An Agent-Based Method for Automatic Building Recognition Based on Lidar Data

Farhad Samadzadegan[1], Fateme Tabib Mahmoudi[2]

[1]Dept. of Geomatics, Faculty of Engineering, University of Tehran, P.O Box: 11365-4563, Tehran, Iran
samadz@ut.ac.ir

[2]Dept. of Geomatics, Faculty of Engineering, University of Tehran, P.O Box: 11365-4563, Tehran, Iran
fmahmoudi@ut.ac.ir

Abstract

Lidar data has proved to be a promising data source for various mapping and 3D modeling of buildings. Nevertheless, traditional manually building extraction from Lidar data is highly labor-intensive, time-consuming and very expensive. During the past decade many researchers in photogrammetry, remote sensing and computer vision communities have been trying to study and develop the automatic or semi-automatic approaches for building extraction and reconstruction. Although, several studies related to the building recognition have been published during recent years, the performance of obtained results is still dependent to several assumptions and simplifications. In this research, an agent-based method is proposed for automatic building recognition based on Lidar data. The proposed methodology in this paper has two main steps; first one is pre-processing and second one is the agent-based building recognition. In the pre-processing step, ground, vegetation and near ground objects are removed from the first pulse range Lidar data. The second step of this algorithm is an agent-based method for using the advantages of all Lidar range and intensity data for improving initial candidate of building regions obtained from the previous step. Using an agent as a basic concept of the artificial intelligence can be useful also in the field of building recognition because in the agent-based method, it is possible to define relational knowledge between objects and complete contextual information in such a way to recognize buildings from other objects, precisely. By using agents, one can apply adaptive image processing algorithms on each dataset, based on local contextual information, and then fuse the results in decision level. The results of implementation the proposed methodology, show that using the best pre-defined characteristics of an agent, can solve most of the problems in the field of building detection.

Keywords; Building Recognition, Agent-based Method, Contextual Information, Decision Level Fusion

1 Introduction

Building recognition from remotely sensed data has an important role in many photogrammetric and computer vision applications such as map updating and change detection in an urban area. During the past decade many researchers have been trying to study and develop the automatic or semi-automatic approaches for building extraction and reconstruction. So, many algorithms have been proposed in the field of building recognition from aerial photographs or satellite images [2].
After coming Lidar technology, some researchers used Lidar range and intensity data solely or combining other remotely sensed data for automatic or semi-automatic building extraction [1, 4, 7, 8, 9, 10, 11, 12]. A complete Lidar dataset has range and intensity products. These Lidar products have different characteristics and fusion of them has more advantages. However Lidar data has proved to be a promising data source for various mapping and 3D modeling of buildings, but the complicated relationships between buildings and other objects like trees, cars and vegetation areas cause some difficulties in the field of building extraction in urban areas.
Nowadays, using the concepts of artificial intelligence is widespread in many applications. Agent as a basic concept of distributed artificial intelligence has a lot of capabilities making it useful in a large number of applications [5, 6, 13]. According to the problems in the field of building recognition in urban areas, an agent-based method may be a good solution for distinguishing between buildings and other objects based on contextual information [14]. By an agent-based method, one can use contextual information and object relational knowledge in an urban area to detect and improve building regions.
In this paper the capabilities of agents are used to solve the problems related to the building recognition in complicated urban areas.

2 Related Works

One of the most important problems in the field of building recognition is removing trees and vegetation areas near by buildings. Most of the proposed algorithms use classification methods such as binary classification, Bayesian Nets and rule-based methods to solve this problem [2, 8]. According to the advantages of Lidar technology, the discrepancy between first pulse and last pulse Lidar range data can be calculated to recognize trees from buildings [1].
Because of the difficulties in separating buildings from trees in an urban area, Schenk in [14] proposed a novel method using an agent-based system for building and tree recognition in parallel. In this proposed multi-agent method, two different kinds of recognition agents are used to recognize buildings and trees separately.
Agent-based methods have high potential abilities for using in photogrammetric and computer vision applications such as automatic building recognition in urban areas, if the agents have the best pre-defined characteristics and environments.

3 Agent Technology

Agent as a basic concept of distributed artificial intelligence is a computer component that located in a dynamic environment and by perceiving the environment, behaves in such a way to reach its pre-defined goals [6]. In general, agents cannot have complete information on their environment. Thus, to solve complicated problems or reach goals, agents must work with other agents. In a multi-agent model, several agents with specific goals and tasks are deployed, and they are trying to reach the main goal together [14].
The pre-defined characteristics for each agent in an agent-based system affect on the abilities of that system. Every kind of agents should have some main characteristics such as autonomy and Proactivity, but there are some other characteristics those should be defined in special cases. For instance, in a multi-agent system having social ability is necessary for each agent [3].
Another important aspect in the agent definition is its internal architecture. Architecture defines agent's internal structure and behaviors. In one point of view agents based on their architectures, can be divided to deliberative and reactive. A reactive agent just responds to the external changes in environment. But a deliberative agent has a reasoning model to decide about its behaviors related to the environmental situation. The most popular reasoning model has three structural elements, belief, desire and intension [5,13]. Belief is the information of agents about themselves and their environments. Each agent has a collection of goals whose are his desires, and must select some of the desires as the intensions and do his best to reach them.
Nowadays, according to the above mentioned capabilities of the agent technology, using an agent-based method is widespread in many complicated applications. Because of the high difficulties in the field of automatic building recognition from Lidar data, using the advantages of an agent-based method may be so useful.

4 Proposed Method

In this paper, a novel building recognition method based on the fusion of Lidar range and intensity data using an agent-based system has been proposed. The proposed method has two main steps; first one is the pre-processing of Lidar range data to extract initial candidate building regions and the second one is using an agent-based method for improving and solving the problems of the initial candidate of regions based on the contextual information extracted from all kinds of Lidar datasets.

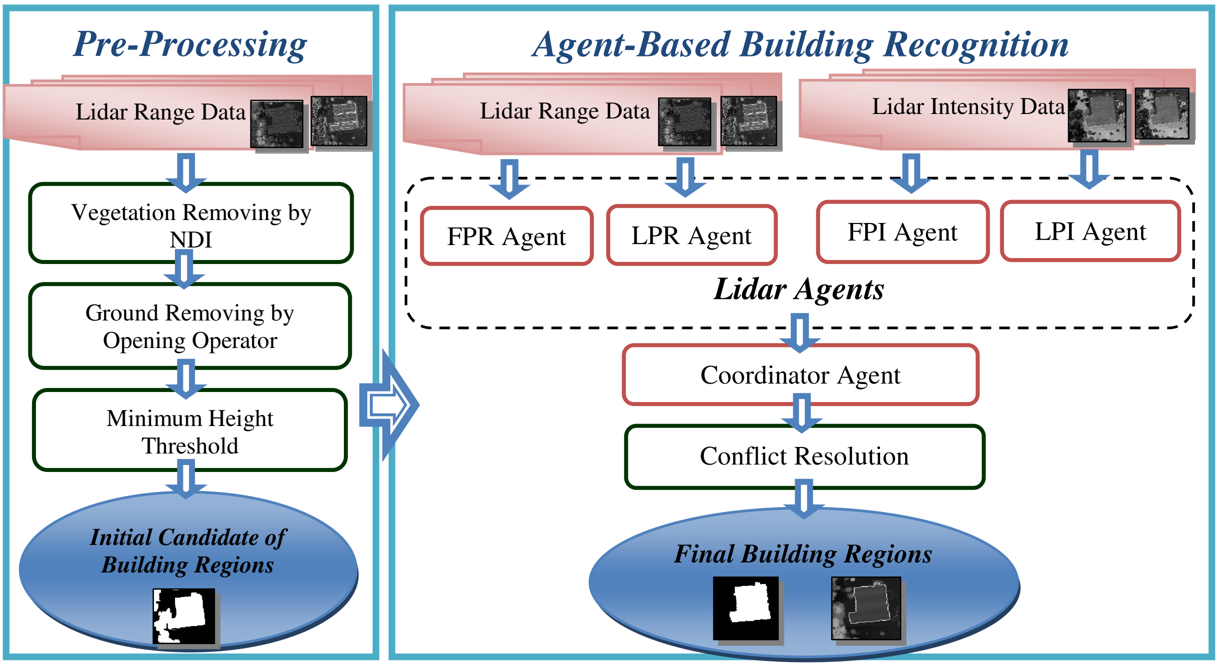


Fig. 1. Scheme of the Proposed Building Recognition Methodology

4.1 Pre-processing

Since Lidar range DSM is a surface containing ground structures and all off-terrain objects such as trees, buildings and cars, removing ground and other non-building objects may be so useful for building boundary extraction from Lidar data. Therefore, proposed pre-processing algorithm has three main steps to remove trees and vegetation objects, ground structures and other solid non-building objects, respectively.
Vegetation removing is based on the characteristics of Lidar range data. Since laser beam can penetrate trees and all other non-solid objects, Lidar first pulse and last pulse range data may have different values in locations relating to penetrable objects, such as trees. Therefore, normalization of Lidar first pulse range data minus Lidar last pulse range data can represent the location of the majority of trees.

$$\mathrm{NDI} = \frac{R_F - R_L}{R_F + R_L} \qquad (1)$$

NDI is the normalized difference index between first and last pulse Lidar range data, R_F and R_L are the first and the last return Lidar range data, respectively. Using this Normalized index, first pulse range data can be filtered and then by applying a morphological opening operator with small structuring element, this filtered DSM may be smoothed.
On the other hand, another opening morphological operator with structuring element, larger than the maximum size of buildings in the study area, has been used to generate digital terrain model.

$$\mathrm{DTM} = (\mathrm{FirstDSM} \circ b) \qquad (2)$$

In this equation, *DTM* is the digital terrain model and *b* is the structuring element of opening morphological operator.
It is expected that, filtered DSM has only buildings, ground structures and other solid non-building objects. So by subtracting generated DTM from filtered DSM, ground structures will be eliminated. Finally, after applying minimum height threshold, a binary image representing candidate building regions is produced.
However, it is expected that only building regions remained in the results of pre-processing step, but according to the complicated relationships between objects in urban areas, some trees and other natural or man-made objects close to the buildings are still in the surface. So, in the second step of the

proposed algorithm, based on the contextual information in the scene, candidate building regions have been improved by properly definition of an agent-based method.

4.2 Agent-Based Building Recognition

The generated binary image of candidate building regions has some problems especially with regard to the relationships between buildings and trees. One of the most important problems is related to the remained vegetation areas, larger than the minimum building size in the study area. Another problem are single trees being next to the buildings and merged with them in candidate regions. On the other hand, using opening morphological operator with small structuring element may cause some deformations on the building's shapes.
Generating height difference images between Lidar DSM and DTM those called normalized DSM and texture measurement on it, gradient of Lidar data and edge images generated using Canny operator, may provide some useful contextual information for improving each of candidate regions and solving the above mentioned problems.
On the other hand, special abilities of agent-based systems can provide a perfect field for improving building regions. So four different types of Lidar agents with deliberative architecture, define in this proposed agent-based method. Each agent is responsible for extracting contextual information from one kind of Lidar data. Since the objective is building recognition from the fusion of range and intensity Lidar data, an additional agent is defined for coordination between Lidar agents and conflict resolution among their results by performing a rule-based decision level fusion for each candidate region.

4.2.1 The Coordinator Agent

The coordinator agent is responsible for extracting centroid coordinates and maximum radius for each candidate building region and sends this information to all Lidar agents. Lidar agents use this information to define the study area in their own Lidar data.
The main task of the coordinator agent is the investigation of all Lidar agent's results to detect conflict areas among them. If coordinator agent finds a pixel with different states (building or non-building) in the results of four Lidar agents, conflict resolution is performed based on the additional information extracted from original Lidar datasets. In other word, the coordinator agent fuses all Lidar datasets in the decision level in order to obtain the best results in the field of building recognition.

4.2.2 The Lidar Agents

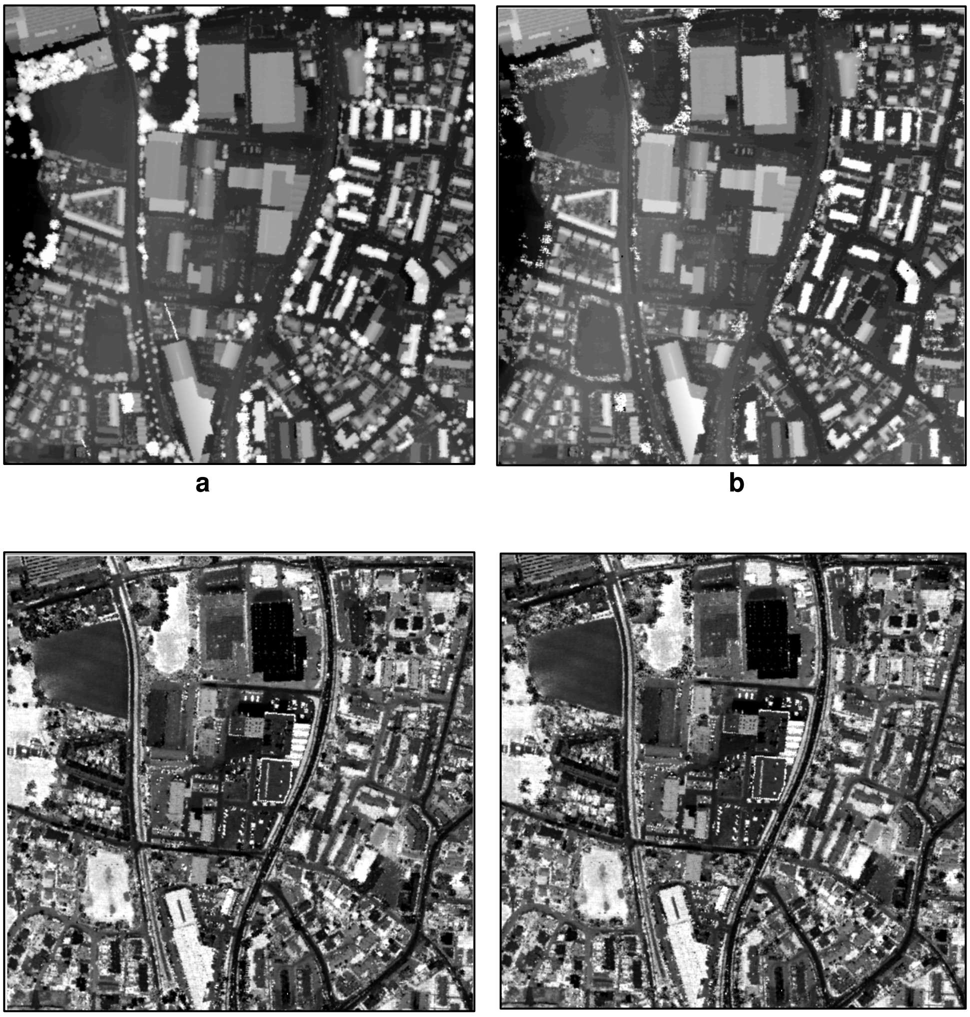
Each of four different kinds of Lidar agents defined in this algorithm is responsible for building recognition from only one kind of the Lidar data. FPR agent's tasks are computing features such as entropy, energy, contrast and homogeneity from Lidar first return range DSM minus DTM (nDSM), apply Canny edge detector on first return range data and generate gradient magnitude image of this data. LPR agent has the same responsibilities related to the Lidar last return range data. FPI and LPI agents are defined for doing observations of the first pulse intensity and last pulse intensity Lidar data, respectively.
Edge images, gradient images and all produced texture images are used as agents' environments.
Because the main problems in the field of building recognition are related to the adjacency between buildings and trees and complicated relationships between vegetation and building areas, the main goal of all Lidar agents are vegetation detection and removing. For this reason, each Lidar agent observes all of its environments (i.e. edge, gradient and texture images) to obtain beliefs about vegetation's thresholds in each environment.
First of all, Lidar range agents, FPR & LPR, used normalized vegetation index from the discrepancy between the Lidar first and last return range data to detect and remove some vegetation pixels. For this reason, each agent locates on the NDI pixels and a 5*5 search window is defined around it in the agent's environments. After that, vegetation removing will be completed by means of applying some rules based on the agent's beliefs which obtained from each environment.
From the other side, intensity agents work directly on the candidate building regions obtained from pre-processing step and improve them based on the beliefs extracted from environments. The results of intensity agents are such useful for improving the results of range agents in conflict resolution step.
After each kinds of Lidar agents performed its processing tasks to remove vegetation from related Lidar dataset, four result data are generated which may have some different aspects as conflicts. For instance, if FPR agent removed one pixel as vegetation but LPR agent preserved it as a pixel of building region, a conflict arises. In this situation, coordinator agent uses additional powerful rules based on the contextual information of both Lidar agents to solve the conflicts between them. After

that the final result of range agents will be compared by the results from both intensity agents for conflict resolution and obtaining the best and reliable result.

5 Implementation

5.1 Study Area and Datasets

The proposed automatic building recognition algorithm has been tested by Lidar range and intensity data from an urban area in Stuttgart, Germany. The selected study area has nearly the flat ground structure with complex relationships between buildings and trees in the streets.



a b c d

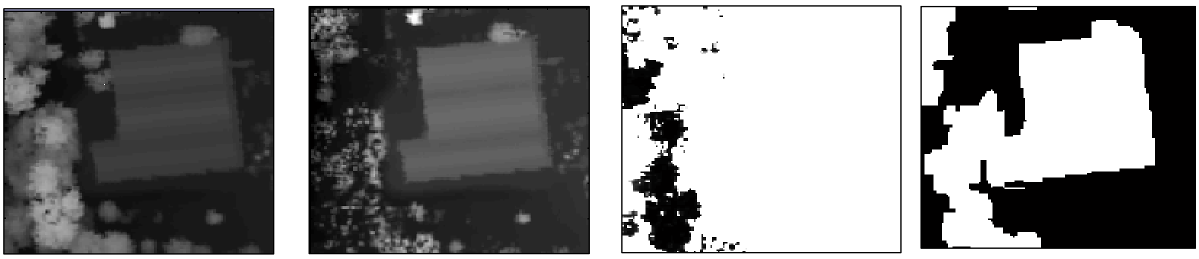
Fig. 2. a. First return Lidar range data, b. Last return Lidar range data
c. First return Lidar intensity data, d. Last return Lidar intensity data

5.2 Experiments and Results

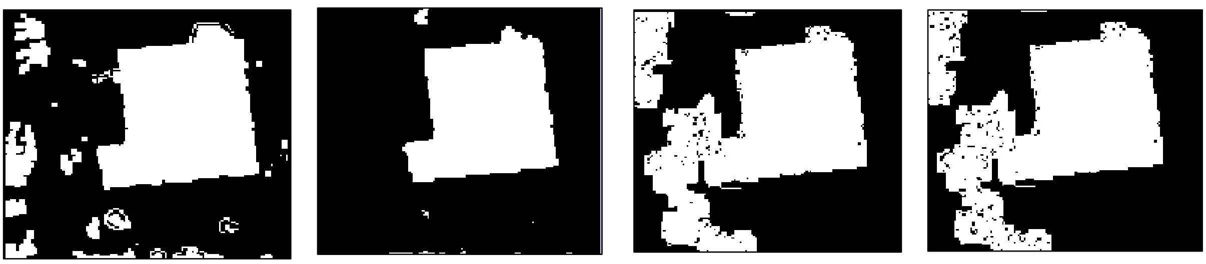
As mentioned above, it is necessary to perform some pre-processing tasks on Lidar datasets before using them in the proposed agent-based building recognition method. Since the objective is to detect buildings among the collection of other objects, removing terrain structures and all non-building objects especially penetrable ones, is useful for properly building recognition. In the proposed pre-processing algorithm the majority of ground structures and vegetation areas were detected and removed from the original Lidar first return range dataset. After that, by applying height threshold equal to the minimum building height in the study area and binarization the final result, a binary image of initial candidate regions is generated.

Fig. 3. Initial candidate of building regions

According to the complicated relationships between objects in an urban area, the initial candidate regions obtained from pre-processing step, have some problems and need a further improvement. So, in the second step of this proposed algorithm based on the contextual information from Lidar datasets and using an agent-based method, candidate regions are improved in some of the problematic areas.



a b c d

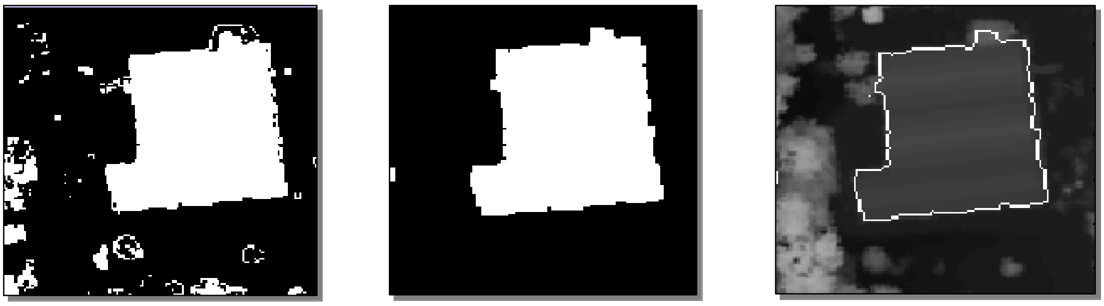


e f g h

Fig. 4. One of the problematic candidate regions(a. first pulse range data, b. last pulse range data, c. NDI, d.Initial candidate region from pre-processing algorithm), the results of each Lidar agents(e.result of FPR agent, f.result of LPR agent, g.result of FPI agent, h.result of LPI agent)

Fig 4.d shows some problems between buildings and vegetation areas in initial candidate region. As it is clear, on the top of the area, a single tree is merged to the building region and on the left, remained vegetation area caused some deformations on the shape of candidate region.

To solve these problems, FPR and LPR agents work on texture measures from nDSM and gradient and edge images from the first return and last return range data, respectively. These two kinds of Lidar agents try to detect and extract building regions directly from the Lidar range datasets. On the other hand, FPI and LPI agents try to remove vegetation areas from the initial candidate region based on texture images and edge images from the first and last return intensity datasets. After conflict resolution between the results of all Lidar range and intensity agents, the final result for this problematic area is obtained.



a b c

Fig. 5. a.result of conflict resolution between range agents, b.result of conflict resolution between range and intensity agents, c. the final result of agent-based building recognition algorithm overlaid on the Lidar range data

6 Conclusion

Lidar data has proved to be a promising data source for different applications such as object recognition and reconstruction. But, according to the problems relating to building recognition in complicated urban areas, combination of artificial intelligence concepts with traditional image processing algorithms will be more valuable.

In our proposed pre-processing algorithm, most of the important DSM filtering processes used by other researchers were applied, but the results demonstrated that candidate regions still have some problematic areas and need more refinements.

The main problems in candidate regions are related to the vicinity of trees and buildings or large vegetation areas. In this paper, we introduced the capabilities of agent as a basic concept of distributed artificial intelligence, for solving the problems in candidate building regions.

The initial obtained results of our proposed agent-based building recognition method, shows that using agent can solve complicated problems in the field of building recognition and detecting building areas from trees and vegetations next to them. But this methodology will be more powerful if agents observe more valuable contextual environments.

Reference

1. Alharthy, Bethel. "*Heuristic filtering and 3D feature extraction from Lidar data*". [2000].

2. A.Brunn, U.Wiedner. "*Hierarchical Bayesian nets for building extraction using dense digital surface models*". [1998].

3. B.Darragh, J.Bellman."*Communicating spatial uncertainty using geospatial reasoning*". [2004].

4. E.Balsavias et al."*Extraction of buildings and trees using images and Lidar data*". [2008].

5. F.Bellifemine, G.Caire."*Developing multi-agent systems with Jade*". [2007].

6. F.Riadh et al."*Analysing spatial-temporal geographic information based on blackboard architecture and multi-agent systems*". IJCSNS International Journal of Computer Science and Network Security, VOL.6 No.8A, [2006].

7. F.Rottensteiner, J.Jansa."*Automatic extraction of buildings from Lidar data and aerial images*". [2001].

8. F.Rottensteiner et al."*Fusing airborne laser scanner data and aerial imagery for the automatic extraction of buildings in densely built-up areas*". [2003].

9. F.Samadzadegan."*Object extraction and recognition from Lidar data based on fuzzy reasoning and information fusion techniques*". [2002].

10. G.Sohn, I.Dowmann."*Building extraction using Lidar DEMs and Ikonos images*". [2002].

11. H. Neidhart, M. Sester."*Extraction of building ground plans from Lidar data*". [2008].

12. L.Matikainen."*Classification Tree based building detection from laser scanner and aerial image data*". [2007].

13. R.Bordini et al."*Programming multi-agent systems in agent speak using Jason*". [2007].

14. T.Schenk."*Object recognition based on multi-agent spatial reasoning*". [2008].