Slum Modelling by using Ontology and Geoinformatics: Case study of Gulbarga

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Abstract:
India is undergoing a steady urbanization process and the current trend shows that the future is inescapably urban. Slums are a part of this urban reality, and this acute problem of slums occur not only in large cities but also in smaller cities and towns. Accretion of rural immigrants into the cities causes slums and the continuous changes in their aerial size. To address the problems of Slums, we should go for classy methodology. Using ontology on spatial model for detecting slums as well as using geoinformatics to model the slum growth could be one of the logical approaches in this direction. Hence here is an attempt to build ontology based slum model coupling with CA & MCE in GIS environment for Gulbarga city. The final result shows that, with ongoing urbanisation and large a rea under open space, Gulbarga is the most vulnerable city for slum growth.

1. Introduction

1.1 Urban Scenario

Cities are constantly changing. They are built, rebuilt, transformed, occupied by different groups, and used for different functions. Unfortunately, the urban expansion has often been associated with poverty and slum growth (UN-HABITAT, 2008). India is also undergoing a gradual transformation from a rural agrarian society to an urban society. Slums are a part of this urban reality and a combination of socio-economic, legal, and administrative parameters leads to the creation of slums in many Indian cities. To address the problem of slums, traditional census based approach and personal survey methods might not be useful and may require classy methodology (Naga Jyothi et al., 2008). Ontology can be used to identify the slums, and future growth of slums can be modelled by using geoinformatics. This could be one of the logical approach in this direction. With the advent of very high resolution data, it is comfortable to convert the spatial information in to knowledge input for urban planning. For the present study, ontology has helped to identify the factors responsible for the formation of slums and thus acted as the input for slum modelling.

1.2 Research Scenario

Accurate and detailed land use/land cover information are indispensable for urban land management and urban planning. The availability of high spatial resolution imagery provides new opportunities for detailed urban land cover mapping and offers an increasingly luxuriant area for research with studies focusing on slum mapping (Mason and Fraser, 1998, Sliuza et al., 2008, Hofmann, 2001, Sur et al., 2004 and Shekhar, 2012). Geo spatial technique also significantly contributes to this process, and has brought a surge of changes in urban research. (Batty and Xie, 1994a and 1994b, Clarke et al., 2002, Batty, 2003 and Shekhar, 2004, 2006). GIS and CA can be integrated to model, simulate, predict and dynamically visualize the growth of urban areas (Ward et al., 2000, Singh, 2003, Batty and Longley, 1994, Wegener, 1994 and Yeh and Xie, 2001). Integration of multi-criteria evaluation and GIS is also getting popular in recent years. Visual interpretation performed by interpreters familiar with local conditions provides a flexible and useful approach to slum mapping (Sliuzas, 2004, Baud et al., 2010 and Jain et al., 2007) though it has shortcomings and lacks control on quality over time and between interpreters. Recently ontological framework is used for defining slums and as a basis for image-based classification and modelling (Hofmann, 2008a, Hofmann et al., 2008b, Kohli, 2011, Khelifa and Mimoun, 2012, Sietchiping et al., 2004 and Sietchiping, 2005).

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2. Study Area

Gulbarga is a city in the Indian state of Karnataka (Figure 1), and it is the administrative headquarters of Gulbarga District and Gulbarga Division. The population of Gulbarga city is 5, 41,000 (COI, 2011b) and the total area is 64 km2 (GCC, 2012). The climate is hot and dry with an annual rainfall of about 750 mm (Gulbarga CSP, 2011). The city is undergoing rapid changes in terms of population growth as well as in the degree of urbanisation. It became a nodal centre for many developmental activities and many more projects were in the pipeline. Hence, Gulbarga started attracting the rural folk from neighbouring districts and the slum population is slowly increasing.

3. Data Base and Methodology

For the present study, cartosat data (2008) is used as spatial data. Other a spatial data includes data from Census of India and Gulbarga City Corporation. The methodology is shown briefly in the flow chart (Figure 2) and the mechanisms of building ontology to identify slums are discussed separately in detail.

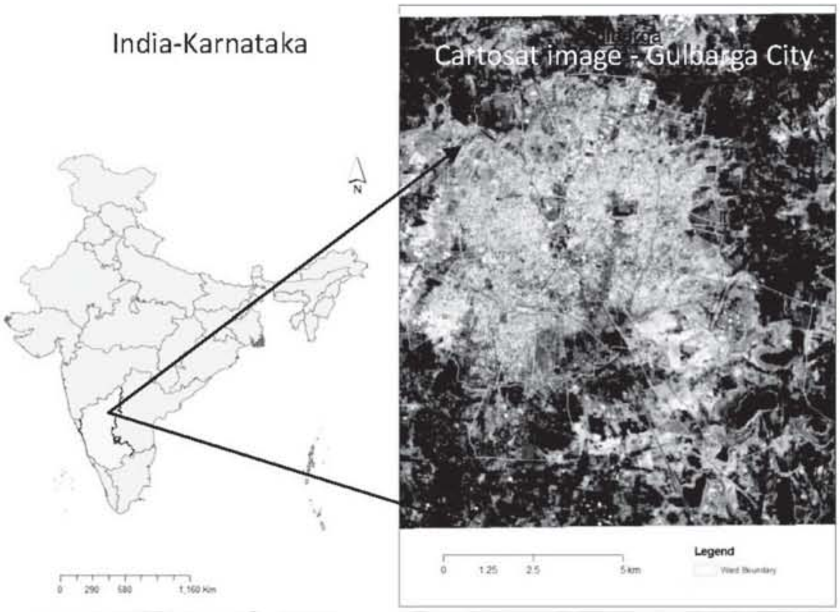


Figure1: Study area

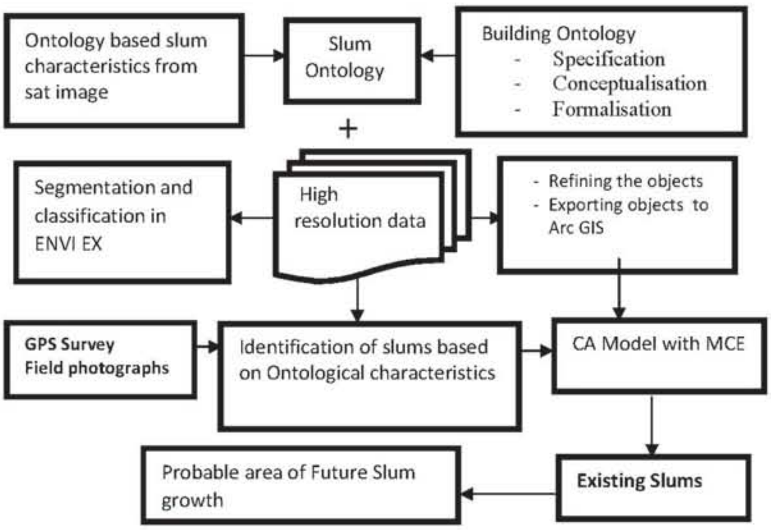


Figure 2: Methodology

3.1 Ontology

Ontology has acquired a lot of importance in knowledge representation in the past few years, and isused in a variety of fields (Matei, 2008, Guarino, 1995, Gasevic et al., 2009 and Casati et al., 1998) and now gradually paved its way into GI Science (Agarwal, 2005 and Kohl, 2011). Lot of Research Studies were carried out to define, to build and apply ontology in the urban environment (Gruber, 1993, Chandrasekharan and Josephson, 1999, Winter, 2001, Agarwal, 2005, Kohli, 2011, Belmonte et al., 2008, Fonseca et al., 2000 and Teller et al., 2007). The idea behind these studies is to get a common understanding of the domain of interest, facilitate information-exchange. Ontology is defined as a specification of conceptualization, i.e. an abstract and simplified representation of real world entities.

3.1.1 Building the ontology

Various methods are devised by experts in different contexts. In this study (with little alterations), the enterprise ontology developed by Uschold and Grüninger (1996) (Uschold, 1995 as mentioned in Fernández López, 2002) and specification, conceptualisation and implementation process of methontology developed on IEEE standards are used.

Specification: States why the ontology is being built and identifies the key concepts and relationships in the domain of interest. As per UN definition a slum household is a household that lacks access to improved water, improved sanitation, Security of land tenure, Durability of housing and sufficient living area, but all these criteria are difficult to detect from remote sensing images. Remote sensing (RS) images can only detect informality, high density, irregular morphology and spatial clustering (Turkstra, 2008). As per the census of India (2001,2011) definition, the only factor that can be recognised in the RS data is poorly built congested tenements.

Conceptualization: Conceptualization helps to structure the domain knowledge into meaningful models at the knowledge level (Figure 3). The slum characteristics, which can be identified, from high resolution images are Building Characteristics, Building density, Location information and Neighbourhood characteristics. Contextual information contained in the image is also an important source for detecting objects of interest (Jeon and Landgrebe, 1992, Yu et al., 1993, Houzelle and Giraudon, 1991 and Yu et al., 1999). Earlier research shows that slums excel in marginal or less valuable urban land such as riverbanks, steep slopes, dumping grounds, abandoned or unexploited plots, along transportation networks, near industrial areas and market places, and in low lying areas or wetlands (Global Urban Observatory, 2003, Kohli, 2012 and Shekhar, 2012).

Formalization: It transforms the conceptual model into a formal or semi-computable model. It is also expressed as "Coding" which involves explicitly representing the acquired knowledge in a formal language.

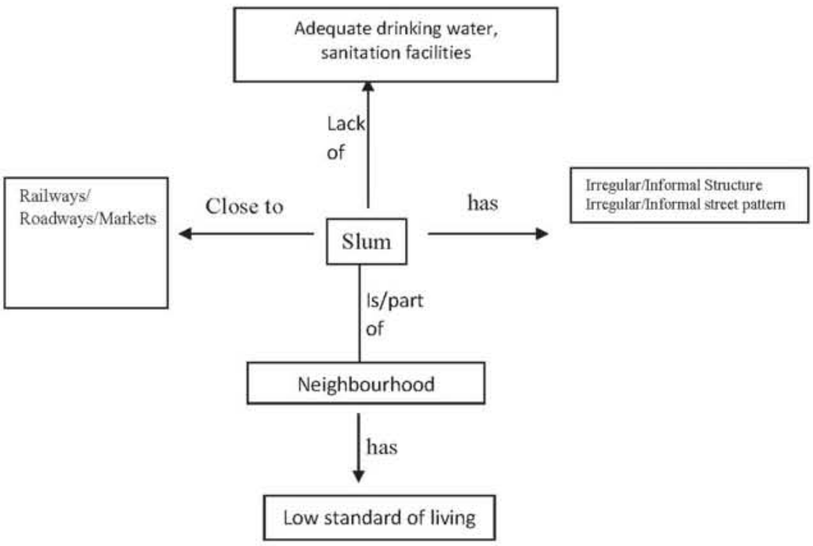


Figure 3: Slum ontology

Table 1: Formalisation of concepts (after Kohli et al., 2011 with local adaptation)

Level	Indicators	Observation	Image Interpretation Elements
Environs	Location	Close to highways, major roads, railways, open land	Pattern, Association
	Neighbourhood characteristics	Close to employment opportunities such as Market area industrial areas, middle/high socio-economic status neighbourhoods.	Pattern
Settlement level	Shape	Irregular, linear	Pattern
	Density	Highly dense compared to planned Presence/ absence of vegetation	Texture Association
Object level	Building	variable Range of values - 10 to 40 m^2 Roofs-slates/stones, concrete, tin sheets Range-variable Regular but clumped together	Shape (geometry) Size Texture Colour (in case of MSS data) Orientation Shadow - Association height
	Access network	Irregular , Haphazard Paved/unpaved access streets Range – variable	Shape Type Width

Implementation: It builds computable models in a computational language (Table 1). It also includes integrating existing ontologies such as generic slum ontology developed by Kohli (2011, 2012)

Evaluation and documentation: It is similar to maintenance of methontology (after Fernández López, et al., 1999) which updates and corrects the ontology. The developed ontology was evaluated through classification of cartosat data, GPS survey. The physical, socio-economic conditions were documented with the help of field photographs.

3.2 Cellular Automata and Multi Criteria Evaluation

Cellular automata (CA) comprises five elements such as Cell space, cell state, time step, transition rule, and neighbourhood. In CA, the state of the cell itself and the states of its neighbouring cells at a previous time step determine the state of a cell in the future. If a cell has a strong propensity for development and it can get support for such development from its neighbourhood, then development will occur to that cell. However, not all the cells in the urban system develop at the same time or the same speed. There are various conditions under which the change (transition) from one state to another state can take place. These conditions can be either physical, socio-economic, or institutional or combinations of any or all (Liu and Phinn, 2001).This information can be modelled to find the suitability of a particular land use say, slum for each cell, using Multi Criteria Evaluation (MCE).

3.2.1 Building the model

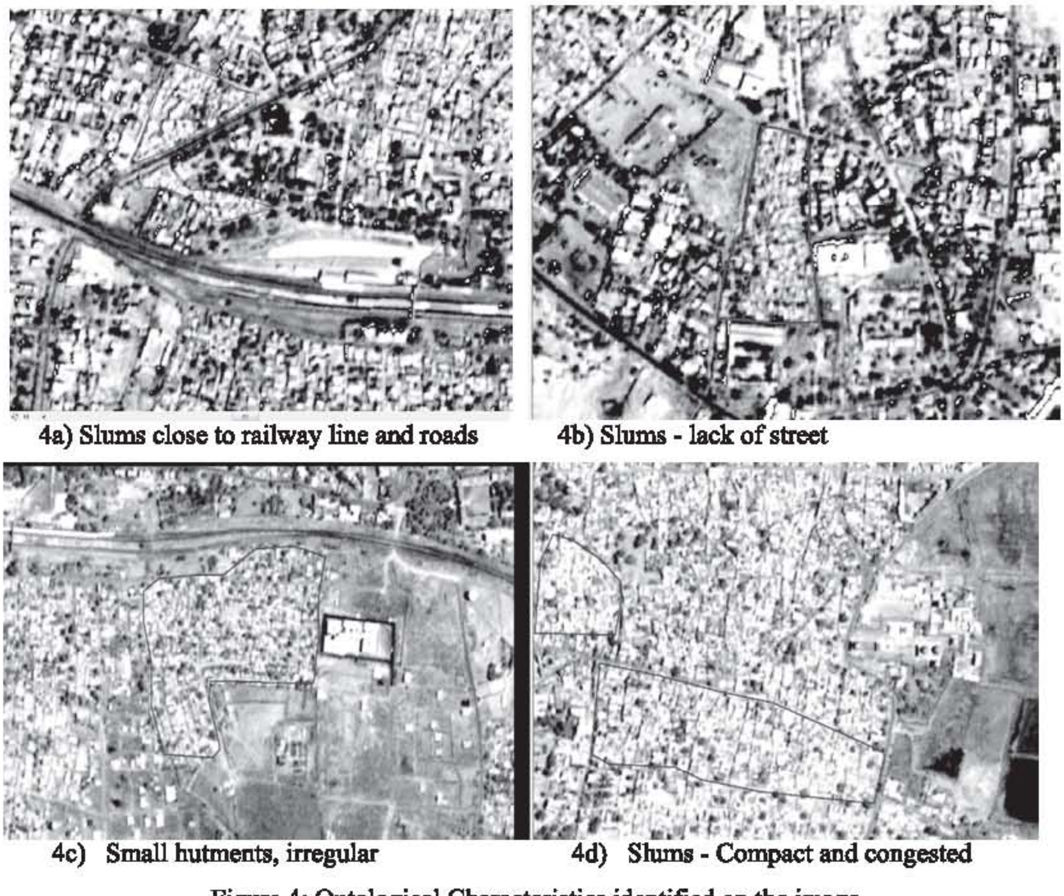
Cell space represents a subset of the geographical area, and the land use represents the status of a cell. The transition rules are built to address the selected factors responsible for different growth processes of a cell. State of cell (S) at xy (Location of the cell) in time t+1 is the function of status of the cell at xy in time t. S t+1xy = f (Stxy). In this study, the Base map for neighbourhood analysis was prepared with 2 states such as open space and slums. The conversion of one state to another state will take place only among these two in a linear direction, and the conversion of any cell is possible only to slum. With the help of MCE, all the candidate cells (those available for slum development) can be given a score (Table 2) on the basis of weightage of the factors. The final score should be the integration of the suitability scores (Su) obtained by the factors and the neighbourhood influence (N). Thus, the final score (Final score = Su + N) determines the probability of the cell for slum growth. As per the transition rules, If the status of the cell is "Z" (Z = slum or Z = open space) in time t, then in time t+1, it will remain as "Z "only if the cell is surrounded by all "Z" cells in its neighbourhood. The second rule is If the status of the cell is open in time t, then in time t+1, it will change into Slum if the cell is surrounded (Majority) by Slum cells in its neighbourhood. These rules will be applied in a 3x3 matrix neighbourhood with "Majority" option, and the output is neighbourhood map (N).

4. Results and Discussion

After the development of ontology as described in the previous section for slum identification, cartosat data was classified in to required classes for modelling such as, open area (excludes agricultural land with crops and hill slopes) and slums. As per the slum ontology, basic inputs for CA model (Figure3 and Table 1) were identified such as being close to a road, Railway line, Lake, density, informality (Figure 4a, b, c and d) and criteria maps with scores were generated by using Arc GIS model builder. The suitability map was created by giving appropriate weightage to the factors. The final result was obtained by adding neighbourhood analysis with suitability map created by MCE. As slum growth can speedup or slow down due to a number of factors including transportation networks and human decision making behaviour, using linguistic variables such as "The Most", "Moderate" and "The Least" can give us different scenarios of slum growth. When the slum map prepared based on slum ontology was overlaid on the final result (Figure 5), it showed that 61.3% of slums are present in most suitable areas and 38.7% of slums present in moderate suitable areas.

Table 2: Ontology based factors with their suitability scores

Selected Factors	Suitability scores		
	Most - 3	Moderate - 2	Least Suitable - 1
Distance from Lake	Less than1000m	1000-2000	Above 2000m
Distance from Road	Less than1000m	1000-2000	Above 2000m
Distance from Rly Line	Less than1000m	1000-2000	Above 2000m



4a) Slums close to railway line and roads

4b) Slums - lack of street

4c) Small hutments, irregular

4d) Slums - Compact and congested

Figure 4: Ontological Characteristics identified on the image

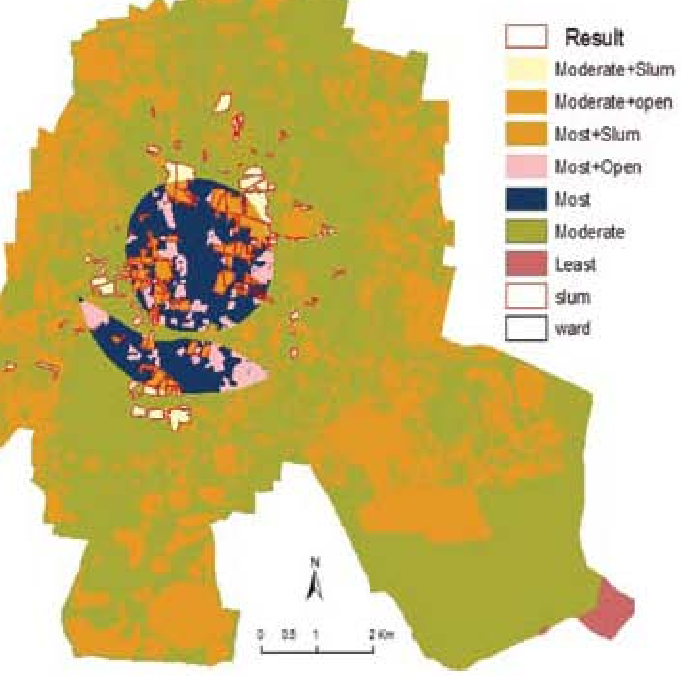


Figure 5: Final result

In Gulbarga, the slum expansion is due to lack of affordability, poverty of rural migrants and mostly on un-used, un-protected and un-suitable government land, along the roads, railway lines and near the lake. It has been observed that the large number of slums exist in the central part of the city (under the *most* suitable category), and there are chances for further slum expansion along the linear features like, roads, and railway lines in peripheries. It is because, more than 42 km^2 area of open land such as agricultural land without crops and barren land present in moderately suitable areas and only 2.14 km^2 open land is present in most suitable areas for slum growth. Hence, open moderately suitable areas will attract more slum growth than those open areas present in most suitable category,

5. Conclusion

The present study shows the capability of ontology for slum modelling. The final result shows that the most suitable area for slum growth is already occupied by the slums and open space available in the moderate suitable area is vulnerable to future growth of slums. There is a scope for extending this study by incorporating more socio, economic factors in model building, which are the real cause, of informal settlement development, and will help us in preventing further expansion of slums.

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