Crossmedia Imaging of Latin American Informal Cities

"Learning from the existing landscape is a way of being revolutionary for an architect. Not the obvious way, which is to tear down Paris and begin again, as Le Corbusier suggested in the 1920s but another, more tolerant way; that is, to question how we look at things."

—Robert Venturi, Denise Scott Brown and Steven Izenour, 1972

ADIB CÚRE
University of Miami

CARIE PENABAD
University of Miami

CHRISTOPHER MADER
University of Miami

Gaining accurate data on urban informality is essential to address a range of pressing issues such as housing, healthcare, transportation, economic competiveness, security, and environmental wellbeing that affect the living standards of city residents. Mapping informal cities, however, poses many challenges. The methods often used by governments and private contractors rely heavily on computer modeling based on satellite and aerial images. These approaches have been criticized as inadequate both in terms of their mapping quality and their top-down approach to data collection. More promising are community-driven strategies, which involve residents of informal settlements in the gathering, processing, and control of information about their urban environment. The end result is often not only more accurate mapping data, but also the enhancement of grassroots campaigns that contribute to community empowerment and democratization.

This paper will present the work of various interdisciplinary design studios that have sought to strengthen and facilitate local, community-driven efforts by designing a set of innovative mapping practices that serve as the basis for our design decisions. Our goal is not merely to provide a technological quick-fix, but rather to create a set of adaptable tools that overcome current deficiencies in mapping and that will enhance modes of development that engage residents of informal settlements as protagonists of social improvement.

Our new "toolkit" includes software for mapping using hand-held mobile devices as well as advanced image analysis collected by autonomous aerial vehicles (also known as drones): together, these methods allow for a level of mapping detail, ease of use, and frequency of observation currently not readily available at a reasonable cost. Our ultimate goal is to create freely available ("open source") tools that will help to provide accurate and comprehensive data for documenting urban informality and for predictive modeling. The capabilities of these systems will allow urban designers and architects, local communities, governments, development agencies, and researchers to monitor trends in urban growth, improve public policy decisions, respond to urgent crises, understand urban life, and create more resilient and inclusive cities.

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Figure 1: Fisherman's Shack, Las Flores informal settlement, Barranquilla Colombia, *on-site photo*

WHAT WE HAVE ACHIEVED THUS FAR

For the past several years, members of our team have been working on multiple design, technology and outreach components of this project. Faculty from the School of Architecture have organized design studios on the topic of informality in architecture and urban design and conducted research on urbanism in informal settlements in places such as South Africa, India, Mexico, Colombia and Cuba.

In pursuing these projects, the School of Architecture collaborated with the Center for Computational Science Software Engineering Group to explore developing software tools for mapping and documenting urban and demographic features of informal cities. As a result of this collaboration, we developed a concept for a mobile device (Android) application for use in recording and documenting these features. In addition, we have used quad copter drones to obtain aerial photos and produce a series of photomosaics at the various sites. Thus far, we have developed key software to support this process, which includes software to correct for lens distortion and other necessary steps in the process of creation of orthorectfied photomosaics for map making. Finally, the group has also been researching existing open source software components that can be used and integrated to support the entire map making (and map serving) process.

A number of efforts exist worldwide that are aimed at producing maps and other documentation of informal settlements. There are mapping efforts (e.g., Map Kibera) and tools (e.g., OpenStreetMap) that are currently being used, but there exists a great opportunity to improve and contribute to the body of resources currently available. For example, Slum Dwellers International has organized projects since the mid-1990s aimed at elevating the visibility and interests of these communities with respect to their local governments. Enumeration and map making efforts are often the essential first step in gaining better access to infrastructure (e.g., water, sanitation, public transportation), and establishing land tenure thereby helping to prevent peremptory eviction or destruction of housing. Current methods of mapping employed by these projects typically combine some type of aerial photography with an on the ground mapping effort (measurements and photos taken on the ground). The aerial photographs are often obtained from archival sources such as Google Earth or local archival photos produced by a traditional aerial survey. While Google Earth is an excellent public resource for obtaining these types of images, the resolution is at best 60cm/pixel, which is often insufficient for making detailed maps in densely settled areas, where individual structures may only measure several meters on each side.

Recently (especially during the past year) small autonomous aerial vehicles (aka drones) have received a great deal of attention in the press with respect to their possible application for delivery of goods, surveillance systems, photography and remote sensing for numerous applications. Some of this increased attention is due to the pending release of FAA rules regarding their commercial use, but much of it also reflects the fact that these devices have evolved technologically to the point where they are now truly practically useful.

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During the past two years our collaborative team has been experimenting with using drones and other mobile computing technologies for mapping and documenting informal settlements (aka slums) throughout Latin America. While we are absolutely convinced of the applicability of this technology to our specific area of interest, we are also certain that it can be successfully applied in many other domains, such as; agriculture, construction and engineering services, mining, architectural preservation, archaeology, and journalism. Also, an increasing number of Universities and other educational institutions are creating programs related to applied drone technology. Applied drone technology provides an excellent venue for establishing interdisciplinary curricula and research; and there are opportunities to catalyze projects with contributors from (at least) the areas of architecture and urbanism, computational and computer science, engineering (electrical and civil), ecology and other natural sciences, as well as journalism and geography.

RESEARCH METHODOLOGY

Our drone applications initiative explores practical applications of UAV technology for imaging, mapping sensing and other uses through the following steps:

Figure 2: Figure ground plan, El Pozon Informal Settlement, Cartagena, Colombia, *digital student drawing*

DATA COLLECTION AND COMMUNITY ENGAGEMENT

At each site we conduct aerial and ground-based photographic surveys, using drones and hand-held cameras; and the collected photographs form the foundation of our map-making efforts. We also apply standard ground-based surveying techniques using a dual frequency GPS to collect control points, which can be used to precisely georeference the data. Our maps have a resolution of at least 3–7 cm/pixel, and in some instances even 1 cm/pixel, which is substantially higher than the typical civilian satellite imagery (i.e. Google Earth at approximately 60cm/pixel).

The system is also relatively easy to deploy and provides a rapid means of producing a record of the current state of the settlement, allowing for inexpensive regular surveying of sites to monitor or assist changes in development. The drone and camera that we are currently using together cost less than US$1800, which is significantly cheaper than the cost of a traditional aerial survey. These small drones fly at a lower altitude that allows for the precise document of the fine grain urbanism associated with informal settlements and are also portable, making it possible to ship them using regular mail and share them between multiple sites and organizations.

Learning to operate and program the drone and process the photos into an orthorectified photomosaic and producing a digital map that can be shared on the web or used by other software applications requires gaining a variety of different skills that present a significant barrier of entry to anyone unfamiliar with the process. However, when this barrier is lowered by developing techniques and systems (software and hardware) that are easy to use, there is significant potential for the democratization of this technology, giving independent local groups the capability of using these systems in their own communities.

POST SITE PROCESSING

Using tools and systems currently available at our Computational Science Center, we process the images to produce a set of 3D models and orthophotos, as well as use the collected control points to accurately position and orient these images on the globe. The resultant images are loaded into an ArcGIS database where they can then be used for annotating features as necessary.

FEATURE ANNOTATION

Annotation of our current images is done to map a variety of data (both spatial and temporal) including the perceptual boundaries, identification of lots and lot dimensions, construction materials, building typologies, uses, transportation networks, inter settlement trade networks, evolving/new constructions etc. Each of the annotation types listed above will appear as separate GIS

PUBLICATION OF RESULTS

The ultimate goal is to publish our maps, photos, models, annotated features (as data) and other documentary materials through a number of channels. We are currently developing a website to showcase the overall research initiative, as well as the individual mapping projects. This website will showcase a novel web-based tool for exploring the maps, photos and annotations that will be developed by our software engineering group. In addition to making maps and data available through the initiative website, we will also contribute data to OpenStreetMap (OSM)[ref], the well-known effort to provide a free and editable map of the world. Making our data available on OSM will be a useful contribution to this public resource, but will also make the initiative visible to a wide audience. We are also exploring the possibility of releasing the data and maps to the Instituto Geográphico Augustín Codazzi (IGAC), which is the official cartographic agency of Colombia.

RESEARCH & DEVELOPMENT ACTIVITIES

Possibly one of the most important outcomes of this initiative will be the establishment of infrastructure for higher throughput processing of aerial (and other) photos into 3d models, composite orthophotos and maps. We currently have the ability to do this on a moderate geographic scale (essentially the area covered during a single flight of a drone, approximately 60K m2) and can combine these moderately sized output sets together to cover large regions, however by making use of our software engineering cluster, we will be able to process much larger sets of input images directly.

Open source libraries exist that can be either directly used, or ported to the cluster, but this effort will require some significant time investment. Furthermore, once we have this high throughput capability we will also need to develop some software infrastructure components to manage the input and output information (photos and composite images) in a well organized fashion.

APPLICATION OF COMPUTER VISION TECHNIQUES FOR COMPUTER ASSISTED ANNOTATION OF MAPS

Using experience and capabilities developed during other projects for the high throughput automated classification of images, we will experiment with automatically extracting features such as; buildings, roads, vegetation and bodies of water (for example). We will also experiment in using these same techniques for change detection images taken at different points in time.

INVESTIGATION OF OTHER TYPES OF SENSORS

Currently, all input data are optical images, however we are also interested in exploring acquisition and processing of multispectral images, LIDAR and audio information. Inexpensive sensors of these types are currently available and can be mounted on small UAVs and used to collect these kinds of data. Multispectral images can (for example) be used to build metrics for plant health, which can be used in urban planning/management, agricultural and natural sciences applications. LIDAR can be used to help enhance 3d models

RESEARCH PRODUCTS AND CAPABILITY CREATION

Tangible outcomes from this initiative will include publicly available resources in the form of databases, websites, code and publications as well as new techniques and practices for surveying and creating maps, and materials on which to base and develop new academic courses.

ARCHITECTURAL STUDIOS/ DESIGN PROJECTS

Our team has organized a number of funded upper level design studios that have traveled across the globe to document a variety of informal settlements. These sites have included Barlovento and Las Flores in Barranquilla, Colombia; Santa Cruz del Islote along the San Bernardo Archipelago in Colombia,; Joe Slovo in Cape town, South Africa; and Shaka in Mumbai, India. Learning from these sites first hand has been an essential part of the educational process; and has allowed students and faculty to understand the complex urban patterns that are largely influenced bye geographic circumstances, social conventions and cultural traditions. When students map an existing site and meet with community leaders, they are less likely to propose a tabula rasa design strategy that erases the fine imprint of these communities; but rather they seek more sophisticated and nuanced solutions that respond to the dynamic conditions of these complex urban settlements.

The detailed programs for the given projects have been developed based on on-site observations as well as interviews with the community; and while projects range in both scope

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and scale they are often concerned with two aspects of the urban environment: the lack of public open space and amenities and the need for infrastructural projects that are capable of connecting these sites (both physically and socially) to the adjacent "formal" city. Proposed projects have included designs for public open spaces, communal dining halls, transportation networks with integrated bus shelters, housing prototypes, communal shading structures; outdoor markets etc.

ON-GOING EFFORTS

Sustained funding for this project has permitted us to devote sufficient software engineering time to refine the mapping techniques discussed earlier and to further develop the community outreach mechanisms necessary to support these kinds of documentation efforts. Our objective is to make a sustained improvement of mapping techniques and to scale up our initiatives to address the needs of different types of informal settlements across the region.

The interdisciplinary team has begun to coordinate efforts with grassroots organization to design community outreach and engagement strategies integral to the success of informal settlement mapping efforts. We have produced an extensive series of urban and architectural drawings that permit us to compare and contrast the morphologies of informal settlements and their dynamic urban assemblages. We continue to manage the software development and map-making efforts of the project and provide technical leadership for development of the android application as well as web-based software system components.

In early 2014, we carried out a pilot project in Santa Cruz del Islote, a small island settlement off the coast of Cartagena, Colombia. Santa Cruz del Islote is located on a small key and measures approximately 200 meters on each side, making it very practical to document in a short period of time and (indeed, this community is among the most densely populated in the world). This project produced a compelling set of interactive web-based maps that exposed and presented key features of the informal landscape. The project also produced a GIS database of features and a set of video and photographic presentations. The project has the potential to train teachers and students on how to use these tools to further develop the maps of Santa Cruz del Islote. This increases the accessibility and relevance of the project, as well as the knowledge and engagement of the community. Beyond the initial pilot of this project, its role in community development and education—locally, nationally, and internationally—has tremendous potential for growth.

We envision the development of a platform that allows us to incorporate different dimensions of the informal city: the economy, transportation and mobility, the public realm, garbage treatment, cultural life, and so on. These and other dimensions connect the formal and the informal. The current work is poised to provide the type of spatial platform that will allow multiple stakeholders to understand the life of the informal city, engage in broad dialogues around concrete aspects of urban life, and generate innovations that are not evident without a proper grasp of the ever-changing urban space in these settlements. Our dialogues with community leaders, social entrepreneurs, scholars, and other actors have clearly indicated that planning and policy are not viable without adequate and systematic information about the physical communities themselves.

Figure 3: High Resolution Aerial Image,
Las Flores Settlement, Colombia