A Computational Model for Dyadic Relationships

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***Abstract*— Pairs of agents, called dyads or ego-alter pairs, meet, develop and dissolve within the confines and provisions of the built environment. Within the environment, dyads transfer and receive information from one another and the external world and use this information to (re)evaluate their inclination toward the relationship.**

Thus, any active dyadic relationship can be represented by three states: colocating (COL), telecommunicating (TEL), or evaluating the cost/benefit of sustaining the relationship, i.e. inclination (INC). At any given time, relationships can transition between states. These states/events are manifested within large datasets in the digital era.

The numeric cost of colocating and telecommunicating can be computed easily with context from the geographic environment. Evaluating INC cost is more difficult, but relies on social network alternatives and personal values. When any costs change, agents reevaluate the cost and benefit of relinquishing some relationships for more attractive alternatives. We experiment with this framework using an example action script and collected data from 27 agents.

Keywords-personal relationships; LBSNs, ICTs; GIS; big data; telecommunications; face-to-face meeting

I. INTRODUCTION: COMPUTING RELATIONSHIPS

There is a spatial and temporal rhythm to the events used to sustain dyadic relationships: friendships, family, professional or romantic ties. It's clear that people ebb and flow in and out of each other's lives, but are there regularities in temporal communication patterns of a romantic couple that is breaking up? How often do agents access their primary contact vs. their secondary and tertiary contacts? How much energy is expended sustaining non-proximal relationships? How does tie closeness shift with the introduction of new ties? It has been shown that after migrating, an agent develops a new social network within six months [1].

The dyad is rarely dissected to show how it relies on the built environment, communication and personal reflection simultaneously, and how it progresses with new and changing social and spatial situations. The dyad can be considered as its own scale, i.e. unit of information, for social computing as it conveniently scales up to social networks and down to social cognition [2].

Crucially, as Sprott writes, "It is obviously unrealistic to suppose that one's love is only influenced by one's own feelings and the feelings of the other person..." [3, p. 304]. Thus, external context is important for examining relationships between an agent (i.e. an ego) and other agents (i.e. alters) and can be realized using large data sets. The framework presented below is a simplified representation of a dyadic relationship that can be extracted from large datasets that evidence human movement, spatial telecommunications patterns and the formation and structure of social networks (ex. [4]).

A. Computation, Quantification and Dyads

Over one year, the average person stays in touch with closest friends and family in sum: 210 days face-to-face, 195 days using mobile phone, 125 days with landline phone, 125 days texting, 72 days via e-mail, 55 days IMing, 39 via social network sites, and 8 days with paper mail [5] .

The strength and states of dyadic relationships are largely qualitative (see [6] for a review), but have been modeled with nonlinear dynamics [3, 4], [7] so that alters are attractors in chaotic systems, and relationships may bifurcate toward healthy and unhealthy under certain conditions. Also, unhealthy relationships tend to deteriorate like a run-away train once something hurtful is said, where healthy relationships exhibit more randomness after hurtful words [8]. A system described in [8] has been shown to predict divorce with a 95% success rate using a codified set of verbal and visual cues from a short video of the couple conversing.

B. Relationships within Data

Relationships can be syphoned and detected out of large datasets. Large datasets have been synthesized to extract general patterns in mobility and sociability. For instance, dyads communicate less frequently with increased intermittent distance (ex. [9]), proximal dyads are likely to use the city similarly (many, including Wang), and telecommunications is more of a means to meeting up than a replacement for meeting face to face [10]. This research also informs Colocation, for instance, the use of Bluetooth systems that describe whether two phones are in proximity [11], and more advanced techniques that can capture faces in a digital photo or pair devices that are tethered to the same Wi-Fi port.

A single agent can also find himself and his alters in the data. GPS traces from smart phone data and wearables like FitBit inform an agent on his or her travel patterns as a part of the "quantified self" movement [see 12]. Furthermore, an

agent can use his online data to visualize his contacts using Immersion [13] which aggregates frequency of e-mails between contacts from Google's Gmail, while Facebook's NameGenWeb [14] creates a network from Facebook friends.

Agents can take a simpler approach to reflecting on the digital manifestations of their relationships: e-mail and smart phone systems list one's contacts in "address book" form, including a dynamic list of frequent contacts. This list weights contacts based on how often they are accessed, as do instant message (IM) systems which count the number of messages or lines in specific conversations with alters.

As a result, an agent's antique paper address book is now a digital living log: counting words exchanged, pictures taken, minutes spent together with each entry; sorting entries by recency instead of alphabetically; and even acting "intelligently" to autofill and providing suggestions for contacts.

C. *Valuating Relationships*

Although individuals' data is not always accessible to researchers, many large datasets can be combined to provide a vista of relationships. The details of this combination are not discussed here but largely rely on linking user IDs of agents across different movement and telecommunications datasets to track the relationship's dynamics. Finding a universal metric to quantify a relationship is dangerous, or else we could simply automate a combination of the number of e-mails, length and the affective charge / semantics of each e-mail between two agents. In a simplistic framework, an agent is assumed to have finite energy to sustain relationships [15], and that different proportions of thoughts are dedicated to certain people. How can big data be manipulated to measure, for example, an agent's husband as 10, her child as 12 and accountant as 2 with any validity? What are the variables that lead to this measurement and what causes change in these numbers over time or given certain conditions?

Arguing that a certain ethereal *je ne sais quoi* permits certain relationships is not helpful for computing and forming a theory of relationships from large data sets. A relatively simple model or metric is needed in order to calculate the strength of relationship between two people, if this entity is to be tracked within compounding variables of geographic space and time. Thus, we describe a method for evaluating relationships through tiered questions: Does a relationship exist? Is it 'strong'? How does it progress? This process includes a fictional case study and a pilot study performed with 27 agents.

II. IDENTIFYING AND REPRESENTING A RELATIONSHIP

The framework in this work relies on the following conception of relationships: Humans use their five senses (i.e. telereceptors [16]) to collect information about another person (ex. gestures, posture, facial expression, tone of voice, heart rate, galvanic skin response, word choice, smell, or appearance) [17]. This input enters the brain's chambers, which try to pin them to analogous prior situations (e.g. understanding) [18], an adventure that drives the millisecond-to-millisecond, or lifelong-to-lifelong feedback loops of tie interaction. At each peer-to-peer episode, the mind collects, catalogs, analogizes and rechecks itself over again, in order to judge whether to deem an alter "good." A Boolean deeming of "good" at time t means that an ego would 'like' to see the relationship with her alter continue in some form at time t+x. When relationship partners deem each other good, more information transfer occurs. 'Like' can mean 'sufficiently brings me closer to my goals' [18] and/or that the relationship is an important part of an agent's social support system [6].

A. *Determining Major Components*

What would a robot say if it fell in love? "Upon initial colocation, I engaged in a relationship with my alter. This relationship has been based on information transfer through colocation and telecommunications that has allowed me to deem my alter beneficial to my personal goals. I am inclined to engage my senses to gather more information and process past information which will determine my future inclination towards my alter. The information I perceive and process from my alter tells me that I am coming closer to my personal goals, which include my personal energy needs as well as the needs of my cooperative alters. Information transfer with my alter perpetuates a positive feedback loop. I want to transfer information through its richest medium, face-to-face contact, and telecommunicate when face-to-face contact is not available. At the current time, I want to do this with my alter indefinitely."

It follows that a dyadic relationship is sustained in some elastic combination of three variables: (1) face-to-face meeting, aka, colocation, (2) information and communication technologies (ICTs) and (3) a natural desire or 'inclination' to keep the tie (Fig. 1), wherein (3) is a challenging quantification task. Simply, the three variables are related as follows: information transfer via Colocation or ICTs, allows each agent in a dyad to re-evaluate his or her natural inclination towards an alter, i.e. deeming of 'good', at any time step. This model imposes directionality, where an ego can be invested at a different magnitude than an alter.

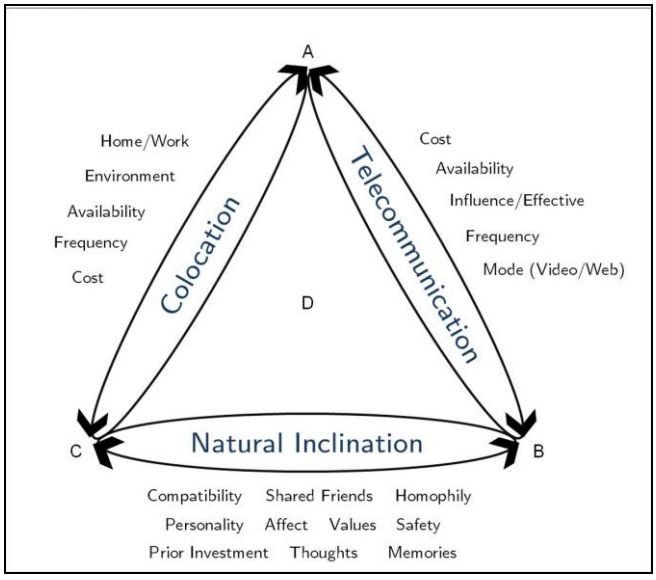

Figure 1. A Tri-cyclic model illustrates three major variables that sustain a social relationship: colocation, telecommunication and natural inclination, as well as the factors that affect each variable (listed outside triangle).

B. Relationship Variables

1) Colocation Colocation is the state of being in the company of one another. Variables that affect Colocation include distance, environment type, availability of transportation service, frequency of travel as permitted by a job or family, and the monetary, time and/or psychological cost of travel. With powerful GIS data and tools, we can derive a significant amount of the cost of colocation between a pair of agents, given only a set of longitude and latitude locations. For instance, the relationship would grow stronger if a previously-distant friend moves 'back into town', or if an airline announces an affordable, direct flight between airports of beloved family members.

2) Telecommunications: Telecommunications (ICTs) allow information transfer between peers, or specifically for coordinating colocation in order to transfer information more effectively. Information can be evaluated by the content of what is being communicated, and indicators of affect and valence such as tone of voice, facial expression and body language. Some ties base their information transfer solely on telecommunications—we see this between business colleagues [19]. Additionally, the influence/ effectiveness of the conversation (e.g, are participants paying 'enough' attention?) is important, as is the frequency of conversation, and mode. Today ICT involvement occurs between two people in the same room, even sitting at the same table out to dinner-- sending photos to one another over their mobile devices. Variables that affect ICTs include time and monetary cost and availability of WiFi and telephone signals (Fig. 1).

3) Natural Inclination: We have increasingly reliable evidence that indicates how, why, under what circumstances, and how frequently people relate to one another. Granted social networks have been shown to reflect the connections of real-life friends [20], social network analysis (SNA) has revolutionized the abundance of analysis in this field. In addition, qualitative methods (survey, interview, etc.) help by uncovering details that are too intricate, cumbersome or infeasible for large scale analysis. Variables enabling or preventing natural inclination are more difficult to choose and measure than those of colocation and ICTs but include blood relationships, the prior relationship investments, shared friends, the proximity of their family, cultural and ethnic mores of proximal habitation, issues of age-race homophily, personality traits, such as 'extroversion' [21], common interests, emotions, values (education, music, religion), safety and trust, and the reflection of these relationships via thoughts, memories, or even dreams [22].

C. Utlity

These three variables are each ingredients to every unique relationship, and states/stages. Large datasets provide evidence of these variables in two ways: first to measure an existing relationship, and second, to describe the potential of a future relationship. For example, data showing frequent colocation or telecommunications despite high cost may indicate that the relationship is strong, and will grow stronger if the circumstances change (although the reverse is also likely [6]). Sustained communication despite these costs illustrates a strong inclination. Data showing that two agents have a low-cost of colocation, high telecommunications abilities and shared interests can illustrate the potential of a future relationship.

Importantly, inclination plays a dual role, depending on the model used. If a relationship is being quantified and given a specific value, inclination acts as a number that can be added to the relationship. If inclination is perceived as a reason why events occur over time, it acts as a resting state in which the relationship is re-evaluated. We can think of inclination as a potential energy that converts to a kinetic energy during colocation or telecommunications events. Inclination (1) explains actions (2) predicts future actions (3) delegates interpersonal thoughts and feelings (4) divulges reactions to colocation and ICT events depending on event parameters (5) explains relationship creation and dissolution.

III. Relationship Persistance

A. Action Script

The same simple model of three states can be used to describe a relationship over time. Below is a hypothetical action script of a relationship and a model of this action script with a state change diagram. The following action

script is annotated with states: colocated [COL], telecommunicating [TEL], and being inclined [INC].

Alice meets Bob at a department colloquium for new students [COL]. They enjoy talking with each other about physics but part ways after the colloquium. Bob [INC] sends Alice a text message [TEL] the next day asking if she would like to meet at the library that night. Alice replies yes [INC] [TEL]. Bob [INC] is at the library first, and coordinates his exact location with Alice on their mobile phones [TEL] guiding her through the stairwells until she sees him waving to her [COL]. They enjoy working together because they share a similar goal to be good physics students [INC] and they agree to meet again at the same time the next night [COL]. Alice is traveling for the following week but they speak on the phone to 'catch up', [INC] [TEL] and talk about physics. Meanwhile Bob e-mails Alice links [INC] [TEL] to a few of his favorite journal articles.

B. State-Change Model

The output sequence: [COL, INC, TEL, INC, TEL, INC, TEL, COL, INC, COL, TEL, INC, TEL, INC] can be configured as a Markov model (Fig. 2) with six types of transitions (ex. [COL-INC]: Cease colocation). [23] From our trajectory, our string of transitions is [COL-INC], [INC-TEL], [TEL-INC], [INC-TEL], [TEL-INC], [INC-TEL], [TEL-COL], [COL-INC], [INC-COL], [COL-TEL], [TEL-INC], [INC-TEL], [TEL-INC].

Geography hosts any transition to [COL], as some form of travel is necessary, and any transition to [TEL], which requires ICT infrastructure: a WiFi-enabled mobile device or trustworthy post office.

More generally, the sequence of [TEL-COL] or [TEL-INC-COL] suggests that ICTs are used for logistics, since the result is colocation. Conversely, from a long sequence of [TEL-INC-TEL-INC] we can assume that the cost of colocation for the relationship is too high for realization—as the inclined continue to use ICTs. For a repeating sequence of [COL-INC], we might infer that the cost of ICT is high (e.g. one member does not own a phone), that face-to-face meetings are pre-scheduled, or the less likely prospect of recurring serendipitous coincidence. Our example tells us that Alice and Bob rely on telecommunication over colocation. Transition probabilities show heavy incoming flows to [INC] (the natural inclination—or reflection time) (Fig. 2). It is likely that INC is under-represented in this model, as in real life, thoughts of an alter tend to arise more often. For instance, Bob may have thought about Alice multiple times when deciding whether to send her their first text message but these events are not included in the action script.

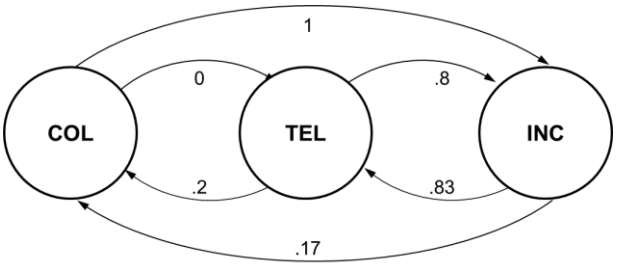

Figure 2. At any given moment, the dyadic relationship is in one of three states. This state diagram (Markov chain) is informed with probabilities generated from if-then rules in the fictional example action script sequence. In our example, the probability from changing states from inclined to telecommunicating is 83%, while changing from inclination directly to colocation is only 17%.

Currently, a state change occurs on-demand. To model a more even distribution of temporality, state changes can be divided into time steps. To illustrate, if each time step x is 30 minutes, four "self-node" transitions, i.e. a transition leaving a state and re-entering the same state, would be used to indicate that the relationship remained in single state for two hours.

C. Elasticities

How does a change in one variable affect another? Differences in relationships may be manifested in datasets in the form of anomalies, behavior changes, or unlikely events: when an agent starts to go to a new bar; a long phone conversation at 3am; taking unpopular flight routes for the holidays.

Measuring how changes in a relationship's variables will affect the relationship relies heavily upon assigned weights. States can be dynamically weighted with properties as per section 2.2: online records, SMS records and text mining capabilities, to reflect the salience of the event.

Perhaps Alice accepts a new a job in Tokyo, far from Bob. Bob evaluates how he can reach social fulfillment in this scenario. Bob's relationship with Alice will incur a skyrocketed cost of colocation, and so information transfer at the sensory-rich form of physical interaction will be rarer. How long will the relationship last?

1) Exogenous Costs: Logistical costs include that flights to Tokyo are $1500 and the trip takes 15 hours. Bob has installed VOIP capabilities and has a web-camera; he can email Alice, and view and respond to her impending Bob's phone is reliable and he can call Alice, and the cost of this is 2.8 cents per minute. SMS messages are free with his new mobile phone plan, but will cost Alice a fee to SMS him in return. Alice's Internet connection will be variably-stable.

2) The Travel Equation: Bob knows about Tokyo's culture, climate, geography, residents, etc. because he is interested in Japanese culture. Bob has had a desire to visit the city since learning more about video game programming in middle school. If Alice was in a location for which Bob did not have an affinity, she would serve as the major pull

factor for Bob's visit. His decision to travel would be dependent on her. However, since Bob is also interested in Tokyo, his inclination toward Alice does not necessarily have to be as strong for him to decide to visit. Alice will see Bob's commitment to visiting her as less of a relfection on his feelings towards her, since she knows that the pull factor of Toyko plays a prominent role in his deicision to visit. Alice does not intend to visit Bob.

3) Endogenous Costs: Bob will be spending more time on the computer, and the psychological cost for this new medium may leave him more isolated than if he was out with friends, as he once was with Alice. Bob is sad to learn from a friend that Alice had seemingly handsome opportunities to stay close to the school. Yet, Bob's own intervening opportunities for social life are improving. A new friend has moved to the school and has a wide social network (enumerable via online records) of extroverted friends interested in meeting Bob and learning more about physics. Bob can still have a tie with Alice and everyone else. When Bob sees Alice's pictures he perceives that her social needs are being met by others, leaving little room for him. Yet, Alice sends Bob emails double the length, and more affectively charged (quantifiably) than she did when the pair could collocate more easily. Lengthier emails describe an effort to transfer information that would have otherwise been transferred by colocation.

4) Refractory Costs: What is Bob's inclination towards Alice after his interpretation of the information he receives from her? What other social opportunities can be used to fill Bob's social needs? Bob's brother mentions he has met a new set of physics students that he will like very much. Depending on the new relationships' ability to form and persist given this small cost of colocation, these new ties may bring Bob closer to his goals (professional, romantic, personal, etc.), in a way that he and Alice's relationship weakens.

IV. EXPERIMENT

A. Description

We have collected data from 27 agents, each of whom tracked their interactions with two alters. Thus, consisting of 54 dyads. Agents (egos) are each undergraduate students enrolled in a GIS course, who tracked the time, duration and notes about their interactions for a week using spreadsheet software Microsoft Excel. Agents were directed to keep a weeklong diary of their COL-TEL-INC interactions with two separate alters: one local (who lives "in town") and one distant alter. Agents chose their own start date for their week, wherein a few agents recorded more than seven days of interaction. For each event, they listed a start time, duration, alter type, and notes/reactions. They also listed the geographic distance and age difference between ego and alter, and how long they have been acquainted (e.g. "2 years" or "since birth").

Agents were given multiple weeks to complete the task and this time period included a one-week spring break. Many students at this university live within four hours of the campus (often less), and can easily travel home for spring break. However, five alters live over 1000 miles away from egos. Agents reported the following alters: mother (15), friend (14), roommate (5) significant other (5; 3 are female), Father (4), best friend (4), undisclosed (2), sibling (2; 1 is female), classmate (1), cousin (1). Almost all friends live in walking distance, and nearly all mothers lived distantly.

B. Responses

In sum, agents reported 222 colocation, 487 telecommunications and 126 inclination events with alters (Table 1). Transitions are enumerated by alter type (Table 2) and in total (Fig. 3). We believe that inclination events were significantly under-reported, as students may not have considered their own personal reflections as noteworthy as a TEL or COL event. The latter required interaction with the physical environment, energy, and alter's participation and results in "proof" of the event, whereas thoughts are more automatic and private, thus potentially overlooked.

Events are often shaped around checking in, including: "to say goodnight" (11 instances) (just "goodnight" (17)), and inquiring about their lives (and hearing a first-hand account of a geographic locale): "about her trip" (10 instances), "Text me that he arrived at the airport safely, and going to board the flight to LA soon.", "Chat to my friend about his field trip to Rome, Italy." These serve the dual role of expressing and communicating inclination and presenting themselves to an alter who then engages in the active relationship when receiving the information.

Events are also shaped around planning, such as "for the summer" (24 instances), "flight" (20), "spring break" (13), "about our trip" (10), which are likely to involve travel. Plans was a frequent term (24). On a Monday morning, an agent converses with a significant other who lives almost 10,000 miles away: TEL "Skyped to discuss plans to travel over the summer." The agent transfers states to INC, reflecting: "It's nice to think about visiting soon."

This TEL-INC pattern can be shaped around common interests (i.e. inclinations) instead of an impending colocation. On a Wednesday morning, an agent talks with his/her significant other: "Texted and talked about House of Cards" Reaction: "I miss him a lot." In another case, the closeness of family is a strong inclination. TEL: "Called to catch up with my Dad. Talked about his weekend with my family." INC: "I miss my family and enjoy hearing about what they are up to." A TEL-INC sequence can also spark a COL. After a conversation with a father, an agent wrote: "Want to have them come down and visit me sometime soon."

Relationships indulge in each other's geographies. At 10:30 PM on a weeknight, a significant other "was lost and texted me his location for help driving to a location." Another agent writes about texts with his/her Mother: "Text her photo of creamery ice cream. She sends me picture of her and dad in San Antonio."

Agents and alters both use secondary media to activate their relationship. These TEL events are rich with more than text, but images and videos as well. Agents note: "Sent me a cool mountain biking video via e-mail." And circle back to the idea of trips: "He sent me some photo of his flight back to London." Meals were sources of COL and often TEL (via text): dinner (51 instances), lunch (18), breakfast (13), within lunch and dinner word counts, "together" frequently followed: dinner together, (11), lunch together (10). These events are most often with local alters. Not surprisingly, the difference between local and distant alters is a decreased number of COL events, although COL events arise for distant alters on the weekends (Fig. 4). TEL events for distant alters are highest on Tuesdays and Sundays.

TEL events are not always direct communication, but TEL events also use passive media; photo-sharing platform Snapchat was most popular (23 mentions) as was the term "picture" (15). An agent writes of his/her mother, "I post a picture on Instagram. She likes it along with 10 others." This affirmation is public, which adds another dimension of the relationship; others can see the support between mother and agent.

A TEL-INC-TEL pattern shows an agent bringing his/her thoughts of the relationship on an overnight camping trip. Friday afternoon: "Texted before he was going hiking and I was going camping." Friday evening: "Thought about him when sitting by the campfire." The inclination manifests itself as a TEL action: "I texted him when I got back from camping when he woke up."

Many TEL-INC sequences brought out feelings of social support. On a Sunday with friend alter: TEL "Text her about cute boy on my bus." INC: "She is my go-to to discuss guys." Not all INC states are positive, and the absence of TEL can cause the agent to impute information. On a friend, an agent reports at 4 PM, INC "She did not reply my text message…Damn…" about 3 hours later, the agent writes TEL INC "She finally replied to my message, but I am not happy about that."

Different types of alters are more prevalent at different times of the week. Regarding social support, egos telecommunicate often with mother alters and significant others during mid-week (Fig. 5). Friends and roommates colocate often, as they tend to be local alters. Understandably, roommates do not telecommunicate as often as friends as they have a natural meeting spot—their home.

TABLE I. NUMBER OF EVENTS BY ALTER TYPE

Alter Type	COL	INC	TEL	Total Events	Total Time (Hours)
Best Friend	7	9	38	54	20.6
Classmate	5	2	4	11	28.0
Cousin		2	8	10	0.3
Father	11	6	22	39	14.5
Friend	78	30	84	192	125.3
Mother	27	39	144	210	76.1
Roommate	52	7	37	96	77.2
Sig Other	31	29	115	175	87.7
Sibling	4	2	14	20	11.3
Grand Total	**215**	**126**	**466**	**807**	**441.1**

TABLE II. STATE SPACE (PERCENTAGES >3 ARE HIGHLIGHTED)

Alter Type	COL	INC	TEL	Total Events
Best Friend	0.9%	1.1%	**4.7%**	6.7%
Classmate	0.6%	0.3%	0.5%	1.4%
Cousin	0.0%	0.3%	1.0%	1.2%
Father	1.4%	0.7%	2.7%	4.8%
Friend	**9.7%**	**3.7%**	**10.4%**	23.8%
Mother	3.4%	**4.8%**	**17.8%**	26.0%
Roommate	**6.4%**	0.9%	4.6%	11.9%
Sig Other	**3.8%**	**3.6%**	**14.3%**	21.7%
Sibling	0.5%	0.3%	1.7%	2.5%
Grand Total	**26.6%**	**15.6%**	**57.7%**	**100%**

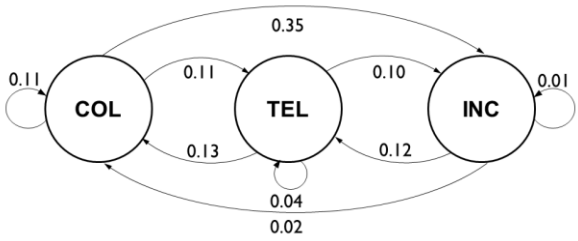

Figure 3. A trained Markov chain with state-change transitions for 27 agents' relationships with 54 alters.

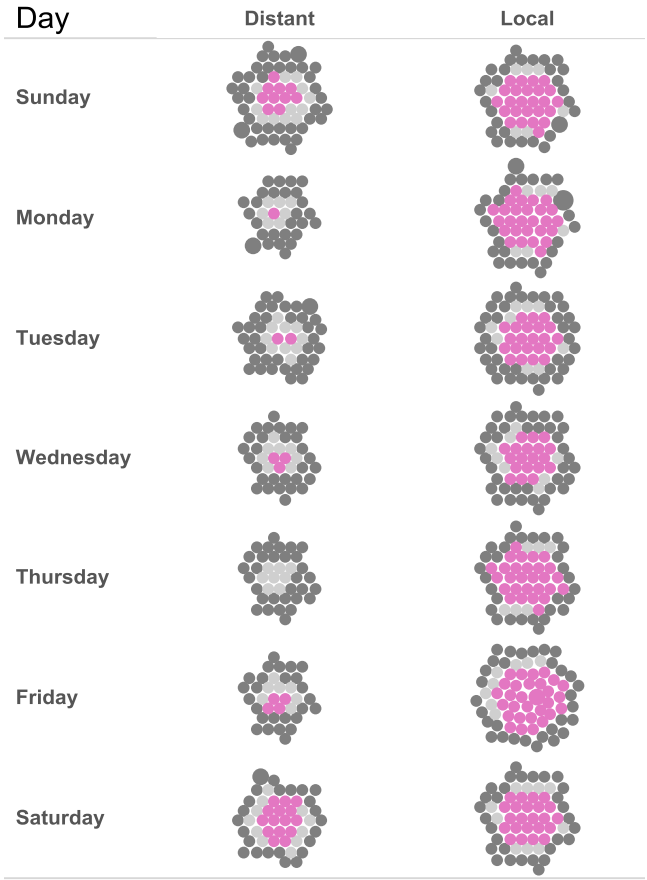

Figure 4. Colocation (pink), telecommunications (charcoal) and inclination (light gray) events are symbolized with a circles for distant and local alters for each day of the week.

V. CONSIDERATIONS

Many relationships do not fit well in this model: dormant relationships, relationships with one's self, inanimate objects, "parasocial" relationships (e.g. an imaginary relationship with a celebrity), and with the deceased ([6] p. 6). We believe that since these relationships consume thoughts and mindshare, they may also direct behavior toward one another and within the geographic environment.

A. *Ethereal Relationships*

An ego meets an alter at a party for the first time; they converse, and part. A year later and the pair has not spoken again, but the ego thinks of his alter: is there still a relationships between the ego and alter? He may not gain information past the initial meeting even, but he continues to recall the event, and the alter. The relationship will most probably not exist in telecommunications and GPS-type data, as it may with other relationships who actively telecommunicate and colocate.

B. *Self-relationships*

Relationships with one's self can also fit this model, an ego is always colocated with himself. He can see a picture of himself, email himself or listen to a recording of his own speech. The ego can gain more information about himself, reflect and re-evaluate his inclination to deem himself "good"! Humans do this daily. However, self-relationships delve into rigorous bodies of knowledge better explained in another setting.

C. *Object Relationships*

Can an ego have a relationship with an inanimate object? A person and an inanimate object can engage in informative video conversations, as the object could have changed since last meeting, or the ego might envision facial responses and vocalized responses from the object. A child may seek information from colocating with a stuffed animal or small blanket. She may be concerned for its welfare while they are apart (or during uncertain events, such as having the item washed) and examine it when she returns. She may talk to it, and imagine that it talks to her as well, although this information was technically not generated from the object, but from her mind.

D. *Incapacitated and Deceased Alters*

Many human relationships are one directional: Imagine an interaction between an ego whose alter is in a coma. The ego will gain information from colocating with his alter, and the ego's inclination toward the alter will be based on his internalization of this information. Similarly, memories and dreams of deceased persons may sustain relationships between an ego and an alter who is deceased. They may have colocated at the alter's resting spot (i.e. grave), and telecommunicate when the ego retrieves textual information or audio/video recordings of the alter in the past. Such relationships can have a significant impact on humans.

E. *External Sources*

If a friend or a newspaper gives information about one's spouse that adversely affects one's inclination to deem the spouse good (as the ego has done in the past), the ego has changed an opinion without transferring information between him/her and the spouse. This situation invites external factors into the model; but our model can salvage the process by regarding the ego's relationship to (aka ability to trust) the informant as a prior condition.

F. *Place Perception*

Our perception of place is significant in our decisions [24] and places are their own processes with multiple identities [25]. This means it is difficult to guess the value the agent puts on the place (a city, a park). Additionally, perception of place is affected by another agent's information. Picture a conversation at work or a holiday party where co-workers are exchanging positive tips about

their vacations in the Caribbean, causing an agent to look more favorably upon those locales. Even a rumor about a location may affect opinions toward that location [26]. Furthermore, we perceive place based on our relationship to the people who live there—in our personal lives (a grandmother in a small, distant town) as well as in media (Angelina Jolie's home in New Orleans, U.S.A).

G. *Drifting Apart and Background Relationships*

Some relationships rely on spatio-temporal coincidence. For example, friends in college may have strong bonds in part because the cost of colocation is minimal and because new friends can ease separation from family and old friends. Is the past natural inclination towards college friends strong enough support these relationships currently? Now, with social media, it doesn't have to be, because ICTs and lifestream media [27] work against the tenuousness of post-college ties. Decades ago, the same friends may have searched elsewhere, out of necessity, to fill their social needs after college.

VI. SUMMARY

We have illustrated a model that can be used to evaluate a single pair's relationship, namely how an ego views his alter. Although telecommunications and colocation have been described previously as related and geographically-embedded [28], this article extends these principles to include inclination, and to a numerical model. We can evaluate the presence and strength of a relationship, in the past, present or future using these numbers. The novelty of this model is the integration of the built environment as dictating the cost of alters colocating and telecommunicating; as well as using the agent's social network to help determine the strength of his relationship with his alter in two ways: through the opinions of others and through the enumeration of possible alternatives to the alter with whom the ego has is evaluating the relationship.

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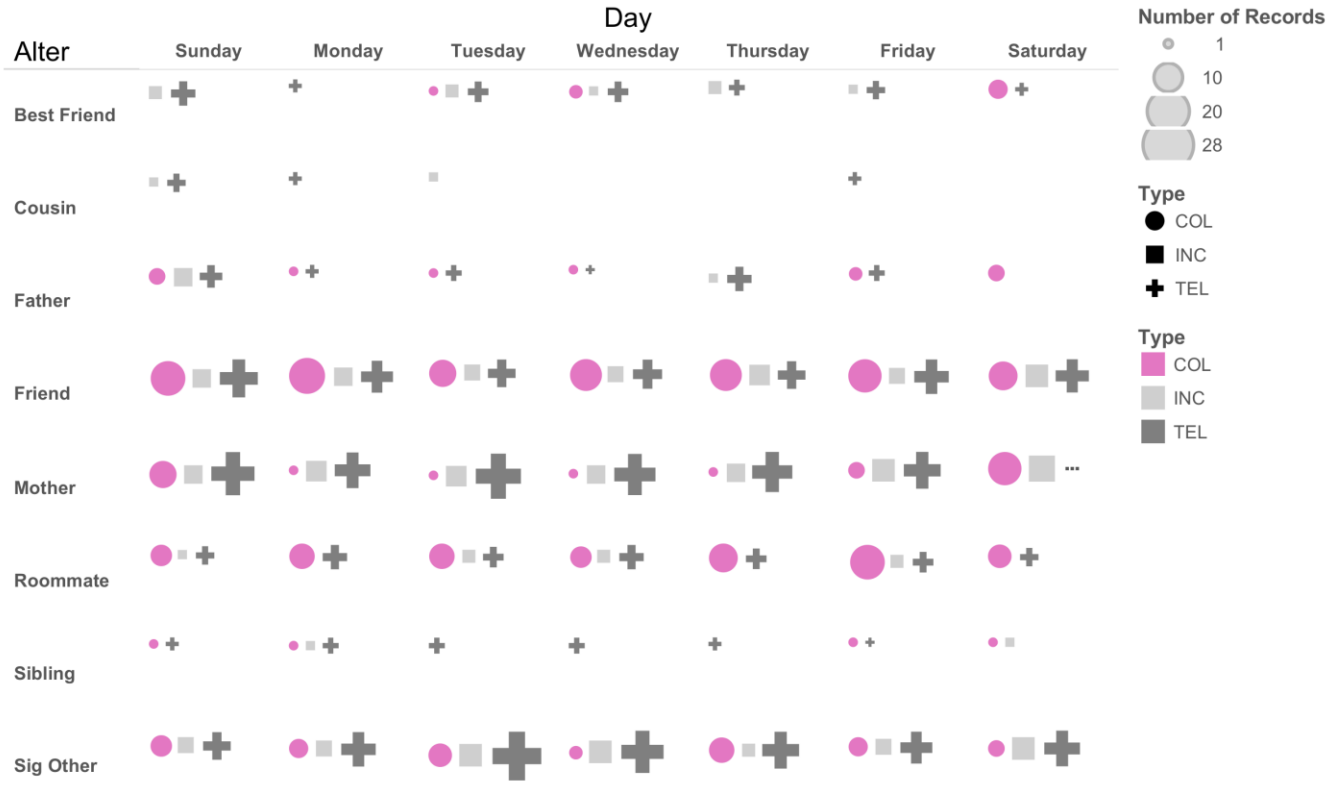

Figure 5. Egos telecomunicate often with mother figures and singificant others during mid-week. Friends and roommates colocate often, but roommates do not telecommunicate as often as friends.