Local Ground: A Paper-Based Toolkit for Documenting Local Geo-spatial Knowledge

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ABSTRACT
Comprehensive spatial knowledge is vital for making good planning decisions - whether it be for planning infrastructure, public projects or addressing other community needs. Often it is the local residents themselves who have the most current and accurate understanding of the uses and condition of any place. Including diverse voices is difficult in the planning process, as many local groups do not have access to the same technologies as larger institutional actors. To address their needs, we have developed Local Ground: a tool that allows local residents to document their personal knowledge of places using simple bar-coded paper maps, computer vision techniques and free, publicly available mapping and charting tools. Users annotate paper maps using simple pens, markers and stamps. These maps are scanned and aggregated online, where they can be analyzed and overlaid on information obtained from other knowledge sources, allowing local perspectives to influence planning decisions. We tested Local Ground with a group of high school youth involved in an urban revitalization project in a low-income neighborhood in Richmond, California. Students and teachers found our tools to be portable, fun, collaborative, and easy to learn. In this paper we describe the Local Ground toolkit, including its strengths as a geo-spatial data collection and dissemination tool, and some findings obtained from our initial field pilot in Richmond.

Categories and Subject Descriptors
H.5.2. [**Information Interfaces**]: User Interfaces – *input devices and strategies; prototyping; user-centered design.*

General Terms
Design, Human Factors

Keywords
Participatory GIS, ICTD, participatory planning, paper interfaces, internet mapping, urban planning, rural development

Figure 1: Students record observations on paper maps

1. INTRODUCTION
When planning and implementing a public development project, it is critical that all parties involved come to the table to discuss their needs, expectations, and ideas. Each stakeholder brings a different set of perspectives to a project and having the proper tools and processes in place to share, synthesize, and document collective knowledge helps ensure that all viewpoints are taken into account. It is important to recognize that local residents are often the true experts of a geographic area, having intimate knowledge of community assets and problems alike. Making a concerted effort to involve local residents and community groups is vital to the success of any public project, as without local adoption, it will undoubtedly fail.

Though securing funding for public projects is often contingent on involving community members, project-sponsored community outreach meetings have limited reach because stakeholders are not always informed of, able or willing to attend the outreach meetings. Furthermore, it is difficult to document, summarize, and share the multitude of opinions and ideas expressed in these meetings, as information sharing is largely done verbally or by taking notes on paper maps and plans, often collaboratively. These tactile, participatory methods are considered the gold standard for eliciting public comments about community members' personal knowledge of their neighborhoods, but the resulting documents are unwieldy and not easily incorporated into Geographic Information Systems (GIS). Often, the resulting paper documents are simply filed away, or perhaps displayed on a wall as artwork.

Though unwieldy, hand-annotated paper maps take advantage of critical affordances that are absent from most handheld GPS devices and GIS software. On a paper map, important areas can be circled, personalized symbols and language can be captured, and multiple parties can collaborate to express a joint idea. These qualitative, information-rich expressions are often lost in formal GIS systems. Furthermore, using paper to gather data enables us to capture knowledge from a larger group of people, which in turns improves the planning process. Finally, the unstructured nature of a paper map interface allows participants to record information that a survey designer might never have thought to ask.

On the other hand, paper-based information is notoriously difficult to aggregate and analyze to discover meaningful patterns. In one of our field visits, one NGO worker pulled out a stack of paper maps from a drawer, saying that for a previous community mapping exercise, she had to go through each one and summarize the main themes in a text-based document, which was difficult due to the spatial and subjective nature of the map annotations.

Our participatory mapping digital toolkit, Local Ground, extends the reach of online mapping tools to paper maps. By utilizing simple computer vision techniques and free, publicly available mapping and charting tools, Local Ground aims to (1) streamline paper-based geo-spatial information collection and geo-referencing, (2) broaden the reach of such information collection initiatives, and (3) expand the kind of information that can be incorporated into these systems (i.e., qualitative information reflecting perceptions, aspirations, and subjective meanings of place).

In this paper, we report our findings from a twelve week pilot project using Local Ground to help local high school students involved in a community revitalization effort in Richmond, California. These students used Local Ground to collect, analyze, and display qualitative data about their neighborhoods (Figure 1), in order to argue for a set of redesign plans at City Hall. We discuss the process we followed with these students to design and implement Local Ground, and some preliminary findings and observations from this exercise.

The rest of this paper is organized as follows: first we examine prior work related to Local Ground, beginning with the theory behind community mapping and participatory design. Next, we describe the Local Ground toolkit and the technology behind it. We then discuss our design process, including how the Local Ground system has developed with each mapping exercise that we have conducted. Finally, we summarize key themes that emerged from our work, and map out future ground to cover.

2. RELATED WORK

The bulk of prior work related to Local Ground can be separated into four categories: (1) the theory of participatory and community mapping, (2) interfaces developed for participatory and community mapping, (3) online map interfaces, and (4) paper-based computer interfaces.

2.1 Participatory and Community Planning

Formal methods in participatory and community planning were developed in reaction to poorly implemented, often oppressive, top-down development strategies that failed to take local considerations into account. There are many examples of failed development projects that resulted in suboptimal outcomes - from failed irrigation and economic development projects to oppressive governmental policies [24][15][8]. To engage local experts, many organizations use participatory techniques to facilitate dialogue and to help reach consensus on a variety of development topics, including irrigation, crop production, and environmental management [4]. Through discussion and facilitation, community members collectively draw a map on paper or on some other tangible medium, where they delineate community boundaries, assets, problems, and ideas. This process ensures that important issues are brought to light from the perspective of the community members [11].

2.2 Participatory GIS

Participatory GIS emerged to address concerns that GIS, when used in a planning context, could further exacerbate social injustice by emphasizing quantitative, formal data sets over local subjective knowledge [6]. By bridging participatory methods, quantitative data, and technology, PGIS attempts to ensure that community knowledge and local politics are sufficiently taken into account while planning projects [1][22]. In addition to the geospatial layers (point, lines, and polygons) that are found in traditional GIS systems, PGIS frequently incorporates visual and multimedia information such as photographs, video, and sketches [3][7]. Kodmany's study of using GIS for neighborhood planning in three Chicago neighborhoods found that "traditional activities and tools, such as sketching with pen and paper, are very powerful and are irreplaceable in the early stages of planning." [2], They experimented with using electronic sketchboards, 3-D modeling tools, and GIS. Participants commented that the technology hindered the social function of the neighborhood meetings. Kodmany ultimately resorted to using pens and large printouts of GIS maps, concluding that GIS alone was not sufficient to meet the communities' needs. There are numerous other examples of PGIS projects throughout the world, but most still rely, in some form, on paper and pen.

2.3 Online Map Interfaces

There are a number of web-based geo-spatial data collection and dissemination initiatives. Google Map Maker [13] and OpenStreetMap [19] both provide web-based mapping platforms that accept user-generated geo-spatial content, and have specific initiatives geared toward digitizing maps in the developing world. For example, in November 2009, residents of Kibera, Kenya's largest slum, used OpenStreetMap and GPS units to annotate what had previously been a blank spot on a map [12]. There are also a number of open-source mapping tools, such as ModestMaps [14] and Open Layers [18], and publicly accessible APIs, such as the Google Maps API and the W3C Geolocation API, that allow users to consume, display, and query existing geographic data. The vast majority of web-based geo-spatial data collection initiatives require a computer or at least a mobile phone for users to contribute information. One exception is Walking Papers [25], which provides a paper-based method for submitting geo-spatial data to OpenStreetMap,

2.4 Paper-Based Computer Interfaces

Our research draws on a long history of research into paper-based computer interfaces. XAX pioneered the idea of a paper user interface to document services [10]. Users could trigger actions by making entries on a paper-based form. The form was identified by scanning and decoding a printed registration mark, allowing the system to interpret the underlying content. The Paper PDA was a similar system, introducing the notion of linking between individual paper resources, and synchronizing between paper and digital content [9]. Paper++ provided a platform for linking barcodes to various kinds of data objects [16]. Paper UIs have also been built with the Anoto digital pen technology, using high-resolution dotted paper and a special camera-equipped digital pen work to record users' pen strokes [3]. CAM, a paper-based user interface designed for mobile data collection in the developing world, allowed users to transfer information from bar-coded paper forms using an interactive smartphone application [20].

There have only been a few paper-based mapping projects. Marked-Up Maps relies on RFID chips embedded in paper maps. The chips can be scanned by a handheld computer or smartphone to retrieve additional information about a specific location from the Internet [21]. The closest prior work is Walking Papers, which uses two-dimensional bar codes to encode a unique URL allowing the map to be geo-referenced and digitized.

3. SYSTEM BACKGROUND

The initial idea for the Local Ground system originated during the summer of 2009, while team members were in Ethiopia to investigate the potential for information and communications technology (ICTs) to support smallholder farmers. As we travelled throughout the country, we noticed a number of large, hand-drawn community maps on the walls of farmer training centers as seen in Figure 2, where local farmers had drawn property boundaries, crop types, facilities, and other community assets.

Figure 2: Farmer-drawn map from Debre Zeit, Ethiopia

Meanwhile, we found that agricultural support organizations consistently needed a better understanding of local community landscapes – both social and physical – to develop relevant strategies for seed and fertilizer distribution, marketing initiatives, and monitoring and evaluation. We speculated that had the right tools been in place, information from these maps could have been used to better inform agricultural support organizations in their strategies.

We then learned of the Walking Papers initiative, which automatically geo-referenced QR-Coded[1] paper maps to incorporate paper-based input for OpenStreetMap (OSM). This approach seemed ideal for participatory community mapping, so we decided to adapt Walking Papers' open source code for a community development setting.

3.1 Community Partners

Having a local partner would allow us to more conveniently test a variety of interface ideas, iterating quickly and easily. Though organizations and communities in the Bay Area cannot be directly compared to those in Ethiopia, we hoped to generate a few insights that could be applicable to both contexts. In both places, there are common community development challenges to serving economically disadvantaged groups, which include overcoming language, education, economic, technological and cultural barriers. Serendipitously, we found the Y-PLAN (Youth – Plan Learn Act Now!). The Y-PLAN is a youth-oriented, community inquiry framework that allows college students to mentor local middle-school and high-school youth, engaging them as genuine, authentic collaborators in real-world development projects. In the spring of 2010, the Y-PLAN was tasked to analyze the redevelopment of the Nystrom area, a neighborhood in Richmond, California, consisting of mostly low-income families, schools performing below the national average, and unsafe and under-utilized community spaces. The Nystrom area also suffers from chronic violence, drug use, and gang activity [23].

The Richmond Housing Authority, the students' "client," asked students to create youth-friendly designs that would connect Nystrom Village Housing – four blocks of public housing slated for redevelopment – with the nearby park, school, and community center to make it feel like a connected, cohesive neighborhood. Mentors worked with two eleventh grade U.S. History classes at a local high school twice a week for twelve weeks to develop plans. During this time, the students participated in mapping exercises, brainstormed suggestions, and finally selected the best ideas to present to the City Manager, the Housing Authority, and other key stakeholders at City Hall. As community mapping was to be such a large component of the Y-PLAN's inquiry process, and because the project was real – not a simulated exercise – the Y-PLAN was an ideal test case for Local Ground.

3.2 Access to Computer Technology

Like the smallholder farmers we observed in Ethiopia, the Y-PLAN students also had limited access to computer technology. Though the high school had a computer lab and some computers available at the library, it was logistically difficult to schedule computer time for students during school hours. The lab was also under-resourced, as most of the computer classes had been cancelled due to funding cuts. We conducted an informal poll of students non-school computer use. All but a few students reported that they had an email account and either a Facebook or MySpace account. More than half of the students owned a cell phone, but none reported having any sort of data service or web-capable smart phone. A handful of students said they had a computer at home, but only one student had Internet access.

4. THE LOCAL GROUND SYSTEM

4.1 Features

Though the Local Ground system evolved as we tested various ideas, this section describes the basic technologies that are currently included in the toolkit. At a high level, the Local Ground system consists of two components: (1) data input tools and (2) data processing and visualization tools. The data input tools leverage maps printed out on paper, QR codes and image processing scripts to gather quantitative and qualitative geo-spatial information. The data analysis and visualization tools include an application programming interface (API) to interact with our data store; a web-based map editor to summarize and tag points, lines, and polygons of interest; and several web-based map viewers. This toolkit allows users to:

1. Print a map of a location of interest from a web browser using map data from Google Maps. This map can be copied and disseminated to many users.

[1] QR or "Quick Response" codes are two-dimensional bar codes.

2. Annotate the map with ideas, issues, plans, or data, using pens, markers or stamps from a template.
3. Scan and upload the resulting map into our system.
4. Automatically process the uploaded map image to straighten the image; geo-reference it so that it can be accurately placed on a map; extract the hand-drawn annotations from the underlying print; and view these hand-drawn annotations on a web-based map.
5. Draw polygons and place markers on annotated areas; tag and describe the uploaded annotations; and associate photographs, video, or audio with specific areas.
6. Summarize and discover patterns by overlaying hand-drawn annotations with other GIS data layers, such as crime zones, demographic information, facility locations, and even other hand-annotated maps. Users can also drill down to the specific annotations of a single area, as well as view any photographs, videos, or audio captured.

4.2 Implementation

4.2.1 Data Input Tools

The Local Ground data input tool utilizes code and ideas from the Walking Papers open source project, which uses OpenStreetMap data and ModestMaps to display, print, and interact with geospatial data. It utilizes the Google Chart API[2] to generate and read QR codes containing information about the printed map's extent and zoom level. It also uses a Python script to process the scanned map image by: (1) rotating and scaling the scanned image and extracting the QR Code using the SIFT algorithm[3]; (2) reading the code and matching it with a corresponding print record in the database; and (3) tiling the image so that it can be digitized and stored in OpenStreetMap.

To achieve our goals, we had to make several modifications to the Walking Papers codebase. The most significant of these was modifying the paper-map-processing script to use Canny Edge Detection [5], rather than SIFT, so that it could successfully process lower resolution map images. The Walking Papers implementation of the SIFT algorithm required that small, reference images be placed at the corners of the map. The script relied on these known images - "needles in a haystack" - to geo-reference the map. Though this technique worked well for high resolution scans, when the image resolution falls below 200 pixels per inch (PPI), SIFT was not able to find the reference images, prohibiting the map from being geo-referenced. This effectively excluded many digital cameras and some scanners from being used to capture the annotated maps.

We experimented with another image processing toolkit, Open Computer Vision (OpenCV) [17], which implements many of the most commonly used computer vision algorithms in C++, with Python bindings. By (1) creating a new print template that framed the map and QR code with a black, rectangular border, (2) increasing the QR code size by 50% and (3) using Canny edge detection to find these rectangular borders after the maps had been photographed or scanned, we were able to automatically geo-reference map images with resolutions as low as 72 PPI, for image files as small as 80 KB. We also provided an email interface so that users could submit their images directly from their camera phones using MMS.

[2] http://code.google.com/apis/chart

[3] SIFT (Scale Invariant Feature Transform): A patented algorithm that can be used to detect features in an image, regardless of variations in scale or rotation.

In addition to these image processing modifications we also changed the Walking Papers code to use the Google Maps API, as there was more data regarding the churches, schools, parks, and facilities in Richmond and Contra Costa County in Google Maps than there was in OpenStreetMap. Also, because we wanted to support overlaying many scanned maps at once, we utilized some of the image processing features available in the Python Imaging Library (PIL) – specifically image subtraction and color subtraction. This allowed us to extract the map annotations from the map background.

4.2.1 Data Processing and Visualization Tools

In order to make the scanned maps usable, we developed a map editor, a simple API to interact with the Local Ground data store, and several different map viewers.

Figure 3. Map viewer focused on paper annotations

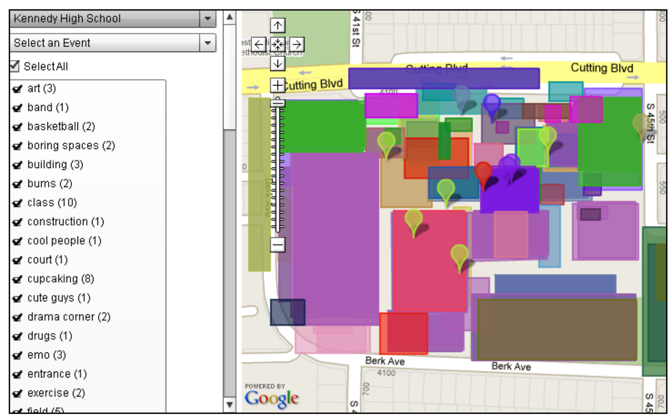

Figure 4. Map viewer focused on summaries

4.2.2.1 Map Editor

We built an editing tool for users to digitally annotate areas with summaries, names, and tags so that the maps could later be searched. The editor allows users to specify and label points and polygons on a map, and uses techniques like tag auto-complete to encourage tag convergence. The "description" field also let users embed multimedia such as photographs, video, or audio.

4.2.2.2 API

To allow easy access to the digitally annotated images and corresponding annotations, we developed a RESTful API. The API returns JSON-encoded strings for any combination of supported queries. Providing an API is critical, since there are many ways in which the data might be presented.

4.2.2.3 Map Viewers

We also experimented with a variety of ways to present the data, using both HTML/JavaScript and Flash/ActionScript. The viewer pictured in Figure 3 allows users easy access to the hand-drawn annotations. Individual maps can be toggled on and off, giving participants the satisfaction of seeing their own map online. The viewer pictured in Figure 4 presents a summary-level view of the data using which decision-makers can quickly browse tags to determine which areas are labeled as "dark" or "important" or "under-utilized." In addition to allowing for the display of paper map imagery, we also support the display of other elements, such as additional KML[4] files and photographs.

5. FIELD PILOT

Over the course of twelve weeks, the project team worked with about 30-40 eleventh grade students (attendance varied) as they observed and mapped their local communities, while developing plans and models to present to officials at City Hall. During this time, we were able to pilot our (1) data collection methodology, (2) map processing and editing tools, and (3) map viewers. The project team also followed the students over the course of the semester to try to understand how the mapped data factored into the final park design ideas that were presented at City Hall. During that time, the Local Ground toolkit also evolved as the design team adapted the framework to incorporate new student artifacts, such as photos, class posters, and other supplementary graphics. At the final presentation at City Hall students were able to present a finalized map, with all of the information the students had collected about Nystrom using Local Ground.

5.1 Data Collection

At the beginning of the students' inquiry, they were asked to walk around and record their observations about their high school and the Nystrom neighborhood. The design team worked within the Y-PLAN's existing data collection framework, by simply adding bar-codes (using our tool) to the paper map templates they had already been using. In all, three paper-map-based data collection activities were conducted by students and community members; using clipboards, paper maps, and colored pens:

1. mapping observations of the students' high school
2. mapping observations of the Nystrom neighborhood
3. mapping broken streetlights in Nystrom neighborhood

5.1.1 Mapping Qualitative Observations

For the first two mapping activities, students walked around the school campus and the Nystrom neighborhood, recording their qualitative spatial observations onto their paper maps (Figure 1). Mentors prompted students by asking questions like "What do you like about this space?," and "What would you change?" Students wrote down whatever they felt inclined to document, in their own language, using their own symbols and references (Figure 5). Students were also given cameras to photograph different scenes as they walked around. They took many interesting photos – some of the houses, streets, landscapes, and construction workers, and others of broken glass, litter, potholes, and loiterers.

[4] KML is an XML-based file format for expressing spatial information developed by Google. However, it was made into an open format.

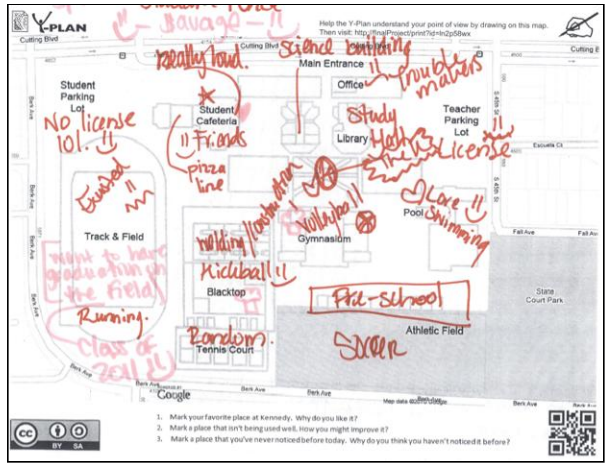

Figure 5. Student-annotated paper map

5.1.2 Mapping Streetlights

The design team also worked with a different local partner, the Martin Luther King Junior (MLK) Youth Council's "Safety Committee," to help document broken street lights as part of a larger Nystrom safety initiative. We learned, after a brief conversation with an employee from the City's utilities department, that the dispatch office needed to know each broken light's location, pole type (metal or wood), and serial number. Armed with colored markers and paper maps of the area, the design team and youth council members drove around the neighborhood one night for several hours, searching for outages. Other than printing the maps from our tool prior to the exercise and speaking briefly with the utilities department, there was no initial preparation or user training for the data collection. Rather, the group decided as we drove to the site, to record metal poles with a red marker and wooden poles with a green marker, and to write down serial numbers (we found that each light had up to four different serial numbers associated with it) in the margins.

As we drove through the neighborhood documenting broken lights, several of the mappers remarked that the darkest areas were not where the streetlights were broken, but rather where no lights were installed at all. MLK Memorial Park, for example, was extremely dark, and the council members mentioned that it felt unsafe. Spontaneously, the mappers circled the areas that were particularly dark, as well as buildings that seemed blighted or abandoned to them. Though the Safety Committee had originally set out to record information about broken streetlights, they ultimately documented other pertinent safety information as well.

5.2 Data Processing and Summarization

Following the data collection, the design team scanned the sixty or so paper maps that students and youth council members generated, and used Local Ground's data import tool to automatically geo-reference the images and extract the user annotations from the map background.

The design team also created a simple map editor (Figure 6) to tag and summarize the participants' annotations into a structured, summary view of the data. Using this editor, we drew a point or a polygon around each annotation and (1) transcribed the hand-written annotation, (2) assigned it a title, and (3) gave it one or more tags to associate the annotation with specific themes, for example "safety" or "street lights." When we didn't understand a annotation, we made a note of it and asked students later. An informal tagging convention evolved as we collaboratively summarized the data, as seen in Figure 6. This summarization process took about two hours total.

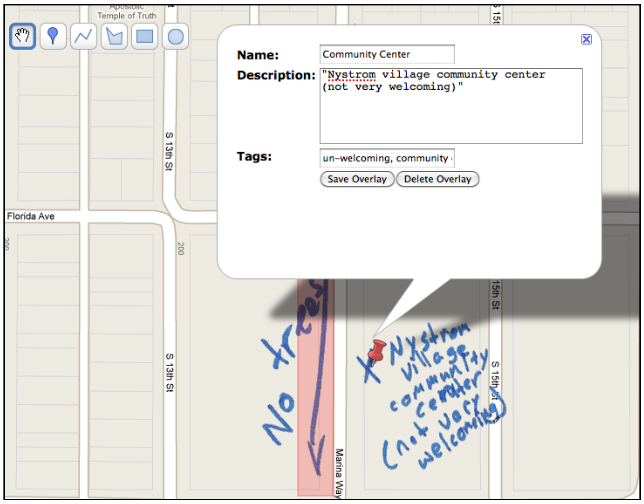

Figure 6. Map Editor

Figure 7. Photo of 3D student visioning model

5.3 Incorporating Other Artifacts

The design team also followed the Y-PLAN students through the rest of its planning process to understand how students used this data and their personal knowledge of the neighborhood to formulate action plans and recommendations. Following the data collection activities, students sorted through the printed photos and paper maps that they had created, and selected their favorites to use as raw materials in collages and posters. Students also made lists and "bubble diagrams" of problems and solutions, and worked in groups to build three-dimensional models of their community designs (Figure 7), using poster, clay, felt, and other objects. As these posters and models were integral to the students' decision-making process, the design team decided to manually geo-reference these posters and photos so that they could also be overlaid on base maps and aerial imagery in Local Ground's web map interface.

5.4 Using the Interface at City Hall

The field pilot culminated at City Hall, where students used Local Ground to communicate their ideas about the present and future of the Nystrom neighborhood to city officials. Student representatives from each class delivered speeches and presented PowerPoint slides (prepared with the help of the mentors). In the presentations, students described their observations and personal experiences of the neighborhood, and made recommendations as to how lighting, landscaping, sports fields, pathways, and youth-friendly programs and activities might improve the neighborhood.

There was also an open-ended portion of the evening, where city officials and guests circulated through the room to view the students' work over the past twelve weeks. An hour before guests were scheduled to arrive, the design team helped two of the students operate the "computer booth," to demonstrate the interactive Local Ground map and describe their mapping process to guests. Surprised to see their own handwriting and notes displayed "on Google," they quickly took control of the keyboard finding their own maps and those of their classmates. When the guests did arrive, the students informally presented their observations, photos, and models in the Local Ground map viewer, which described Nystrom as they experienced it.

6. STUDY FINDINGS

In this section, we present the main findings from the user pilot.

6.1 Scale and Context

Prior to the two mapping events with high school students, the design team ran pre-pilot data collection test at a local middle school. For this exercise, we did not correctly anticipate the students' walking trajectories, and hence did not provide maps that sufficiently covered the area walked. Because of this, students could not map their observations for places that went beyond the extent of the map boundaries. Moreover, as the printed map spanned several miles, it didn't invite detailed comments, as each annotation spanned several blocks.

Guided by this experience, when the mapping team prepared for the high school mapping and the Nystrom mapping events, we made sure that students had maps at the right size and scale. For context, the team digitized the outlines of all of the buildings, classrooms, fields, courts, and courtyards at the high school – since this level of detail is not available in the Google map tiles – and printed out paper maps marked with QR codes. We found that selecting an appropriate map scale was important, as it dictated the amount of space a data collector had to annotate. Map scale also determined spatial accuracy: annotations that were written on maps with a smaller scale were placed in closer proximity to the physical features to which they referred.

6.2 Data Input Modalities

Throughout the study, we used a number of data collection techniques – computers, hand-drawn annotations, photos, and video – to capture students' perceptions and ideas about space, each of which had benefits and drawbacks.

6.2.1 Computer-Based Mapping

In the beginning of the semester, the design team taught a short lesson in the school's computer lab, to introduce the concept of making a digital map. During this lesson, we showed an online map of the Nystrom neighborhood using Google Maps, and asked the students to go through the process of creating and adding a marker (i.e., contributing their own information). Though most students were eventually able to add their own markers to the map, there was definitely a learning curve, and most students required the help of a mentor. The project team noticed large variations in computer literacy within the class. We also found that the logistics of reserving the computer lab and ensuring that students had access to a functioning computer were not trivial, taking nearly a week of negotiating with school staff.

6.2.2 *Paper-Based Mapping*

In contrast to the computer lab - where four or five mentors took about twenty minutes to make sure that twenty-some students had marked a single place on the map - the students needed no hands-on instruction to draw on the paper maps, although prompts from the mentors helped to stimulate their imagination in the qualitative mapping exercises. Moreover, the logistics of paper and pens were much easier to administer, and the unstructured nature and familiarity of paper allowed each student to mark down ideas and notes in the way that was most natural to him/her. The project team noticed that since there were no technical hurdles to record observational data, students were free to discuss their surroundings and share anecdotes, rather than focusing on their interaction with a computer.

6.2.3 *Cameras and Videos*

During the mapping exercises, we handed out two digital cameras that students took turns using to photograph their observations. The imagery captured by students was extremely compelling, and ranged from a beautiful community garden and light-hearted photos of their classmates, to "uninviting" signs and a group of people loitering outside of a methadone clinic (Figure 8), ironically located next to a playground. Like the paper maps, the photographs were open-ended, and were able to capture relevant, but unexpected observations as the students navigated through their high school and the neighborhood.

Figure 8. Photo of methadone clinic, taken by student

6.3 Structuring Unstructured Data

Though Richmond was only eight miles away from Berkeley, the design team, the U.C. Berkeley mentors, and even City staff were decidedly outsiders, both in terms of understanding what it was like to live in Nystrom and how teenagers experience the area. Though, arguably the City Manager's office and the Housing Authority could have created a survey with multiple-choice or Likert-style questions, such a strategy assumes that survey designers have adequate prior knowledge of problems and assets; that questions are worded using language that is understandable to teenagers; and that the City and the teenagers find the same things important. Had such a top-down strategy been employed, important information – pertaining to questions that no one thought to ask – would never have been captured. The Y-PLAN coordinators felt that a more open-ended, exploratory strategy of data collection was most appropriate, since so little was known of the students' perspectives at the beginning of the semester.

Local Ground supported this open-ended approach to data collection. Though every observation that was written on a map was automatically associated with a particular place and time, the observation itself could be anything that could be written down or drawn. Students, using paper and markers, were able to express what they thought was worth noting in their own way, using a wide variety of symbols and slang. For the high school mapping, students documented how spaces were used by drawing images of cupcakes to mark popular make-out spots; smiling or frowning faces to indicate likes or dislikes; and candid descriptions of the buildings and the nearby park, revealing colloquial place names. For the Nystrom mapping, this included annotations like, "looks like a crack house" (referring to the Nystrom Community Center), "trash everywhere," or "robbery type area" (

Figure 9). One of the open questions in our study was how then to summarize these unstructured, hand-drawn annotations in a way that could maximize additional collaborators' understanding of the community-generated data. Local Ground's data editing tool and summary map viewer was a first attempt to make sense of this information by making it browsable and searchable.

Figure 9: Selected student drawings of Nystrom

As the design team began using the map editor to tag the data, we found that whereas some information, such as "broken street light" or "broken glass everywhere" was relatively easy to interpret, other information, such as student drawings, required us to follow up with the students. For example, we noticed that a number of students had drawn pictures of cupcakes on their maps of the high school, which confused us. When we consulted with a few students and asked them why so many people drew cupcakes, one student told us that cupcakes symbolized places where teenagers "either 'make out' or...god knows what they do there. Some people call them lovers' spots."

6.4 Facilitating Dialog

The cupcake example illustrates one of the biggest trade-offs made when using an unconstrained data collection methodology, such as the one supported in Local Ground: because structure isn't imposed up front, an additional interpretive step may be necessary after the data is processed, depending on the context. Furthermore, it may be the case that only someone from the community that generated the data in the first place can interpret it.

Interpretation, however, is always required in the planning context. At the beginning of an engagement between vastly different groups of people, say, city officials and teenagers, the inner workings of a city budget are likely as foreign to a teenager as a fun teen hangout would be to a city planner. That being said, both the teenager and the city planner have to learn a bit about each others' perspectives in order to successfully collaborate. Through Local Ground, initial city plans - created from a planners' perspective - could be overlaid on the same map that a group of teenagers uses to display notes, photographs, and plans of their own. At City Hall, the design team observed that the map fostered a meaningful dialog between two very dissimilar groups. As one student explained to a guest at the computer booth:

> "If you click right here, it shows all our maps stacked up. I think it looks better stacked up because it shows everybody and it shows a more artistic view."

The guest responded saying:

> "I like that, though. It really gives you a sense of the complexity of the place – it's multi-layered and there's [sic] all kinds of different things that you have to take into consideration."

By looking at a map which contained boundaries and aerial imagery (familiar to the city official) and drawings and photos (familiar to the student), a common dialog could take place that facilitated a shared understanding of the underlying place. Though Local Ground certainly could not substitute for the face-to-face dialog itself, by displaying many collaborators' ideas and perspectives at once, each party could ask clarifying questions, which in turn encouraged a richer conversation.

6.5 Qualitative and Quantitative Information

During our pilot, the design team explored how QR-coded paper maps could be used for both qualitative information and quantitative information. For more qualitative information, such as how a space felt, or looked, the flexibility and openness of paper made it an ideal medium. For more quantitative information, such as the streetlight enumeration, we found that paper was equally well suited.

During the streetlight mapping, two of the mappers noted that it was difficult to stay oriented while marking locations on a paper map from the back seat of a moving car. Because of this potential for error, we decided that three people should record the same street light outage data, for quality purposes. This redundancy proved to be very useful once the scans had been processed: if one of the streetlight locations had been marked incorrectly, there were two other scans to compare against. An example of this can be seen in Figure 10, where three green dots at the bottom right-hand corner of the map (labeled with the number "3") – extracted from three different paper maps – all refer to the same street light outage. Note that two of the dots are marked on one side of the street, while the third is on the other side.

The design team cross-referenced these markings with Google's aerial imagery, in order to find the closest streetlight to the paper map annotations. Using the editing tool, we then documented the precise coordinates of the streetlight relative to the aerial photograph the serial number and pole type and sent it to the utility companies and to the city. All the lights were fixed within three weeks.

During this process, we found that paper was also useful for recording unanticipated and unsolicited information. As mentioned above, we ended up also recording information about empty, dark, and seemingly abandoned places. In Figure 10, we see that the same paper was used to document broken street lights was also used to document an "empty lot" (top left), and numerous other observations. Following the street light mapping, one of the Safety Committee members reported to a partner NGO that there weren't as many broken street lights as she expected, but that there were entire blocks that had no lights installed at all – especially around the park.

Figure 10. Street Light Mapping Data

6.6 Visibility of Community Data

Based on both interviews and observations, everybody liked seeing the actual student annotations overlaid on the digital map. Students wanted to see what everyone else had drawn, and immediately understood when and how the information had been collected. An NGO employee noted during an interview that the summary view was helpful, but that she would also want to be able to drill down to find out how annotations had been summarized, and who had created each. She stated that she would weigh a local resident's opinion differently from the opinion of a city planner.

Y-PLAN staff and mentors also liked being able to see the students' work on the maps, but from the lens of community empowerment. They felt that having the students' data and three dimensional models available online was another way to honor student work, and they found it very powerful. Throughout the semester, there was much discussion about the lack of "good news," due to Richmond's national reputation for high-crime. Having a way for student ideas and voices to be heard by a wider audience had universal appeal to Y-PLAN mentors and staff.

7. DISCUSSION

7.1 Paper Keeps Things Fun

The design team found that community collaborations are both serious and lighthearted at the same time. Though community members and paid employees come together to carry out important work and solve common problems, community participation is largely dependent on volunteer efforts, so the process must be fun. The free-form and flexible nature of paper allowed data collectors to express their ideas in their own way, using their own language. As the students walked around campus and their community, the flexibility of paper allowed them to be themselves, rather than having to fit their responses into a predefined data entry form. Later, when students were actually able to view their own maps on a Google Map, they thought it was hilarious to see their own slang superimposed on top of satellite imagery. Given that participatory mapping and visioning exercises designed to foster creativity, reflection, and self-expression, the bar-coded paper maps honored the spirit of community collaborations.

7.2 Paper Accommodates All Information

Paper allowed for flexible expressions of space, and could be adapted, on-the-fly, to fit a number of different scenarios. Using the exact same paper interface, we were able to collect information about high school cliques, beautiful spaces, litter, broken streetlights, and areas that felt dark or unsafe. Paper served as an all-encompassing medium for community experiences, allowing for locations, observations, perceptions, and ideas to exist together. We speculate that, especially for more exploratory contexts, where the questions to ask of community members are not well known in advance, paper maps could provide an ideal medium to document local knowledge and experiences.

7.3 Paper Is Cheap and Simple

In a chaotic high school setting, teachers and mentors are not interested in adding more complexity to the learning process. Hence, a simple data collection medium that doesn't require special training, maintenance costs, or batteries make paper an easy choice. Paper requires a fraction of the training and equipment that alternate data collection strategies would have required.

7.4 Paper Integrates with Existing Processes

Paper maps also succeeded because they were familiar, requiring no training or special devices, and fit well with existing processes. In the case of the Y-PLAN, students collected spatial data in the same familiar paper-based way, except that barcodes were embedded in the maps, allowing information to be extracted and displayed online. Finally, the students were all familiar with doodling, drawing, and note-taking. Whereas teaching students to create a Google map marker took around twenty minutes and scheduled computer lab time, mapping with colored markers was understood immediately.

7.5 Paper Requires Interpretation

The design team found that we needed the students to translate several of the high-school specific references in the paper annotations during our summarization process. Depending on the context, such colloquial data could be of vital importance to a project, and exploring ways for community members to simply communicate salient observations that might not be easily understood by other parties – whether through tagging and summarization, video or audio, or some other mechanism – could be an interesting research direction. Such a feature could also help to build a coherent archive of project-relevant community data, and further strengthen communication across stakeholders over the life of a project.

7.6 Computers Lend Support to Community Voice

Providing students with the ability to publicly display their data at City Hall helped them to demonstrate that their arguments and ideas were based on evidence: observations, photographs, and personal experiences. For example, after students documented and took photos of the methadone clinic patients loitering near a playground, the City Managers' Office, who was not aware of this issue, took immediate action by contacting the clinic to begin a dialogue to arrive at a better arrangement. Had students not documented this observation, such information might have been lost. Similarly, at City Hall, one of the students explained to the audience:

> "There's Nystrom Village and there's a liquor store and in between them there's a busy street. So if we had a snack bar in the community, it would prevent people from walking across the street where it's unsafe."

Students had documented the traffic and the liquor store during the paper map exercise, so their message was reinforced by their online Local Ground map.

8. CONCLUSION AND FUTURE WORK

We have described the Y-PLAN inquiry process and the ways in which they used the Local Ground technology to support the collection, analysis, and use of place-based information. We were able to achieve our primary objective of collecting and processing qualitative geo-spatial data, in a community development context, using bar-coded paper maps. We were also able to explore the beginnings of an interface that supports browsing, searching, and visualization of information collected in this manner. Finally, we were able to observe how Local Ground was used to publicly present students' hand drawn map data, integrated with other data sources – photos, schematics, and other qualitative maps – to city officials and community members. We found that paper was simple, fun, and accommodated a wide variety of quantitative and qualitative information.

However this work has only just begun and many questions still remain. In future research, we would like to explore how Local Ground could be applied to support more community outreach efforts in international development. As a sound understanding of the local context precedes any good development project or process, we feel that Local Ground be invaluable in helping international support organizations communicate more effectively with the communities they serve. We would also like to explore the plausibility of using paper as a viable medium for collecting quantitative data, such as diseased plants, blighted houses, parcel boundaries, or agricultural data. Standardized stamps and stickers might help further automate this process.

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