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Infrastructure and Socio-technical Representation

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ABSTRACT
As use of, and experiences with, social media continue to grow, the systems of representation that underlie their use become increasingly influential. In this paper, we present results from empirical studies of two online communities—Facebook and craigslist Missed Connections—that highlight the ways in which this underlying infrastructure and the user practices on these sites are inherently intertwined. We make particular use of a framework first introduced by Agre that focuses on the influence of eight underlying features of computing practice: ontology, standards, instrumentation, authentication, interpretation, selection, bias, and performance. The results of this analysis indicate how representational systems do more than simply represent the physical world; they are deeply intertwined with the social and material practices of everyday life.

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Representation, infrastructure, social media, online communities, Facebook, craigslist Missed Connections

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Human Factors, Design

INTRODUCTION
Social media systems represent vast quantities of data quickly and in forms that are easily consumed by their users. In this paper, we examine the role of underlying representational systems in online communities through the results of empirical studies of two online systems: Facebook and craigslist Missed Connections. Prior analysis of Facebook and craigslist Missed Connections suggested similarities in what superficially appear to be very different tools [8]. Both serve as representation systems through which people establish, mediate, and maintain relationships.

They capture and reflect information that describe people, places, and details from their lives. We can see a glimpse of these systems at work in the following two scenarios:

Late one night in New York City, half of a newly formed couple asks, "Where is this relationship going?" Certainly this conversation has occurred between couples for as long as anyone can remember, but in this case, it was compounded by Facebook's "Relationship Status," a public profile attribute that announces new relationships to friends, family, co-workers, and ex-lovers.

Across the country in Los Angeles, a man is kicking himself for not being so bold. Having just returned from a night out, he points his web browser to a sub-section of craigslist entitled "Missed Connections." This section is an online equivalent to the "I Saw You" personal ads from newspapers in which people attempt to connect with those they met briefly or, as in this case, to people they wish they had met: "To the really cute blonde guy. I walked past you around 11pm. You had a navy shirt on. I should have talked to you instead of being pulled away by my friends."

Despite the powerful ways people use Facebook and craigslist Missed Connections, these systems are at best imperfect representations of lived experiences. Databases are not filled with the actual people, places, and activities they describe but rather with representations of them. This distinction becomes important in our analysis of behavior around and through these systems because the choices made during design and implementation necessarily impact the resultant socio-technical systems.

In our work, we borrow from Agre, who describes eight "features of the actual practice of computing" significant for the analysis of representational systems: ontology, standards, instrumentation, authentication, interpretation, selection, bias, and performance [2]. A thorough understanding of these features and the ways in which systems enable, inhibit, and mediate information and interactions provides insight into the socio-technical representations in these systems and the ways in which social and cultural practices intertwine with the underlying technological infrastructure to create the final experience. Our analysis particularly highlights emergent practices in the physical world that developed in response to and

through the technological affordances of representational systems in the digital world.

In this paper, we first outline related work focused on representation in Facebook and craigslist Missed Connections, followed by an examination of literature on infrastructure and representation that situate this work. We then present an analysis of the interplay between technological infrastructure and human behavior in these two systems, highlighting two common and related behaviors: the process of creating and maintaining relationships in Facebook and the process of identifying and making connections via craigslist Missed Connections. We then describe themes that emerged during our analysis of these systems together: the interaction between relationships and their representations and the impact of temporality and transience in these systems.

This analysis highlights how data modeling practices and the people and societies these models seek to represent result in a world in which "information is not… a mirror of a pre-given reality. It is, quite the contrary, something deeply bound up with the material practices by which people organize their lives" [2]. We then further engage the technological infrastructure of our two systems using Agre's eight features of computing practice. We close with a discussion of how these issues can change over time alongside the emergence of new user practices and the evolution of design and technology.

BACKGROUND & RELATED WORK

With over 500 million active users, Facebook is the world's largest social networking site (SNS) [16]. Facebook users craft profiles, post pictures, surf social networks, and communicate with "Friends."[1] Meanwhile, over 66,000 Missed Connections are posted to craigslist each month.[2] Authors submit anonymous posts "filled with near misses, brief encounters, strange sightings, lusty longings, and a little hope for love" [34] in an attempt to connect or reconnect with people they saw, met, or otherwise interacted with in the physical world. The submitted posts often include profile-like descriptions of individuals, encounters, and social spaces that mimic functionality found in SNSs. Readers of Missed Connections can browse posts, listed in reverse-chronological order, or use the craigslist search engine to find posts that include relevant words (*e.g.*, locations, physical attributes, etc.).

Research has documented system features and a range of user behaviors in online communities and SNSs. Much of this work is outside the scope of this paper (see [6] for review), however, in this section we outline some of the most directly relevant efforts.

[1] Like many SNSs, Facebook labels user-user connections as "Friends." In SNS vernacular, "friend" is also used as a verb to

[2] Count is based on posts submitted during 2009 to the 25 primary geographic channels.

Facebook

Identification, identity formation, and representation on Facebook have received enormous attention in the research literature. Stutzman published one index of available profile attributes across various social network sites, along with the frequency with which those fields were used [31]. He notes that name, academic information, gender, email, and network of friends are the most common. Lampe *et al.* found that most Facebook users (89%) use their real names, with others providing nicknames or clever but relevant alternatives [25]. Likewise, the number of completed profile attributes is positively correlated with the number of "friends" a user has. However, they found little correlation with open-ended attributes such as "About Me" [27].

Facebook members tend to report that their profiles portray them both accurately and positively [27]. Additionally, researchers have considered the role of these online profiles in relationship to our offline lives, demonstrating how the ostensible "realness" of the profile eliminates much of the online/offline distinction evidenced in earlier research on virtual communities [33]. Instead, users spend the majority of their time on the system surfing user profiles, engaged in a kind of digital crowd-watching [25] while using the system to maintain and establish offline relationships [15].

Together, this research indicates that Facebook users build online profiles and social networks that are at least partially representative of their offline lives. In this work, we push on features of the Facebook system to help further explain some of the practices of identity formation and presentation observed in existing research.

craigslist Missed Connections

In comparison to SNSs, craigslist Missed Connections has received little academic attention. One study of "I Saw You" personal advertisements (Missed Connections' newspaper-based ancestor) highlights the work that readers perform when reading ads [28]. Readers, it is argued, must work "back-to-front from the utterance" to construct the relevant participants, places, and social contexts in which encounters occurred.

Previous work has also documented the use of Missed Connections as a site of "single-use identities" [8]. Authors craft interaction-specific posts to represent themselves, their intended targets, and their interactions, while relying on contextual cues including specific locations, events, and sub-communities. Additionally, without the cost associated with newspaper-based personal advertisements, some users post public responses to other authors. Given the anonymity the site provides, public interactions are frequently in response to a specific post but address larger community norms and values [8,9].

Infrastructure & Representation

In contrast to work on Facebook and craigslist Missed Connections focusing on user experiences and behavior, in this work we adopt an infrastructural perspective in order to focus on the socio-technical interplay between users and the

various layers of these systems. Notably, we draw from Bowker and Star's infrastructural approach to classifications [5] to highlight the role of standards. Standards can be understood as "any agreed-upon rules for the production of (textual or material) objects" [5]. They enable interoperability between various components and features, and subsequently the production of large-scale systems, infrastructure, and computational ontology. As such, standards give rise to the technological systems and the representational data they contain.

A number of other researchers have addressed the issue of representation in organizational practice and CSCW (*e.g.*, [1,30,32]). Importantly, Ackerman [1] notes the problem of the *socio-technical gap*, "a fundamental mismatch between what is required socially and what we can do technically." Research has shown that social practices are highly nuanced and contextual, yet "we lack the technical mechanisms to fully support the social world uncovered by the social findings of CSCW" [1].

In contrast to traditional CSCW systems, examining social media as a specific context is worthwhile due to its focus on representing social identities and interactions rather than facilitating work in organizations. Social media is a primary site through which individuals represent (and increasingly conduct) their lived experiences. In this work we maintain that systems (including their standards and limitations) necessarily shape social interactions both online and off. Informed by earlier perspectives, we seek to explicitly draw attention to the acts of representation inherent in the practice of computing. Through use of Agre's framework we are able to build on previous work and consider specific features of computation in which representation occurs.

METHODS
We conducted a mixed methods qualitative analysis of behavior in Facebook and craigslist Missed Connections. We analyzed the content and technical architectures, associated applications, and interviewed users and developers for both systems. Our data, therefore, include details about the technical systems, user behavior, and users' reflections on their interactions with and perceptions of these sites.

We conducted an in-depth functional analysis of Facebook and its third-party developer APIs. The primary author also conducted participant observation of Facebook application development with a collaborative software team, including frequent interviews with four developers over several months. During this time, we also reverse-engineered a data model of the Facebook system by leveraging technical documentation and discussions from blogs, forums and wikis related to application development. Finally, we conducted interviews with eight Facebook users recruited from our social networks and via snowball sampling. These interviews were semi-structured and focused on issues of representation within the system. Participants were interviewed multiple times over multiple channels,

including IM, email, phone, and face-to-face. Most interviews lasted approximately thirty minutes, and interviewees participated in one to three interviews over one year.

In our study of craigslist Missed Connections we collected 555,008 posts between May 2008 and April 2009 from the 25 most popular geographic channels as of May 2008. In comparison to Facebook, craigslist's technical infrastructure has fewer constraints on social interactions. As such, we relied more heavily on interviews to understand the various ways in which users compensated for (and played with) the limits of the system. In addition to technical details about craigslist, our data include interviews and email correspondence with craigslist founder, Craig Newmark, and informal interviews with 50 Missed Connections users recruited via snowball sampling and conducted over IM, email, phone, and face-to-face.

After collecting datasets from Facebook and craigslist Missed Connections, we analyzed each individually. We first adopted an inductive approach focusing on digital identity management in these systems and related user practices. The results of our thematic analysis drew attention to how these systems and their users engage in representational practices and to a consideration of Agre's features of computing.

Both the similarities and differences in the practices, and the underlying representational systems through which these practices are enacted, encouraged us to analyze these systems together in this work. We engaged in a deductive analysis in which we revisited and coded our data relative to Agre's features. Specifically, this analysis calls attention to the intertwining of representational practices and technical functionality in these socio-technical systems.

FINDINGS
Analysis of our substantial empirical data from Facebook and craigslist Missed Connections illuminates the intricate connection between the technologies of these representational systems and the people, spaces, and activities they seek to represent. In this section, we unpack two related issues: the process of creating and maintaining friends in Facebook and the process of identifying and making connections in craigslist Missed Connections. We present familiar interactions in order to specifically emphasize the interplay between behaviors and the underlying systems that enable them. We start by elaborating socio-technical aspects of connecting on Facebook and craigslist. Next, we compare these systems, outlining similarities. Finally, we present an in-depth examination of the interactions between relationships and representations in these systems and how both temporality and transience impact—and are impacted by—use of these systems.

Making "Friends" on Facebook
As demonstrated in other CSCW literature, "friends" are central to the way in which Facebook represents social

networks [25,26,27]. In our analysis, however, we highlight ways in which friends and friending is complicated in Facebook by the underlying representational system. When Facebook users locate another user with whom they would like to connect, they must send a "Friend Request" and wait for the request to be approved. This friending process is quite different than in offline spaces where the status of a friendship can be ambiguous, asymmetrical, and rarely involves any explicit approval process.

In the underlying data model, the standard for the "Friend" entity in Facebook's database includes the unique identification number of two users who are confirmed as friends, linking their profiles. This standard enforces bidirectional relationships; a user cannot be friends with another user without the relationship being reciprocated. The process of adding Facebook friends—generation, receipt, and acceptance or rejection of the request—conforms to this standard by requiring explicit action by each party before the relationship is solidified and displayed on both users' profiles.

Likewise, Facebook's technological design and implementation requires that the label "friend" be applied uniformly to a variety of interpersonal relationships. As with other SNSs, this design decision has in effect created a new class of interpersonal relationship: the "Friend" [7]. Challenges resulting from the system's identical treatment of various friends emerged frequently in our interviews. For example, Ellen, an intern at a large Washington D.C. based consultancy firm, described her anxiety when she received a friend request from the firm's Director of Human Resources. She was uncomfortable with the director gaining access to her private life, particularly as they had never met, but was uncertain if ignoring the request would be professionally detrimental. This is one example of how the nuances of relationships in the physical world are not captured by Facebook's simplistic representation of friends.

People, however, are able to understand and interpret profile data, including lists of friends, in ways that are different from the types of interpretation the system itself might provide. For example, Facebook's ability to understand the closeness of a relationship is limited to what can be gleaned from communication acts or other interactions on the site. A human, however, is able to understand that users might be socially close, for example, to a spouse despite little interaction via Facebook.

Although Facebook's Reconnect feature was launched after the data collection portion of our study, user responses to this feature exemplify the system's ontological and technological limitations. Intended to encourage interactions between Facebook users who have had little recent interaction, Reconnect often produces surprising recommendations. During the time shortly after the feature's launch, status messages on Facebook and Twitter were prominent means by which users expressed their frustration. Users described requests to reconnect with family members, ex-lovers, and even the dead. "*Facebook just suggested that I 'reconnect' with my 1 year old by writing something on his wall,*" wrote one user. Another wrote: "*Facebook is suggesting that I reconnect with my wife by writing on her wall. I'm thinking coming home every night is a tad more effective.*"

Connecting through Missed Connections

In contrast to Facebook, posts to craigslist Missed Connections operate in a markedly simpler representational system. With no persistent user data, the craigslist Missed Connections system includes no formal profiles, inter-user relationships, or history of interactions. The practices of identification, however, do bare striking resemblance to the practices of finding and friending users on Facebook. Consider the following post:

> capitol south to l'enfant - m4m
> Date: 2009-04-19, 8:34AM EDT, Washington D.C.
>
> *Saturday night.*
> *Monday at about 10:30 am, I got on the metro at capitol south, you were with two other guys, you and I were in shorts and you had what appeared to be some hot pecs, you caught my glance and said hello. We all got off at L'Enfant. If you see this, coffee at Starbucks on the Hill?*

In a post to Missed Connections, users establish a kind of temporary social network, describing themselves and others, the relationships they share, and the social spaces in which those relationships exist. However, without long-term persistence, single-use identities and the social networks in which they exist must be reconstructed for each post.

In the craigslist system, "posts" are situated in a geographic "channel" (*e.g.*, "*SF Bay*"). A Missed Connection post requires a "title", "description" (*i.e.*, the post's message content), and optionally a "specific location" (*e.g., "The Mission*") and "age". Within the Missed Connections portion of the site, users may also select a gender/sexual orientation category (*e.g.*, w4w), which is appended to the post's "title" (*e.g.*, "*To the cute barista - w4w*") to facilitate searching by this category. Nearly all of the data in a post are entered manually. The only automatically collected data are the date and time of entry and the IP address from which the entry was submitted (an element that is stored and used by the system, but not displayed).

A number of community-based standards have developed over time in response to the design of the system. Authors craft messages that usually follow a prototypical format, much like the post seen above, including physical, contextual, and circumstantial cues. Physical locations, for example, are almost always included and provide effective search terms for the craigslist search engine.

Due to the anonymity craigslist provides, authenticating content is a very prominent aspect of engaging with the

system. A user reading Missed Connections must determine whether a post is legitimate (*e.g.*, not SPAM), if they are the intended target, and if the author of the post is someone to whom they want to respond. The specific design of the system does little to structure this process, despite being the primary behavior Missed Connections are meant to support.

Authentication is an issue for authors as well. Posts often request that respondents include specific information about the encounter. Requests such as "*Tell me what my tshirt said…*" have increased in frequency over the three years we have studied craigslist, suggesting that users have adopted this practice from other posts to ensure the authenticity of anonymous respondents.

Finally, the combination of system-enabled anonymity and location information provided by the user has allowed for the emergence of new virtual-physical hybrid performance spaces. For example, a particularly high volume of Missed Connections originate from a popular coffee house in Washington D.C. While the prototypical Missed Connection is posted after the opportunity to connect has passed, laptop-toting professionals who spend substantial quantities of time working and socializing in this space have adopted a practice of posting messages for individuals across the room while still physically co-located.

Relationships and Representations

Despite being technologically quite different, both Facebook and craigslist Missed Connections are ultimately representation systems through which people establish, mediate, and maintain relationships. Users of both systems describe themselves, locations they have been and will be, and interactions they have had or plan to have in the future. There are, however, important differences both between the systems themselves and among the varied user behaviors we observed in our data.

First, the structure of data is paramount in differentiating craigslist and Facebook. One of the technological benefits to Facebook's structuring of user data is a decreased load on the servers as users navigate through efficiently organized data. This data normalization has enabled Facebook to become a central resource for persistent digital identity information. The availability of this information in turn enables interesting social interactions, both inside and outside of Facebook. One interviewee explained that he prefers to stay in touch with friends via instant message conversations in addition to Facebook:

> *…there will come this point in the conversation where you would say 'what are you up to?' or 'are you still with that one girl?' but then I just realize I should be looking at their profile page… so [the profile] kind of becomes like a way to catch up… it helps the conversation.*

Our findings confirm that Facebook is used as an informational resource in addition to a space for identity performance [21].

The underlying design of craigslist, meanwhile, does little more than structure posts relative to categories that mimic different sections of classified advertisements (*e.g.*, "Jobs", "Missed Connections"). This is not to suggest that craigslist is technologically simple. In an interview with craigslist founder Craig Newmark, he explained that resources have intentionally been devoted to features that are often invisible to the user:

> *Underneath, the technologies are fairly cutting edge in terms of database use, the use of caching to keep the site fast… and there we just have a good technical team who's serious about keeping up with technologies that matter.*

When asked if a more structured design might better facilitate users, Newmark explained that "*It turns out if you keep something simple… you automatically satisfy a lot of customer needs.*"

The range of behaviors craigslist facilitates reveals how users appropriate available structures to achieve their objectives within even a seemingly simple system. Due to craigslist's open-ended structure, Missed Connections users rely heavily on contextual information and local knowledge when authoring their posts. While posts frequently include references to locations (*e.g.,* a specific gym or pub), our analysis of Missed Connections reveals that two structural elements of the craigslist system (geographical channel and gender/sexual orientation) shape the content of posts by suggesting a particular audience. For example, one m4m post includes a location *("David Barton Gym"* in *"Chelsea"*) and description of his target *("you were in a white tank and light blue nylon pants")*. The m4m category in conjunction with other contextual cues situate both author and target as members of New York's gay community—an entity that does not explicitly exist in the Missed Connections ontology.

Finally, as socio-technical systems, the technological underpinnings of these systems influence users' offline relationships as well. As in our opening scenario, Facebook's "Relationship Status" has received significant attention in the media [12,29]. Facebook announces changes to a user's relationship status to friends, family members, co-workers, ex-lovers, and anyone else connected via Facebook. The importance of Facebook representations in offline dynamics is exemplified by a story shared with us by a participant living in New York City. He had begun a serious relationship, and while optimistic, he confessed some worry. He had approached his new boyfriend about changing their Facebook relationship statuses, but the issue was casually dismissed. While their online personas remained "Single," our participant enumerated hypothetical reasons for his boyfriend's refusal, the majority of which questioned levels of commitment and fidelity. Representation of their romantic status online impacted his confidence in their long-term potential offline, and as we

were informed later, was a primary reason for eventually ending the relationship.

As a shared profile attribute, existing relationship statuses can also be a source of stress. For example, one interviewee shared a reoccurring pattern in which his girlfriend would remove their relationship status on Facebook following their frequent fights. He explained that even after resolving a particular disagreement, he would often receive email notifications from Facebook the next day informing him that he was no longer "in a relationship." He described these public changes to his relationship status as *"frustrating"* and *"embarrassing."* Knowing that he would receive an email notification, his girlfriend in turn developed an emergent practice in which she intentionally communicated her displeasure through the system by changing their status.

Temporality and Transience
One of the most profound differences we observed between user behavior on Facebook and craigslist Missed Connections was related to the persistence of user data. Data persistence on Facebook allows individuals to craft profiles that grow with the addition of system content. Posts to Missed Connections, meanwhile, are "single-use", require that users provide all relevant content in a single post, and expire after seven days.

The impact of persistence can be seen through several participants who shared their excitement over unexpectedly finding friends on Facebook. Katrina, a busy mother of three who initially resisted the idea of joining Facebook, was delighted by the series of friend requests from former classmates and the ease with which they were able to reconnect. These automated connections occurred simply and easily because of the persistent representation of Katrina and her friends—all of whom shared particular school or geographic contexts easily organized in the database.

Of course, a persistent presence can also result in less desirable encounters. Lindsey, a medical student, joined Facebook at the urging of a cousin who wanted to stay in touch. Lindsey explained that within an hour of setting up her account she received numerous friend requests from current and former classmates, and, to her dismay, ex-boyfriends and one-night stands.

In contrast to the Facebook practice of connecting with existing offline contacts [15], Missed Connections detail recent interactions in an attempt to facilitate new relationships. The transience of posts, however, requires particular user behaviors. For example, it was common for interviewees to describe checking Missed Connections after a night out or on a Monday morning after the weekend.

Given the non-persistence of these representations, the overall effectiveness of Missed Connections is unclear. Interviewees, however, indicate that posts can be effective, particularly when both parties suspect mutual interest or

when the intended recipient's social network notifies them of a relevant post. We experienced an example of the latter scenario during the course of this research. On a Monday morning while reviewing site content, we found a Missed Connection that clearly described a friend of one of the researchers. When contacted, the friend explained that he was already aware of the post. He had spent the morning answering instant messages and text messages from other friends who had seen it while browsing the site.

FEATURES OF COMPUTING PRACTICE
Analysis of our empirical data clearly indicates the close relationship between the underlying technologies of these representational systems and user behavior. To further unpack these issues, in this section we outline the eight features of computing Agre highlights when considering computing as a representational practice. Although these features are inherently interdependent, here we present them separately to emphasize their unique attributes and consider the issues that each brings to light.

Ontology
In information and computer science, an ontology refers to a formal representation of conceptual entities and the relationships between those entities within a specified domain. Agre explains that "a computer can only capture and calculate with what it can represent" [2]. Thus, from a purely computational standpoint, the ontology of a system lies at the heart of its ability to represent elements of the physical world. Explicitly examining ontology in both Facebook and craigslist Missed Connections indicates some limitations in terms of what phenomena, people, and places these systems can represent. It also underscores the enormous flexibility of these systems that allows people to go beyond the defined ontology and represent higher order concepts through creative use of text and other system features – albeit in ways not always understood by the system.

The ontology represented by the Facebook API, for example, defines a user who has one profile, may have many friendships with other users, and may be associated with social networks defined by employers, educational institutions, and the geographical location in which the user lives. Additional information about a user can be present but is not required, including textual information like status updates, as well as rich media like pictures and videos. Meanwhile, craigslist Missed Connections builds on the craigslist ontology, which is inherently simpler than Facebook. Each post belongs to a geographical channel and a system section (*e.g.*, "Missed Connections", "Furniture for Sale"). As we have demonstrated, a wide range of behavior can occur inside these posts. However, as much of it exists outside of the defined craigslist ontology, the system is limited in what it can understand about these behaviors.

Standards
Data standards are required to make information manageable and useful for computing systems, particularly

as different systems or subcomponents need to interoperate. The existence of the various Facebook APIs and SDKs are indicators of the prominent place such standards have in the world of systems designers and developers. "The uniform imposition of standardized categorizations and measurement schemes" ([10], as cited in [2]) allow for the kind of ontological uniformity and interoperability needed to support massive systems of representation.

Designers create data standards for each of the entities in a system's ontology. On craigslist, for example, the post entity is composed of the data elements described earlier (*e.g.*, title, IP address, etc.). Designers make use of established standards as well. As a simple example, Facebook requires that users provide a date of birth when creating an account. The standard for dates in the Facebook APIs are based on the Julian calendar system, but the user interface formats the order of day, month, and year to match the standards of the local geographic regions (*e.g.,* month/day/year in the United States, year/month/day in Japan). When a user submits the date back to the system it is formatted into the Julian standard before being stored in the database. In this way standards exist at various layers in the system, and are central to how systems interact.

Instrumentation
Capturing and recording data requires some set of instruments. Instrumentation as a concept is broad and inclusive of a wide variety of data capturing technologies. This includes web forms that enable manual input, but also sensors and GPS systems that automatically geo-tag data. The processes by which these instruments collect data necessarily organizes user behavior and the data users provide.

Facebook and craigslist Missed Connections are predominantly asynchronous communication tools and rely on text-based user input for much of the data they capture. Each post to Missed Connections requires that craigslist users recreate the details of their (non)encounters. This explicit input allows each user to craft an optimal self-presentation in ways that the immediacy of a live interaction does not afford. Likewise, until Facebook's recent introduction of the chat feature, communication between users on Facebook consisted of publicly visible comments posted to the user's profile "Wall" and private messages sent via Facebook's internal email system.

Users are necessarily aware of their production of data inside these systems when creating messages. Unlike a synchronous communication system or an array of ubiquitous sensors that captures data in real-time, the use of asynchronous tools allows users to reflect on and revise messages before they are posted. As a greater number of automated applications are brought into Facebook, such as those that geo-tag photos or report a user's location, the instrumentation may become less visible, but its impact will remain important.

Authentication
When speaking of authentication, Agre is not referring to login credentials, but rather the authenticity of data and the means by which people accept these data as valid representations. A system "which claims to report the activities of particular people and things must presuppose some material process to verify" these data [2]. Instead of requiring the system to authenticate data, representational systems like Facebook and craigslist display data to end users who perform this task.

Consider searching for a former classmate on Facebook using only his or her name. In response to a specific query, the system will show a list of individuals whose names match the search, but Facebook cannot guarantee that a particular user is the desired friend. Users must examine the information provided (*e.g.*, the school listed, the year of graduation, a list of common friends) and determine the authenticity of the representation themselves.

We see a more central example of authentication work on craigslist. With no user profiles, no user history, and large quantities of SPAM, users must determine the legitimacy of each post. Because authors also receive SPAM and problematic solicitations in response to their posts, the practice described earlier of requesting that respondents answer a question about the encounter (*e.g.*, tshirt color, conversation topic, etc.) is one way in which authentication is performed by craigslist users.

Interpretation
Interpretation involves a host of activities focused on synthesizing information into a form that is amenable to computation. Certainly, enormous efforts in natural language processing, information retrieval, and information visualization indicate interest from the computing community in producing automated interpretation and synthesis of data from representational systems. Facebook already employs a massive automated interpretation system to target users with advertisements based on variables like location, age, sex, and relationship status.

End-users, however, are still essential in synthesizing information. On craigslist, human interpretation plays a central role in content moderation. craigslist has implemented a user-powered flagging system that allows the community to mark posts as "miscategorized," "prohibited" (due to terms of use), "spam/overpost", and "best of craigslist." The craigslist help section explains that *"Free classified ads receiving a sufficient number of qualified negative flags are subject to automated removal"* while *"Funny or memorable postings may also be flagged, for inclusion in 'best of craigslist'"* [17] – a section that displays user-nominated posts. Thus, the flagging system enables users to act as sensors that synthesize messages into categories usable by the computational system.

Selection
Although computation gets cheaper all the time, every system has limits. A system cannot capture and represent

everything, and thus, "the question arises of which data are created in the first place, and which are stored" [2]. Systems designers must select which data are relevant to the representations they are building.

In the creation of the profile system and its related data standards, Facebook developers selectively pre-determined what constitutes a person. Familiar attributes include age, location, relationship status, and so on. As new applications using Facebook's APIs are developed, launched, and used, they rely on a subset of data that are already available via Facebook and potentially gather new data as well.

The craigslist system, meanwhile, contrasts with Facebook in that its standards do not include personal information such as names, birthdays, and profile pictures. Moreover, Missed Connections users have community-based rules about information that should not be included. Posts with photos of the intended recipient, while rare, are quickly flagged for removal. Finally, Missed Connections limits the data being stored temporally. Posts are displayed in reverse-chronological order and are removed after seven days. Users can (and do) post copies of an original post, effectively extending its life and securing a higher position relative to other submissions. This, however, requires explicit action and may result in a post being flagged as "spam/overpost."

Bias

The construction of any computational system is subject to bias. Often these biases can be invisible or go unnoticed by the users or even the developers [4,18,19]. As individuals grow more reliant on online systems—whether blogs, online communities, or other social media—to understand the world around them, these biases become increasingly important to reveal and unpack. However, recognizing and conceptualizing these issues is challenged by the very idea of a representational system that seeks to present back to its users a relatively undistorted view of captured data. As particularly noticeable examples, we describe the gender and sexual orientation biases present in both systems.

Facebook and craigslist Missed Connections only allow particular representations of gender. On Facebook, users can indicate that they are "Male" or "Female." It is not possible for a user to use a transgendered label, such as "M2F" or "F2M", or to identify as intersex. Bias such as this has received extensive attention in other spaces [11,23,24], and suggests that the exclusion of other categories from Facebook's system reifies normative gender identities. Likewise, Facebook does not allow users to identify their sexual orientation with a label. Users select the gender(s) they are "Interested in", which proxies labels such as heterosexual, homosexual, and bisexual. Similarly, Missed Connections are divided into *w4m*, *m4m*, *m4w*, *w4w*, and *unspecified* categories. When posting a Missed Connection users must choose one of these and, in so doing, choose their gender, the gender of their target, and an ostensible sexual orientation.

Both Missed Connections and Facebook eliminate the ability to self-identify with customized labels that users might feel are more representative of their identities, such as "queer." Facebook users can optionally add third-party applications such as "SGO" which provide a wider set of sex, gender identity, and sexual orientation options. These applications, however, do not replace Facebook's data: instead, they display information in a separate profile location and store choices in a separate database not accessible by Facebook.

Performance

Once people become aware of and accustomed to having their activities presented to others through representational systems, Agre argues that people will alter their activities with the consequences of those systems in mind ([13,32], as cited in [2]). Agre's use of performance differs from other notions of performance and performativity (*e.g.,* [3,11,20]) and focuses on how individuals alter their actions based on perceived consequences. Performance here includes an understanding that actors are aware of their activities and act with the representational system in mind. In this model, their activities become manufactured performances that project, to the greatest possible extent, the participants' preferred construction of reality.

Users of both Facebook and craigslist Missed Connections use these systems to present ideal versions of themselves [7,25]. However, our interviews of Facebook users suggest that this presentation requires some maintenance. Several users mentioned managing Facebook content tagged with their names (*e.g.,* images) or posted to their profile by other users. One participant explained having a series of discussions with his mother about what type of comments were appropriate to post on his profile, and because others might view her online behavior, her own profile as well. This example highlights the complexity of performance on SNSs in which others' behavior influences the system and the consequences of its use.

In many cases, Missed Connections describe scenarios in which the author ostensibly could have avoided the need for the post by crossing the bar and introducing himself or otherwise being more direct. A woman in the Castro writing *"to carly at the cafe"* sums up the frustration that many authors express: *"why didn't i get your number????"*

Many preemptively rationalize or apologize for their use of craigslist rather than having the interaction in person. A post authored by a 21-year-old man about a brief interaction outside a Washington D.C. dance club claims that:

> *what i told you at the end of the night was the truth, i had to get home or else i would be in trouble!*

The availability of Missed Connections allows users to capitalize on otherwise lost encounters. However, some of our participants speculated that the existence of this system enables individuals to avoid the risk of an in-person encounter by relying on craigslist instead. These results

indicate that people reorient themselves toward the world and these representational systems in light of the functionality those systems provide.

DISCUSSION

Online spaces like Facebook and craigslist Missed Connections capture and represent data about the physical world in a virtual format, enabling new kinds of interactions and altering the socio-technical experiences of their users. However, these systems are at best imperfect representations of lived experiences. The design and underlying infrastructure influences user behavior; at the same time, user behavior influences iterations of these systems both in terms of their design and emergent standards. This is in line with existing work on the impact of system infrastructure on usability [14].

Agre's features of computing further highlight the ways in which a system as an ontological space can provide novel forms of interaction, such as the management of offline relationships through "friending" on Facebook or provoking connections from across the room through posts on craigslist. Thus, when studying these systems and the data they collect, it is important to remember that representational systems create new virtual-physical hybrid performance spaces that do not capture or exactly reflect the lived realities of their users or the ontologies defined by these systems.

Still, users often appropriate system features in ways that make sense for their worldview but exist largely outside of defined ontologies. In our studies, user communities created the structures and standards they needed to facilitate the kind of interactions they wanted to achieve. This kind of appropriation alters system designs and layers new technological and community based standards on top of existing systems. Thus, when studying user behavior in these kinds of collaborative online spaces, one must consider not only how users are interacting with one another but also how they are interacting with—and even collaborating with—the systems and thus their designers.

Representational systems are inherently intertwined with user practices and technological infrastructure. Iterative design practices already account for some level of dynamism. However, our analysis indicates that this tight integration can exist at a variety of places in the technology stack. For example, reappropriation of ontology and standards may often be overlooked when design practices are restricted to user-facing domains such as instrumentation (*e.g.,* applications and interfaces). This situation necessitates the inclusion of ongoing and engaged design practices that step beyond a static model focused on iterative design of technologies and instead focus on the social, the technical, and the interplay between the two.

CONCLUSIONS AND FUTURE WORK

In this paper, we have demonstrated how the computational features of two representational systems—Facebook and craigslist Missed Connections—are deeply intertwined with user practices. This analysis draws attention to the similarities in the practices of identifying and connecting with other users, as well as differences in the representation of relationships and the temporality and transience of related interactions both online and off.

Perhaps most importantly, however, this analysis also draws attention to new areas of research. For example, the structure of Facebook does not handle certain user behaviors well, such as when two individuals choose to share a Facebook account. Similarly, the development of applications on top of Facebook's infrastructure can create new challenges for users. As mentioned, Facebook application developers can select and interpret data differently than Facebook based on their own ontology and standards. Similarly, feeds and search engines layered on top of Missed Connections have the potential to challenge some of the ways people think about authorship and readership. These issues leave open research questions focused on both the users and developers who are leveraging the underlying systems, but also about the system designers who create infrastructures and the processes by which they make their design choices.

Finally, as users appropriate these representational systems for their own purposes, they sometimes alter or ignore existing computational features and focus on "workarounds." These emergent practices should be examined and better understood. For example, though they were in the minority, posts in Missed Connections sometimes did not fit the standard model of a recent and geographically relevant encounter. These posts often included proclamations of love or apologies days or even years after the end of a relationship. It is not yet clear what work these kinds of posts are doing for the authors nor how the user community considers them. These kinds of online interactions should be examined alongside the emergent hybrid physical-virtual practices described earlier.

This paper provides two contributions to the community. First, by highlighting computing as a representational practice, we have demonstrated the importance of accounting for the underlying technological features when researching user behavior in social media. Second, our analysis reveals particular ways in which Facebook and craigslist Missed Connections as representational systems have created new hybrid virtual-physical spaces in which people both take advantage of and are subjected to the affordances and limitations of these systems in representing their lived experiences.

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