Mechanical & Industrial Engineering
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An Ontology for Formal Models of Kinship

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Outline

Why Kinship?

- No formal axiomatizations of notions of kinship outside of Family History Knowledge Base (FHKB) [Ste+14] and reasoning
  - No ontological basis in its design
  - No requirements were proposed
  - No verification nor validation was done
  - No analysis of its ontological commitments
- Work done in anthropology shows there is interest in representing the structures of kinship algebraically and as formal models [Rea+84; Rea06; Rea15]

Mediation Structures & Kin Term Maps

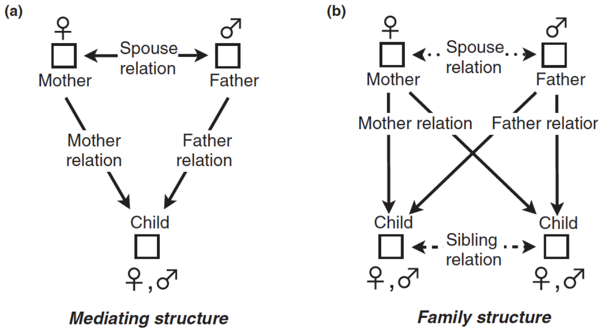


Figure 1: Read's mediation structures for kinship. (a) shows a mediation structure for a family with one child, and (b) shows a mediation structure for a family with two children with the inclusion of a sibling relation. (Figure 2 from [Rea15])

Mediation Structures & Kin Term Maps (cont.)

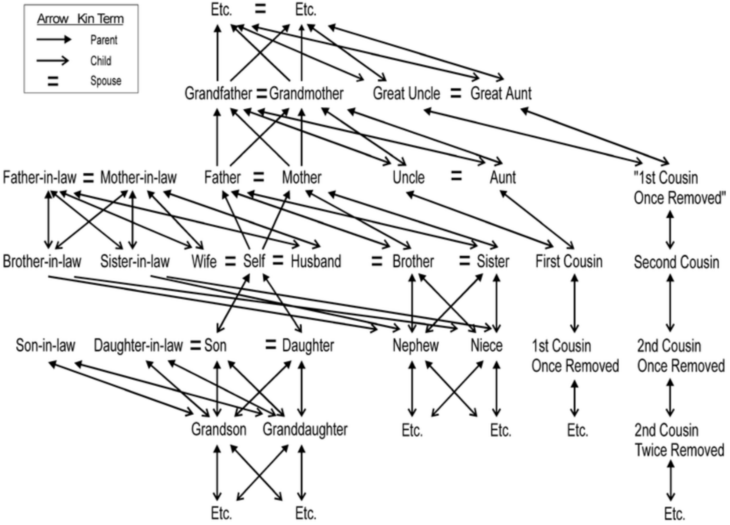
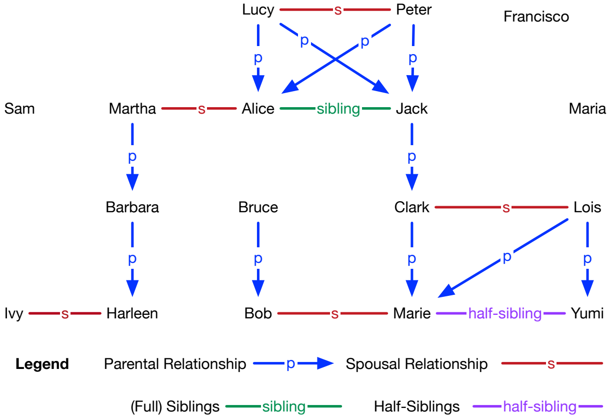


Figure 2: Kin term map and various relationships. (Figure 5a from [Rea15])

Kinship Structures as Graphs

- Based on consanguinity constructs in anthropology, models of kinship can be depicted as *connected graphs*
- Defined relations correspond to paths in the underlying consanguinity graph in the model of the ontology.



A First-Order Ontology for Kinship

- Three theories in $T_{kinship}$ form the basis of the ontology:
  1. T_{spouse}: defines spousal relationships,
  2. $T_{ancestor}$: defines ancestral relationships, and
  3. $T_{kinship}$: combines the theories above
- Relationships can be defined as classes and relations using definitional extensions.
- This axiomatization is *agnostic* of gender, despite anthropologists adopting an explicit gender binary in their algebraic representation of relationships.

T_{spouse}: Spousal Relationships

Common-sense notions of spousal relationships are captured:

$$(\forall x \forall y\, (hasSpouse(x, y) \supset (person(x) \wedge person(y)))). \tag{1}$$

$$(\forall x\, (\neg hasSpouse(x, x))). \tag{2}$$

$$(\forall x \forall y\, (hasSpouse(x, y) \supset hasSpouse(y, x))). \tag{3}$$

$$(\forall x \forall y \forall z\, (hasSpouse(x, y) \wedge hasSpouse(x, z) \supset (y = z))). \tag{4}$$

$T_{ancestral}$: Ancestral Relationships

Similarly, for ancestral relationships:

$$(\forall x \forall y\, (ancestorOf(x, y) \supset (person(x) \wedge person(y)))). \tag{5}$$

$$(\forall x\, (\neg ancestorOf(x, x))). \tag{6}$$

$$(\forall x \forall y \forall z\, ((ancestorOf(x, y) \wedge ancestorOf(y, z)) \supset ancestorOf(x, z))). \tag{7}$$

$$(\forall x \forall y\, (ancestorOf(x, y) \supset \neg ancestorOf(y, x))). \tag{8}$$

$$\begin{aligned}(\forall x \forall y\, (ancestorOf(x, y) \supset (\exists z\, (hasChild(x, z) \wedge \\ (ancestorOf(z, y) \vee (y = z)))))\end{aligned} \tag{9}$$

$$\begin{aligned}(\forall x \forall y((ancestorOf(x, y) \supset (\exists z(hasChild(z, y) \wedge \\ (ancestorOf(x, z) \vee (x = z)))))))\end{aligned} \tag{10}$$

$$\begin{aligned}(\forall x \forall y \forall z \forall u\, (ancestorOf(u, y) \wedge ancestorOf(z, y) \wedge ancestorOf(x, u) \wedge \\ ancestorOf(x, z) \supset (ancestorOf(u, z) \vee ancestorOf(z, u) \vee \\ (z = u)))).\end{aligned} \tag{11}$$

$T_{kinship}$: Constraining Who Can Be Spouses

$$(\forall x \forall y \forall z\, ((hasSpouse(x, y) \wedge ancestorOf(z, x)) \supset \neg ancestorOf(z, y))). \tag{12}$$

This axiom is needed to capture Read's kinship algebra, but it will need to be relaxed to model family structures that contain spouses that share a common great-great-grandparent (e.g., the British Royal Family: Queen Elizabeth II and Prince Philip are descendants of Queen Victoria).

Defining Relationships with $ancestorOf(x, y)$

- Approaches to define kinship relations, such as those in [Rea15], use the parent/child relation and define all others through composition.
- However, this is not first-order definable using $hasChild(x, y)$ due to the partial ordering over ancestors.
- Consequently, with the ontology, we use $ancestorOf(x, y)$ as a *primitive* and define all other kinship relationships as successor relations.

$$(\forall x \forall y\ (hasChild(x, y) \equiv (ancestorOf(x, y) \land \neg(\exists z\ (ancestorOf(x, z) \land ancestorOf(z, y)))))). \tag{13}$$

Relationships as Defined Relations

We can axiomatize definitions from anthropology and legal documentation:

(**EX-1**) *hasCousin*(x, y): *first cousin* is the child of a parent's sibling.

$$(\forall x \forall y\, (hasCousin(x, y) \equiv (\exists k \exists w \exists z\, (hasChild(k, z) \wedge hasChild(k, w) \wedge hasChild(z, x) \wedge hasChild(w, y) \wedge (w \neq z))))).$$

(**EX-2**) *hasGrandchild*(x, z): a *grandchild* is the child of someone's child.

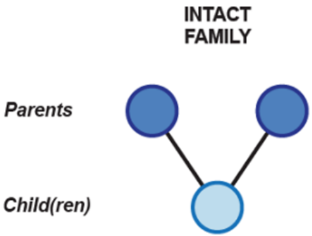
$$(\forall x \forall y\, (hasGrandchild(x, z) \equiv (\exists y \exists z (hasChild(x, y) \wedge hasChild(y, z))))).$$

Legal Definitions: Intact Families

Statistics Canada defines an *intact family* as a family unit where "all children are the biological or adopted children of both married spouses or of both common-law partners [Min17]."

$$
\begin{aligned}
(\forall x\,(\mathit{intactfamily}(x) \equiv\ (&\mathit{familygroup}(x) \wedge \\
&\exists y \exists z\, \mathit{inFamily}(y, x) \wedge \\
&\mathit{inFamily}(z, x) \wedge \\
&\mathit{hasSpouse}(y, z) \wedge \\
&(y \neq z) \wedge \\
&(\forall u\,(\mathit{inFamily}(u, x) \wedge \\
&(u \neq y) \wedge \\
&(u \neq z)) \supset \\
&\mathit{hasChild}(y, u))))).
\end{aligned}
$$

(a) Axiom for intact family using $T_{kinship}$.



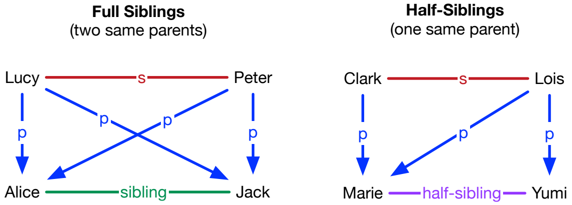
(b) Figure 3 in [Min17].

Defining Types of Siblings

Similarly, we can define sibling relationships:

$$\begin{aligned}\forall x \forall y\; hasFullBloodedSibling(x, y) \equiv\; & \exists w \exists y \exists z\; hasParent(x, y) \land \\ & hasParent(x, z) \land hasParent(w, y) \land \\ & hasParent(w, z)\end{aligned}$$

$$\begin{aligned}\forall x \forall w\; hasHalfSibling(x, w) \equiv\; & \exists y \exists z\; hasParent(x, y) \land \\ & hasParent(x, z) \land hasParent(w, y) \land \\ & \neg hasParent(w, z)\end{aligned}$$



Extensions, Usage, Future Work

Current Usage and Extensions

- Royal Bank of Canada (RBC) is using and implementing this ontology with Prover9 and Prolog
- Natural-language (NL) parser and scraper being developed to answer questions about kinship
  - e.g., “find Queen Elizabeth II’s great-second cousin” by scraping Wikipedia entries and using the semantic parser

Future Work

- Ontological analysis of $T_{kinship}$ outside of social mores
- Temporal version of $T_{kinship}$ to model how relationships change over time

Summary

- Provided a first-order axiomatization of the work done by anthropologists that models kinship and consanguinity graphs, which comprises three theories:
    1. T_{spouse}: covers spousal relationships
    2. $T_{ancestor}$: covers ancestral relationships
    3. $T_{kinship}$: combines the above together, limiting who can be spouses
- Relationships are axiomatized using defined relations.
- $T_{kinship}$ can be extended to axiomatize definitions of kinship in various legal contexts.

Thank You!

Any Questions?

References

[Min17] Minister of Innovation, Science, and Economic Development. *2016 Census of Population: Families, households and marital status*. June 16, 2017. URL: https://www12.statcan.gc.ca/census-recensement/2016/ref/98-501/98-501-x2016004-eng.cfm (visited on 01/17/2020).

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