geometric objects in geometry using the primary geometric concepts of a point and a line, we may use the kin term product to define a sibling term for descriptive ter minologies as a kin term product of a primary ascendant with its reciprocal descendant kin ter m. Then, from the product definition of a sibling term, we can establish a key property that di stinguishes a sibling term from ascendant and descendant kin terms.

> *Definition of a Sibling Term*: If K is a primary ascendant kin term and L is its reciproc al term in a descriptive terminology, then L o $K = M$ will be called a *sibling term*.

For example, in English, with K = *parent* and L = *child*, then L o K = *child* o *parent* is the (covering) sibling term for [*brother*, *sister*]. From this definition it follow that the sibling kin term, M, is reflexive, meaning that M o $M = M$. This follows by noting that M o $M = (L \text{ o } K)$ o $(L \text{ o } K) = L$ o $(K$ o $L)$ o $K = L$ o *self* o $K = L$ o $K = M$. Hence a sibling relation satisfying the above definition is transitive: a sibling of a sibling is a sibling. A sibling term so defined differs from an ascending term by the fact that it is reflexive and products of sibling terms are horizontal in that, genealogically speaking, they stay within the same generation.

These are, of course, properties that can be derived from a genealogical definition of sibling terms such as individuals A and B are genealogical siblings when they share the same genealogical parents. The critical point is that the genealogical definitions are not necessary and instead these properties derive from the defining concepts of kinship terminologies, hence are part of the conceptualization of a kinship terminology whether or not the terms are instantiated as categories of genealogical relations or by other criteria such as adoption.

Since kin terms are often sex marked, we need to take sex marking into account for products of sibling terms. For the Punjabi terminology, we have the sex-marked sibling terms *bhai* ('brother') and *bhain* ('sister') and so we have the equations *bhai* o *bhai* = *bhai*, *bhai* o *bhain* = *bhai*, *bhain* o *bhai* = *bhain* and *bhain* o *bhain* = *bhain*.

As Morgan noted, not all terminologies have terms that distinguish collateral from lineal genealogical relations. These will be terminologies for which L o K = *self*, where K is a primary ascendant kin term and L is its reciprocal term. For terminologies like this, which Morgan referred to as classificatory terminologies, a sibling term is not defined through a kin term product since L o K = *self*, but instead it is a primary kin term. Hence siblinghood will be a primary concept in the kinship domain of societies with classificatory terminologies. We can see this in comments such as "siblingship is the determinant that descent [parent-child links] might ha

ve been expected to be ... descent was probably always calculated from siblingship ... and sibl ingship rather than descent always provided the definitive norms of social behavior" (Burridg e 1959/60: 128, 130) for the Tangu of New Guinea, a group with a classificatory kinship term inology.

We can distinguish terminologies in which a sibling term is determined from a kin term produ ct; e.g., [*brother*, *sister*] = *child* o *parent* in English, and terminologies in which the sibling te rms are irreducible; e.g., *kaja* ('elder or ascending brother'), *margara* ('younger or descending brother'), *turdu* ('elder or ascending sister) and *mari* ('younger or descending sister') in the ter minology for the Kariera, traditionally a hunter-gatherer group in western Australia, by equat ions relating a primary ascending term to a sibling term. Whereas for the descriptive terminol ogies we have an equation of the form *sibling term* = *descendant term* o *ascendant term*; e. g., [*brother*, *sister*] = *child* o *parent* in English, the classificatory terminologies have an equati on of the form *ascendant term* o *sibling term* = *ascendant term*; e.g., *papa* o *kaja* = *papa* in t he Kariera terminology for the sibling term *kaja* (and similarly for the sibling terms *margara*, *turdu* and *mari*). We can express this structural difference diagrammatically (see Figure 2). T he difference between referring to *parent* of *sibling* and *child* of *parent* is also noted in ethnog raphic comments. For example, when the Kaluli of New Guinea are working out kin relation s they "frequently invoke a sibling relationship as the link that explains the application of a te rm—'I call him brother because my father calls his father brother.'" (Schieffelin 1976: 54).

[Figure 9 about here]

Classificatory Terminologies

We now have the formalism we need to formally define a classificatory terminology.

Definition of a Classificatory Terminology: A terminology will be called a *classificatory terminology* when the terminology has a primary ascendant term, *K*, and a primary sibling term, *S*, satisfying the equation *K* o *S* = *K*.

For *S* to be a primary sibling kin term, it cannot be written as the product of other primary terms, hence *S* ≠ *L* o *K*, where *L* is the reciprocal term for *K*. Consequently, *L* o *K* = *self* (where *self* has the same sex marking as *L* and *K*) in a classificatory terminology, thus collateral genealogical relations are not distinguished terminologically from lineal genealogical relations. From this definition, the property of classificatory terminologies equating the kin term '*father*' with the kin term product '*brother*' o '*father*' (and '*mother*' with '*sister*' o '*mother*') may be shown to be a logical consequence of having a primary sibling term (see Read 2007, Bennardo and Read 2007 and Leaf and Read 2012 for details).

Spouse Terms

The third kind of primary kin terms is affinal terms such as *spouse* = [*husband, wife*] in English. The English neutral spouse term is structurally distinguished by the fact that it is self-reciprocal: *spouse* o *spouse* = *self*. Sex-marked spouse terms, such as *husband* and *wife* in English, are reciprocal terms in both directions: *husband* o *wife* = *self* = *wife* o *husband* for the English terms *husband* and *wife*. Two equations that hold for the English primary affinal term *spouse* and the ascendant and descendant primary terms *parent* and *child* are: (1) *spouse* o *parent* = *parent* (read "spouse of parent is parent') and (2) *child* o *spouse* = *child* (read "child of spouse is child"). Equations like this are widespread in kinship terminologies by virtue of the common requirement that the child of a woman is only presumed to be a legitimate societal member when she is married.

These two equations illustrate, in particular, the way in which a terminology can incorporate equations that express the conceptual "interaction" among different kinds of primary kin term

s by linking together the spouse dimension and the parent-child dimension for the primary kin terms. They also illustrate what appears to be a universal property of kinship terminologies, namely that if an equation, *E*, holds in the terminology then so does its reciprocal equation E^r. By the *reciprocal equation* for the equation *E* is meant the equation formed by taking the reci procal of any kin term products and/or of any primary kin terms in the equation, *E*. For exam ple, if *E* is the English affinal equation *spouse* o *parent* = *parent*, then the reciprocal equation E^r is the equation *child* o *spouse* = *child* since (*spouse* o *parent*)^r = *child* o *spouse* and *parent*^{r} = *child*. Thus these two equations that express the relationships among *parent*, *child* and *spo use* for English speakers can be reduced to a single equation, *spouse* o *parent* = *parent*, and th e property that a kinship terminology is closed under forming reciprocal equations.

Other equations may limit the extent of the affinal portion of the kinship terminology. In En glish, for example, the equations (1) *child* o *parent* o *spouse* = *spouse* o *child* o *parent* (read 's ibling of spouse = spouse of sibling = sibling-in-law'), (2) *parent* o *parent* o *spouse* = 0 (read "parent of parent-in-law does not correspond to a kin term') with reciprocal equation *spouse* o *child* o *child* = 0 (read "spouse of grandchild does not correspond to a kin term') and (3) the s elf-reciprocal equation *parent* o *spouse* o *child* = 0 (read 'parent of child-in-law does not corre spond to a kin term') constrain the domain of affinal kin terms. Other terminologies will have different equations that constrain the affinal domain.

In some terminologies with prescriptive marriage rules such as the Kariera terminology, there are no spouse terms distinct from the consanguineal kin terms. Among the Kariera, the prescr iptive marriage rule stipulates that a man marries a woman whose kin relation, prior to marria ge, is specified by the kin term *nuña* ('cross-cousin'). After marriage she is still referred to as *nuña*. Terminologies like this do not have separate affinal terms, but instead construct the str ucture of affinal relations from the kinship terminology as it stands before the prescriptive ma

rriage rule is in place (see Leaf and Read 2012 for a detailed discussion of the Kariera termin ology and its prescriptive marriage rule; compare with Read 2010 for a Dravidian language te rminology with a superficially similar, so-called prescriptive cross-cousin marriage rule).

Commentary

In the limited space of this article, we can only outline the beginning steps in working out the conceptual logic of kinship terminologies. Here we have indicated how basic ideas of kinshi p terminologies – generally but not necessarily, as shown here, expressed genealogically in ac counts of kinship terminologies – can be defined using the basic concepts of a kinship termin ology. The basic concepts include the notions of ascendant/descendant kin relations that trav erse generations when instantiated genealogically, horizontal kin relations that stay within the same generational level, and affinal relations established through marriage. New kinship con cepts are generated through taking kin term products using the primary kinship concepts, whe re a kin term product formally expresses the way the users of kinship terminologies compute new kin relations from already defined kin term relations. The kinship concepts generated in this manner can be expressed diagrammatically or formally through kin term product equatio ns using the primary kin term relations. New kinship concepts can be defined at levels varyin g from individual terms to the level of the terminology as a whole; e.g., the definitions of des criptive versus classificatory terminologies. Properties entailed by these concepts can be deri ved logically from their underlying premises; hence we can distinguish between kinship conc epts that are necessarily part of the kinship conceptual system due to its primary concepts and kinship concepts that may have been introduced for cultural or pragmatic reasons extrinsic to the generative logic of the terminology.

The goal of the formalism is to demonstrate how the terminology, as a whole, may be generat ed, in a consistent manner, from its underlying concepts. Users of a terminology can comput

e kin relations in a mutually understood and consistent manner only because they are working with symbols/kin terms generated in a logically consistent manner in the same way that the c oncepts of Euclidean geometry or arithmetic are formulated and then used in a logically consi stent manner. By grounding the formalism in what we experimentally elicit, we avoid the eti c/emic problem of whether the analysis is simply an imposed ordering or an ordering that aris es from the nature of the phenomena in question. The formalism expresses what we have alre ady elicited, hence it makes explicit an ordering that is part of the kinship terminology system being analyzed. In this way, the formal argument leads to greater understanding of the cultur al kinship systems upon which human societies are founded.

5. **KAM: Services and Architecture**

Although most research with genealogical data does not include substantial reference to termi nological systems, genealogical data as reported by informants is not a record of pedigrees pe r se, but a record of the outcomes of behaviour framed by local conventions of relatedness. R elatedness can either be genealogical as determined through genealogical tracing based on par ent, child and spouse or terminological and expressed referentially through kin terms. As disc ussed in Read, Fischer and Lehman (forthcoming), universally, genealogical relations (Figure 10, Genealogical Space) are constructed through recursion using the familial relations of par enthood, childhood, and sibling-hood (Figure 10, Family Space) culturally abstracted from th e connections created biologically through reproduction (Read 2001) and affinal relations cre ated culturally through marriage. Terminological relations are determined from the primary f amilial and affinal relations through a composition of kin terms based on the way kin relation s are computed terminologically through calculations such as "If I (properly" refer to him as u ncle and he (properly) refers to her as daughter, then I (properly) refer to her as cousin" witho ut necessarily knowing the genealogical relations (let alone the pedigree relations) involved

(Figure 10, Kin Term Space). The Genealogical Space and the Kin Term Space are linked thr ough (a) a constructed mapping from Kin Term Space to Genealogical Space (solid vertical ar row in Figure 10) and (b) categorization of genealogical relations through a derived mapping from Genealogical Space to Kin Term Space (dashed arrow in Figure 10).

[**Figure 10 about here]**

The kin term system expressed through a kinship terminology formalizes (emically) these loc al conventions of relatedness, identifying relationships that will be referenced in conditioning behaviour and establishing relationships that can serve as the basis for further relationships. R ead and Fischer (2004) argue that the integration of terminological and genealogical systems helps establish a deeper understanding not only of the genealogical data, but also how this rel ates to other systems of knowledge and activity.

KAM support for producing kin term maps includes entry of kin terms as text, selecting tentat ive primary terms (e.g., parent versus mother and father, in English) and displaying diagram matically the corpus of kin term products based on the primary terms. A kin term map alone i s a significant outcome since it encapsulates the local logic used to relate different terms as ha s been noted by numerous ethnographers (see examples and references in Read 2007) and, by induction, the different kinship relations, expressible through kin terms, that are possible bet ween individual people. Significantly, kin term maps make it easy to visually compare struct ural differences between kin term maps (compare Figures 5 and 8), a kind of comparison that is extremely difficult to make with the representation of a kinship terminology through labeli ng the positions in a standard genealogical diagram with kin terms. We suspect that the lack of research relating genealogical relations to kinship terminologies is due to, heretofore, inade quate ways to formally represent the relationship between genealogical structure and kin term structure.

A second service provided through KAM is establishing the core logical and structural properties of a terminology. For example, in the American Kinship Terminology, gender is a late binding property. The core structure, as demonstrated analytically, is based on the kin terms *parent* and its reciprocal *child*, not the sex marked terms *father* and *mother* and their sex-marked reciprocals. The sex marking of *parent*, as the analysis demonstrates, is introduced into the kin term structure through what we can call male and female sex markers introduced, as the structure is generated, only after an ascendant structure of kin terms and an isomorphic descendant structure of kin terms has been constructed. The basic logic of the AKT does not depend on the gender associations of terms and the gender of a term is established as the final step in deriving the location of a term in the structure of consanguineal terms in the terminological space. In the Punjabi kinship terminology, however, analysis demonstrates that gender is a basic property that divides the generative logic into both a male and female set of logical relations and creates a unification of these structures at the final stage into a single terminological system. From the analysis, we predict that a male/female distinction is a more fundamental, deeper opposition in Punjabi thinking than it is in American thinking (e.g., the use by Americans of "it," a gender neutral expression, as a way to refer to a newborn does not have any specific lexemic counterpart in the way Punjabis refer to newborns.

KAM assists in this process by providing an (extensible) menu of operations for simplifying the structure of the complete kinship terminology according to a theory for the construction of kinship terminology structures as a cultural object (see Read 2007, Giovanni and Read 2005, Leaf and Read forthcoming). The KAM program reverses the generative direction as if we were peeling an onion to reveal its core structure. These operations seek to reduce the complexity of the entire diagram by identifying the key structures that are universally parts of all kinship terminologies, such as an affinal structure, a sex-marking structure, a reciprocal structure, a

nd a descendant and an ascendant structure, each of which is defined using kin term products and kin term equations. In this way, we can use the formalism of algebraic structures as a wa y to determine the basic structural properties of the terminology and, by default to also recove r terminology specific properties (e.g., the "ith cousin j-times removed" system for labeling of cousin positions in the American/English terminology). The presumption is that the complete terminology structure and relationships among kin terms expressed in the kin term map can b e derived from the core structure and a set of generative principles applied consistently.

The third service KAM provides is establishing an algebra whose set of products can be rema pped to the original kin term map. The choice of algebraic formalism stems from the fact that the computations users of a terminology make with kin terms to compute kinship relations is, as it stands, in the form of an abstract algebra. An abstract algebra consists of a set of elemen ts (the kin terms, in the case of a kinship terminology) and one or more n-ary products defined over that set of elements. For kinship terminologies, there is a binary product over the kin t erms determined by the compositions made by users of a terminology; e.g, as mentioned abov e, a computation such as "If I (properly) refer to him as *uncle* and he (properly) refers to her a s *daughter*, then I (properly) refer to her as *cousin*", so the (binary) product of *daughter* and *u ncle* is *cousin*.

The algebra is based on the outcomes of the kin term map reduction process used to obtain a core set of relationships that represent core generative principles for the terminology structur e. The analyst chooses between several common operations, such as how sibling terms are int roduced (i.e., as a composite in English where *sibling = child* o *parent*, or as a generating ter m in classificatory terminologies such as the Polynesian, Austronesian and South East Asian t erminologies, among others), introduction of reciprocal relationships (defined through structu ral equations), introduction of affinity (a complex topic!) and introduction of gender. To supp

ort these operations, KAM provides ways to select and express diagnostics features that indic ate the relationship between the original kin term map, the current representation of the parts of the kin term map that are accounted for by the algebra (including a test for whether the two structures are isomorphic), and a graph of the products of the current algebra. A key aspect of KAM is an underlying algebra engine that calculates and reduces products according to struct ural equations. The outcome of the analysis is an algebra expressed in the form of a set of gen erators, structural equations for simplifying products of the generators (which give the algebr a its structure), and graphs relating the algebra to the kin term map.

Further services are under development to support modeling and simulation based on the alge bras produced by KAM, to compare multiple kin term maps both structurally and logically, to position a given algebra within a space that relates it to algebras representing other terminolo gies, comparing different instantiations over the same population of the same algebra. Eventu ally we hope to broaden KAM to deal with other semantic domains, at least at the level of op erations relating to “semantic maps” in Leaf's sense (see section 2) to explore the extent to w hich algebraic and other ‘strong’ models (self-referentially structured; see Fischer, 1994) can account for the relationships between ideas in these maps.

6. Conclusions

Other algebraic approaches to terminological analysis have been extant for over 50 years, but have either fitted terminologies to prescribed structures, or been difficult to instantiate on actu al populations... there was no easy way to relate the algebraic account and the instantiation of kin terms in groups of people. Additionally these systems tended to depend on considerable al gebraic creativity and understanding on the part of the analyst.

The approach through KAM is algebraic and algorithmic. That is, the models are algebras, an d producing these algebras is done following a algorithm. We have developed a computer pro

gram that generates the algebras directly from the source data (lists of terms and indigenous j udgements on relationships between terms), using only a very limited set of user decisions w here more than one algebra is possible for a set of algebra generators and base equations.

There are many more terminologies possible that do not possess such a structure. That the hu man mind should settle on a more limited set that must be describable by an algebra implies s ome deep commonalities in the forms of logic that humans employ that go far beyond the pro duct of being informative and simple recently suggested by Kemp & Regier (2012).

Additionally,

i. a formal model of an ideational system derived entirely from judgements on te rminological relationships, not on an instantiation in a population. (knowledge not behaviour)

ii. the ideational model contains possibilities that specific populations (e.g. Ameri can, Shipebo, Punjabi, and Trobrian groups) do not exhibit, (implies limits)

iii. this model can be instantiated over a specific population in many ways (it is de scriptive), and

iv. results that are predictive of the set of instantiated relationships in specific pop ulations. (it is explanatory)

KAM and the underlying logic provides a means of representing the potentialities of a cultura l system and relating these to specific contexts without performing the reductions a particular context would normally require - reductions are properties of the process of instantiation (app lications), not the underlying symbolic domain.

The most remarkable outcome, from our perspective at least, is that by combining a small sub set of knowledge about the ideational properties of the terminology, the generating terms of t he algebra, and a small subset of the knowledge about instantiation - how the generating term

s are instantiated - that the structure of the complete terminology can be generated precisely (Read and Fischer 2004). To our knowledge this is the first example of a predictive model of a symbolic system that can be based entirely on data consisting of relational judgements of th e relationships between tokens. This result is not possible by looking at the behavioural data (instantiations in populations) alone, nor by construction of an ideational model alone, only b y combining aspects of both in a single model. That is, the ideational model can be over-gene rative as long as the instantiation process fails to instantiate 'impossible' results.

In some ways this draws us back to the distinction between competence and performance ada pted by Chomksy (1957) following de Sassaure. Perhaps this is where we often go wrong. He notes that we cannot simply analyse the structures that occur, because there are 'errors' and litt le variants that will 'spoil' any formal description. But this is not the real reason. We cannot si mply analyse narrow behaviour where the behaviour is influenced by ideational systems and l ogic because overt behaviour is only the result, and a single behaviour can potentially be imp acted by many different ideational systems. What results is what is instantiated (practiced). T hat is, contrary to Chomsky's conjecture that separated the analysis of competence from that o f performance, the point of instantiation between these is critical in analysis from either an id eational or material perspective. Ideational analyses that ignore altogether issues of instantiati on cannot account for the form, variation in or stability of ideas, nor can materialist analyses i gnore the principles of ideation, instantiation of practice or behaviour and hope to account for the behaviour these address.

Bios

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Figures