Spatial legal identity through the spatially enabled addressing system. A case for informal settlements

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Keywords: Spatially enabled; address system; bisection method; legal identity

SUMMARY

An addressing system is an important aspect of modern-day society. In addition to contributing to one's legal identity, it serves as a linking point between service providers (mainly government and businesses) and the citizenry. While traditional addressing systems are very important and in use, they are very few in most developing countries - Uganda inclusive. Characterized by unplanned settlements, the scarcity and in most cases absence of such systems make service provision at an individual household level difficult if not impossible.

The lack of addressing systems emanates from a lack of an enabling infrastructure in most developing settings. By utilizing cascading geographies and the enabling qualities of Geographical Information Systems (GIS), however, spatially enabled address systems can be conceptualized and realized.

This paper proposes and realizes an addressing system using alphanumeric cascading coded geographies that divide the country into enveloping polygons from the national- to the household level. The households were generated from national building footprints, themselves derived from OpenStreetMap (OSM) and updated with high-resolution satellite imagery. Python framework was used for the management of both the front-end and the back-end manipulations. In the end, a harmonized geospatial database of both building footprints and the corresponding enveloping addresses was developed enabling a 2-way retrieval of spatial location given the address code and vice-versa.

Visualized through an interactive website and a corresponding mobile application, results show that each household can be located with an alpha-numeric code, enabling independent navigation to the address code when a building footprint location is specified. This independent location of households provides improved service provisioning, data integration, linking, and prospects of aiding electronic (e-) governance through facilitated 2-way communication between businesses, government and the citizenry.

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1. INTRODUCTION

In many progressive societies, the government and its authorities need to communicate with the citizenry and the citizens need to communicate with the authorities (Manoharan, Ingrams, Kang, & Zhao, 2021). Classically, this two-way communication often takes the form of letters and other write-ups sent to specific addresses where the beneficiary (addressee) is registered. While an address in this case acts as the end-point of the communication link, addresses have wider applications as they are primary requirements for universal legal identity (Universal Postal Union, 2012). The Sustainable Development Goals (SDG 16.9) define legal identity as "the recognition of a person's existence before the law, facilitating the realization of specific rights and corresponding duties" (Oppenheim & Powell, 2015).

While this legal identity definition is wide, close examination emphasizes the recognition of a person's existence. This further points to answering the three questions of 'who the person is' – name, 'where the person can be found' – address and 'what does s/he do for a living' – profession. Unfortunately, these records (Name, Address, and Profession) remain out of reach of the world's poor. The United Nations Development Programme (UNDP) in its communication on "Legal empowerment: linking addresses, identity and land, and property rights" contends that an estimated 4 billion people live outside the protection of the law due to a lack of legal identity (Universal Postal Union, 2012).

To this end, it should also be noted that the 'who' question (name and profession) is fairly understood and is answered through the issuance of personalized national identification cards. What is not fully handled in most settings, especially those in the developing world, is the component of the legal identity concerned with 'where the person can be found' for this points to having some form of an addressing system/infrastructure in place. Having an addressing system facilitates the seamless dissemination of information, and in countries where they exist, they constitute one of the most essential tools for locating events, phenomena, and/or information relating to citizens, business, and public administration (Lind, 2008).

An address can be understood as an unambiguous specification of a point of service delivery, with the point of delivery denoting the actual location where the service is to be provided (Coetzee & Cooper, 2007). Addresses, therefore, aid in (1) the formal identification of citizens; (2) enabling easier navigation around the city; (3) facilitating the delivery of emergency services – health, police, fire; (4) location of urban facilities and amenities; (5) improving planning and management of municipal services; (6) improving tax revenue collection; (7) providing a platform for better management of utilities. Therefore, the role of an addressing system can be summarized as the ability to determine a location (Gakh, 2020). This location can then be used in optimizing the applicability of development policies through targeting, reinforcement of the law, supporting electronic (e-) governance, and promoting democracy by expanding electoral participation (Bonica, Grumbach, Hill, & Jefferson, 2021). Consequently, it goes without mentioning that addresses, address systems, and address infrastructures are indispensable in accountable public governance.

Uganda, like many other developing nations, has no existing national addressing system. The only relatable system is the Post Office Box system operated by Posta Uganda (formerly Uganda Post Limited); a body solely responsible for postal services in the country – incorporated in 1998. With just about 300 post office branches and about 70,000 post office boxes most of them shared, it can be deduced that such a constrained network might not allow for personalized 2-way communication between the government of Uganda and its citizens (about 44 million now). This challenge points to the need to re-imagine, re-design, and implement workable options to supplement or even replace the current infrastructure.

The need for a national address system has long been recognized in Uganda. In the National Postcode and Addressing System Policy of 2019 (draft), the Ministry of Information and Communications Technology and National Guidance details this desire. In its preamble, the policy points to the need to have an ICT-driven Postcode and address infrastructure, in urban and rural areas alike (Ministry of ICT, 2019). Through the use of a national Geographical Information System (GIS), the policy also proposed to link such addresses and postcodes to the real world to leverage the advantages of spatially-enabled communities (Aturinde et al., 2019).

2.1 Problem statement

Addressing has its roots in street design and naming. As such, in communities where these two are not common, addressing too has suffered the same unappreciated fate. It can be said, with certainty, that the inability to effectively plan for people in underdeveloped nations has its roots in their inability to precisely know where their citizens reside and what they do. Such population-level information is only facilitated through some form of addressing, and sadly, this is missing for most rural and peri-urban settings of Africa and the developing world.

Having an addressing system is commonplace in most developed countries. Throughout their history, these communities have created ways of uniquely identifying and reaching the homes and residences of their citizens mainly through the use of Postcodes and Zip codes (Kirby, Delmelle, & Eberth, 2017). By taking advantage of GIS capabilities, these ‘codes’ are often geo-coded (to real-world coordinates) hence proving a way to uniquely and independently reach them using navigation technology. This not only brings public services closer to the people through mutual communication, but it also plays a key role in interventions reaching the intended beneficiaries (consider an ambulance dispatched to evacuate to an emergency case or prescription dispatched after a diagnosis through telemedicine avenues).

To put this into perspective, consider the details captured on a typical National Identity Card in Uganda. The location details of a hypothetical individual can be captured as “Kisaasi Central village, Kyanja Parish, Nakawa Sub-county, Nakawa Division, Kampala district.” Anybody conversant with this locality will confirm that these details are too coarse that independent identification of one's housing unit within Kisaasi Central is close to impossible for there are many houses to consider. It is even worse for the specific road where the individual stays is not listed, and neither is his/her house number. As such, in case of a critical emergency and an ambulance is successfully dispatched, it will take a long time to reach the patient, at best, or get lost at worst. For emergencies where every second counts, this ambiguity in providing precise patient-locational details could result in a loss of life.

This research, therefore, aims at providing a spatially-enabled addressing system for the informal settlements through a standardized use of alphanumeric characters to uniquely and independently identify households in the study area.

2.1 Objectives

The specific objectives are:

1. To design a multi-level enveloping system of quadrants with assigned alpha-numeric identifiers
2. To link the enveloping quadrants to the building footprint
3. To enable user-driven 2-way spatial querying of building locations

2. METHODOLOGY

2.2 Conceptualization

The study area was conceptualized as a single square grid capable of being subdivided until the smallest spatial unit (10 meters in our case). This 10m unit for the smallest addressable spatial extent was chosen to avoid very many iterations (Argyros & Khattri, 2013). It involved adopting a Bisection method of generating quadrant enveloping addresses (Burden & Faires, 2016).

The procedure involves creating child address quadrants that are subsequently enveloped by parent address quadrants up to the region of interest's spatial extent (Press, Teukolsky, Vetterling, & Flannery, 2007). Methodically, such a problem requires a root-finding technique that is capable of iteratively halving the parent quadrants' extents up to a preset child address quadrant as the minimum iteration.

2.3 The Bisection Method

Mathematically, enveloping address quadrants generation like all root-finding problems takes the form of function $f(x)$, where the process of finding the root involves finding the value of x for which $f(x) = 0$. If the function equals zero, x is the root of the function.

For a function $f(x)$ that is continuous on an interval $[a, b]$ and $f(a)\cdot f(b) < 0$, then a value c (a, b) exists for which $f(c) = 0$.

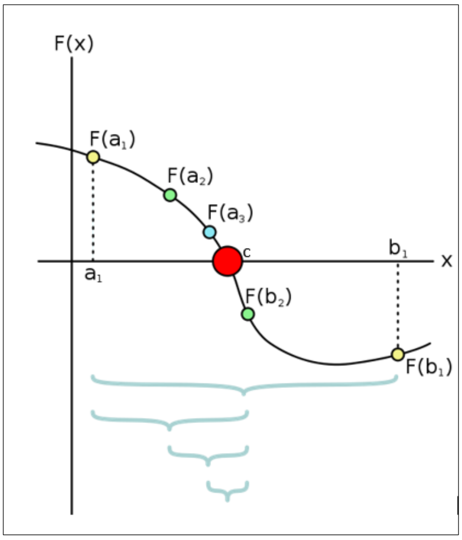


Figure 1: The Bisection Method

Let c = (a1 +b1)/2 be the middle of the interval (the midpoint or the point that bisects the interval). Then either f(a) and f(c), or f(b) and f(c) have opposite signs, and one has divided by two the size of the interval (Sikorski, 1982).

The Bisection Method looks to find the value of c for which the plot of the function f crosses the x-axis (Oliveira & Takahashi, 2020). The value of c is in this case an approximation of the root of the function f(x). How close the value of c gets to the real root depends on the value of the tolerance set for the Bisection Method algorithm.

2.3.1 Bisection Method Algorithm

For a given function f(x), the Bisection Method algorithm works as follows:

Algorithm 1 Bisection Method for Generating Quadrant Addresses

inputs
Two endpoint values (quadrant extent) a, b for which
An optional tolerance TOL,
Maximum iterations $NMAX$
Require: $f(a) > 0$ and $f(b) < 0$
outputs
A midpoint c is calculated as the arithmetic mean between a and b,
$c = (a + b)/2$
The function f is evaluated for the value of c
if $f(c) = 0$ **then**
we found the root of the function, which is c
else
$f(c) \neq 0$ we check the sign of $f(c)$:
$f(c)$ has the same sign as $f(a)$ we replace a with c and we keep the same value for b
$f(c)$ has the same sign as $f(b)$, we replace b with c and we keep the same value for a
end if

Figure 2: Bisection Algorithm

2.1 The QGIS Processing Framework

The Bisection Method algorithm was realized in a geoprocessing workflow within the QGIS environment.

The Spatial Legal Identity Tool (SLIT) plugin GUI was designed and developed using the Qt Designer, a lightweight application bundled with each QGIS distribution. The Qt development framework was used for its flexibility in developing applications that run on Windows, Mac, Linux as well as various mobile operating systems.

Specifically, PyQGIS with its vast python libraries was utilized in developing the QGIS plugin. Using PyQGIS, relevant python bindings were included in the QGIS design to display the plugin on graphical user interfaces for the geospatial analysis.

3. RESULTS AND DISCUSSION

This section details the outputs of the SLIT within the QGIS environment and is visualized through Figures 3, 4, and 5.

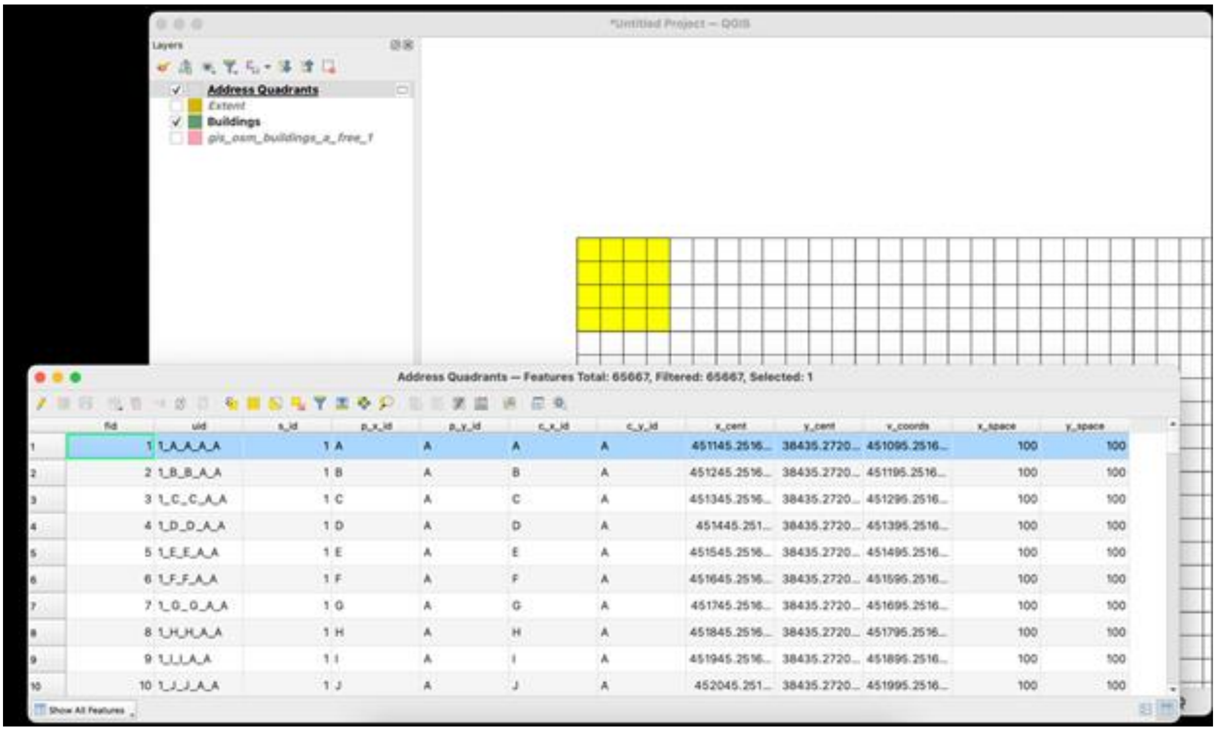
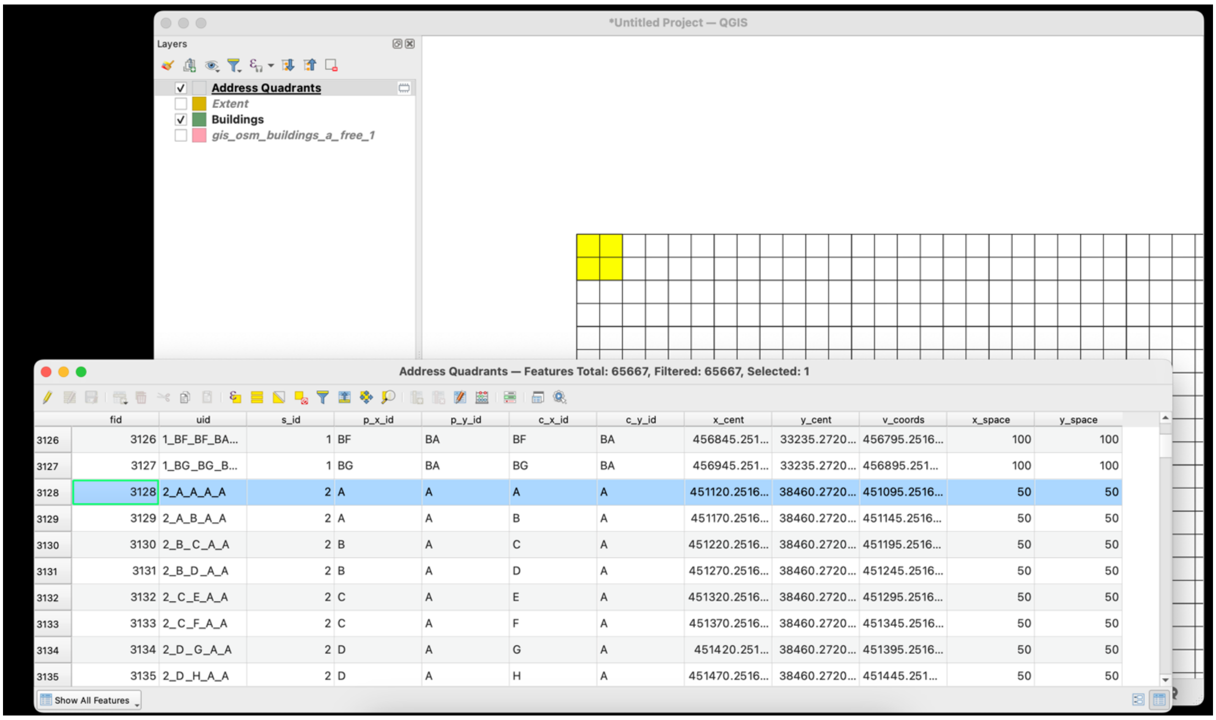


Figure 3: Level 1 Enveloping Parent Address Quadrants

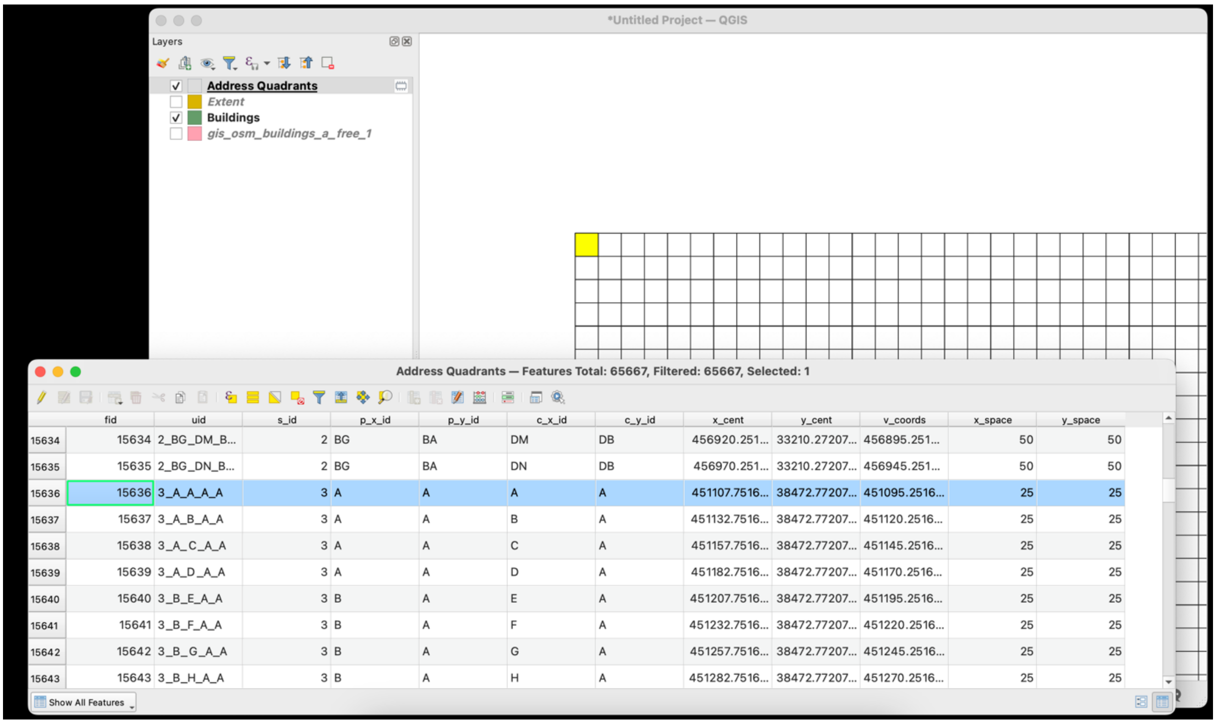
Figure 3 shows the level 1 parent address quadrant. It can be seen that each final quadrant can be reached after three iterative subdivisions, with each subdivision producing child subsets of the mother higher-level iteration. This is illustrated in Figure 4, where the parent address quadrant has undergone one subdivision.

The “1” in the alpha-numeric address code “1_X_X_X_X” shown in the attribute “uid” shows the level of the subdivision with the parent quadrant inheriting the “1” and the daughter quadrants having “2” and the grandchildren quadrants having “3”, and so on.



	fid	uid	s_id	p_x_id	p_y_id	c_x_id	c_y_id	x_cent	y_cent	v_coords	x_space	y_space
3126	3126	1_BF_BF_BA...	1	BF	BA	BF	BA	456845.251...	33235.2720...	456795.2516...	100	100
3127	3127	1_BG_BG_B...	1	BG	BA	BG	BA	456945.251...	33235.2720...	456895.251...	100	100
3128	3128	2_A_A_A_A	2	A	A	A	A	451120.2516...	38460.2720...	451095.2516...	50	50
3129	3129	2_A_B_A_A	2	A	A	B	A	451170.2516...	38460.2720...	451145.2516...	50	50
3130	3130	2_B_C_A_A	2	B	A	C	A	451220.2516...	38460.2720...	451195.2516...	50	50
3131	3131	2_B_D_A_A	2	B	A	D	A	451270.2516...	38460.2720...	451245.2516...	50	50
3132	3132	2_C_E_A_A	2	C	A	E	A	451320.2516...	38460.2720...	451295.2516...	50	50
3133	3133	2_C_F_A_A	2	C	A	F	A	451370.2516...	38460.2720...	451345.2516...	50	50
3134	3134	2_D_G_A_A	2	D	A	G	A	451420.251...	38460.2720...	451395.2516...	50	50
3135	3135	2_D_H_A_A	2	D	A	H	A	451470.2516...	38460.2720...	451445.251...	50	50

Figure 4: Level 2 Enveloping SubAddress Quadrants



	fid	uid	s_id	p_x_id	p_y_id	c_x_id	c_y_id	x_cent	y_cent	v_coords	x_space	y_space
15634	15634	2_BG_DM_B...	2	BG	BA	DM	DB	456920.251...	33210.27207...	456895.251...	50	50
15635	15635	2_BG_DN_B...	2	BG	BA	DN	DB	456970.251...	33210.27207...	456945.251...	50	50
15636	15636	3_A_A_A_A	3	A	A	A	A	451107.7516...	38472.77207...	451095.2516...	25	25
15637	15637	3_A_B_A_A	3	A	A	B	A	451132.7516...	38472.77207...	451120.2516...	25	25
15638	15638	3_A_C_A_A	3	A	A	C	A	451157.7516...	38472.77207...	451145.2516...	25	25
15639	15639	3_A_D_A_A	3	A	A	D	A	451182.7516...	38472.77207...	451170.2516...	25	25
15640	15640	3_B_E_A_A	3	B	A	E	A	451207.7516...	38472.77207...	451195.2516...	25	25
15641	15641	3_B_F_A_A	3	B	A	F	A	451232.7516...	38472.77207...	451220.2516...	25	25
15642	15642	3_B_G_A_A	3	B	A	G	A	451257.7516...	38472.77207...	451245.2516...	25	25
15643	15643	3_B_H_A_A	3	B	A	H	A	451282.7516...	38472.77207...	451270.2516...	25	25

Figure 5: Level 3 Child Address Quadrants

The final level (in this case level 3) quadrant as shown in Figure 5 allows for the specification of the centroid planer geo-coordinates associated with the quadrant (451107.75, 38472.77).

2.3.2 Linking the building footprint to the enveloping quadrants

Using the QGIS environment (Quick OSM plugin), the building footprint centroids of the study area from OpenStreetMap were extracted and stored as a comma-separated variable file. A spatial query (contained) was then used to link the enveloping Quadrants to the household/building footprint.

Our project, having conceptualized the location problem as a bisection problem, realized its set objective of uniquely identifying household locations. The addressing challenge is not new in Uganda and neither is it unique and has over time called for a solution; for example, there was a Postcode project piloted in Entebbe in 2013 (Ministry of ICT, 2019) even when it had limited spatial capabilities, and in many ways provided location labels only.

Additionally, in Kampala Capital City, the Kampala Institutional and Infrastructure Development Project 2 (KIIDP2) and CAMV/CAM project by the world bank (2018 to 2019) have provided location identifiers to most routes (roads, drives, lanes) and house labels within the Capital (KCCA, 2013) albeit lacking the much required navigational (and geocoding) components.

With the success of this concept, additional work needs to be directed towards evaluating the feasibility of the approach for wider areas. In our testing, the generated polygons quickly overwhelm the capabilities of most desktop computers demanding high-end servers to handle the rendering as well as the volumes of vector polygons generated.

Nonetheless, similar projects can be implemented in other areas, especially in the new cities with no historical address challenges. These projects in other cities would benefit immensely from the lessons learnt and approaches used in this project.

4. CONCLUSIONS

This project set out to design an addressing system capable of locating individual households using cascading enveloping polygons. The alpha-numeric codes inherent in the cascading enveloped polygons were used to reference the households uniquely, allowing for unaided navigation to the households.

Unlike the existing non-spatial POSTA addressing system in Uganda, our cascading enveloping polygons system, realized through the SLIT plugin, allows for the generation of unique address codes for all existing footprints in the study area. Additionally, through its universal coverage, the SLIT approach can be adopted for all settings where current address systems cannot afford coverage, as well as navigation.

In all, the SLIT, as a proof of concept, provides light on household-level addressing challenges, especially in countries with no history of formal addressing systems. The plug-and-play framework allows for seamless on-the-fly generation of permanent addresses that can stand the test of time as long as the underlying geo-coordinates are not changed (due to seismic activity, or tectonic shifts). The applications of this tool stretch from police to emergency, to civil administration, to doorstep delivery in business.

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BIOGRAPHICAL NOTES

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