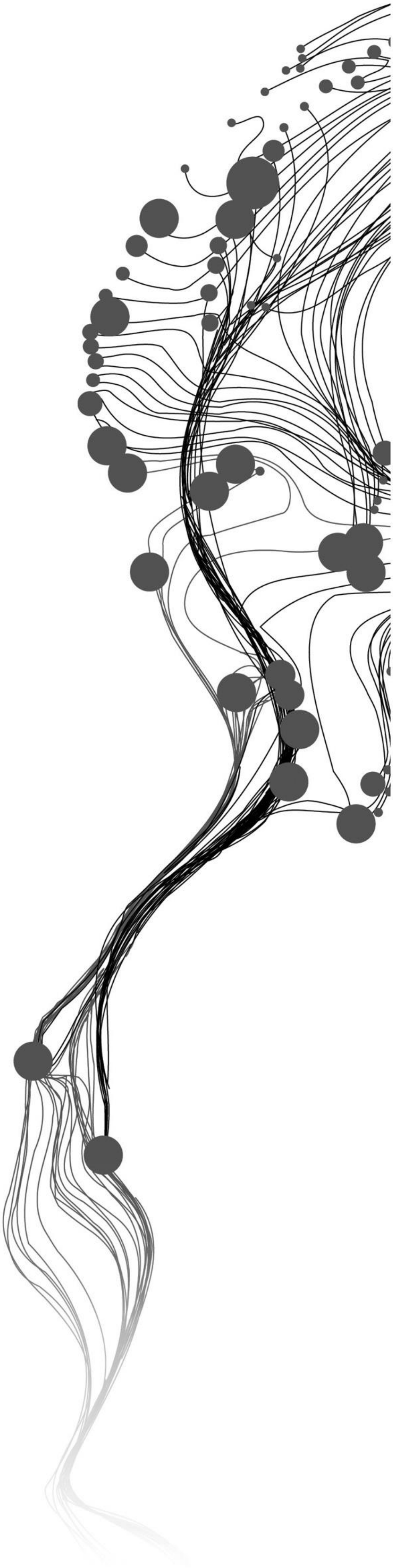
Rapid Land Recordation System for the Urban Villages using UAV images

YAOJUN CAO
May, 2016

SUPERVISORS:
Dr. F.C. Nex
Dr. D. Todorovski
Dr. Y. Yang



Rapid Land Recordation System for the Urban Villages using UAV images

YAOJUN CAO
Enschede, The Netherlands,
May, 2016

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Land Administration

SUPERVISORS:
Dr. F.C. Nex
Dr. D. Todorovski
Dr. Y. Yang

THESIS ASSESSMENT BOARD:
Prof.mr.dr.J.A. Zevenbergen (Chair)
Prof.dr.ir. P.J.M. van Oosterom (External Examiner, Delft University of Technology)

ABSTRACT

This thesis aims to develop a rapid land recordation system for urban villages using UAV images. The existing system cannot comprehend with the demands of the current land situation in urban villages because of China's growing momentum in urbanization. Traditional methods for cadastre surveying are laborious and costly. In this study, UAV technology was used to counter these limitations, simplifying and optimizing land recordation system suitable for urban villages. Digitized orthophoto was generated to capture spatial information of land from UAV images, combined with more reasonable land right information suitable for urban villages. UAV photogrammetry has great potential in reducing time and cost towards an optimized and improved land recordation system.

ACKNOWLEDGEMENTS

I would like to express my sincere thanks to my supervisor Dr. Francesco Nex, for his continuously support throughout my whole work. Thanks are also due to my second supervisor Dr. Dimo Todorovski for his generosity and patience with my work. I would like to give credit to Dr. Yun Yang for her encouragement and advice both in work and life.

Special thanks go to the group of friends who fight beside me during my studies. The classmates whom I stayed together working on lectures and assignments, I am grateful for your time, advice and support. The friends who helped me in my thesis writing, your wisdom and passion make it possible that my work goes to the end.

Finally, special thanks go to my family. There are no words to describe the power and faith you gave me to go through all these. Your love makes me strong to live my life study abroad, and I am so eager for backing to your side to make some contribution back to you. Great thanks to all support throughout my stay in the Netherlands.

Yaojun Cao
May 2016

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

This chapter explains the background and justification of the research, which centres on the problems in land registration for urban villages in the People's Republic of China. The current land recordation system and its associated processes contain intrinsic weaknesses which will be addressed in this study. By generating orthophotos of study area using unmanned aerial vehicle (UAV) images, the new method can be developed in support of land registration in urban villages. With this new measurement technique and modifications in the procedure of land registration system, a specific system fit for urban village would be built.

1.1. Background and Significance

In the late 1970s, China established an agricultural land management system on the basis of the household contract responsibility. The first round of registration resulted in land contracts, providing authentic rights valid for thirty years. In the 1990s, the second round of work was carried out to establish land registers, and to issue contract right certificates to all villagers in China; however, the registration was not completed at that time. Until now, the situation has not changed. A recent phenomenon in land use that needs to be addressed related to the system of land management is a special type of village called "urban village" (Li, Lin, Li, & Wu, 2014). These villages are located in the city, but maintain the rural property type, as well as cadastre and land administrative system style (Yao, 2013).

After several debates on promoting the reform and development of rural areas, the 17th Communist Party of China Central Committee clearly stated: "we need to do a good job in the adjudication, registration and issuing land ownership and land use right certificates"(C. C. of China, 2008). This means that reforming in rural land management system needs to further intensify. The Eighteenth National Congress Party of China declared that the government has to accelerate the management of the new agricultural management system, and provide secured property rights of house sites to all farmers. On 31th December 2012, the Central Committee and State Council issued a decree to complete the registration of the rural land contract rights and issue certificates within five years. The adjudication of rural land ownership is towards identifying farmers' ownership, use rights, and other rights of land within in the rural areas. Rural land right adjudication mainly includes the establishment, the registration, and the certification of the rural collective land ownership, house site use rights, and collective land use rights. The decree was also intended to carry out comprehensive rural land ownership registration certification, as a reform of rural collective property rights system for the effective protection of farmers' property rights.

In China, rapid economic development drives significant progress in many parts of the country, which makes the importance of land management even more apparent. With the commencement of new rounds of land reform policies, the land administration department will confront fresh issues, such as growing complexities of land records. One major problem is the transformation of urban villages in cities, where some criminal cases have already been reported due partly to unclear land rights. The land acquisition department cannot provide complete and valid records of land rights while the farmers are unable to their rightful claims without these certificates. This disconcerting grievance can be blamed on the land recordation system. Land administration cannot be established by a single step, and neither can a land registration system. The existing land registration systems (Dahlberg, 1984; Pouliot, Vasseur, &

Boubehrezh, 2013; Stoter, Ploeger, & van Oosterom, 2013; van Oosterom et al., 2006) in many developed countries have developed after multiple times of adapting from productive relations.

The current land administration system in China cannot deal with new phenomena having been designed mainly for formal land management issues. It faces the problem of land records in urban villages. The land use situation had sharply changed in urban villages, with almost all agriculture lands having been recast into urban construction lands. Land use in urban village has been totally transformed as it was decades before, consequently making the system of land records obsolescent.

The current land registration process includes the following processes: application, surveying, investigation, officer confirming, public announcement, government check and awarding certificates. Figure 1 shows the general land registration processes in the county-level government, and its associated time cost (The people's government of Langfang Guangyang District, China, 2013).

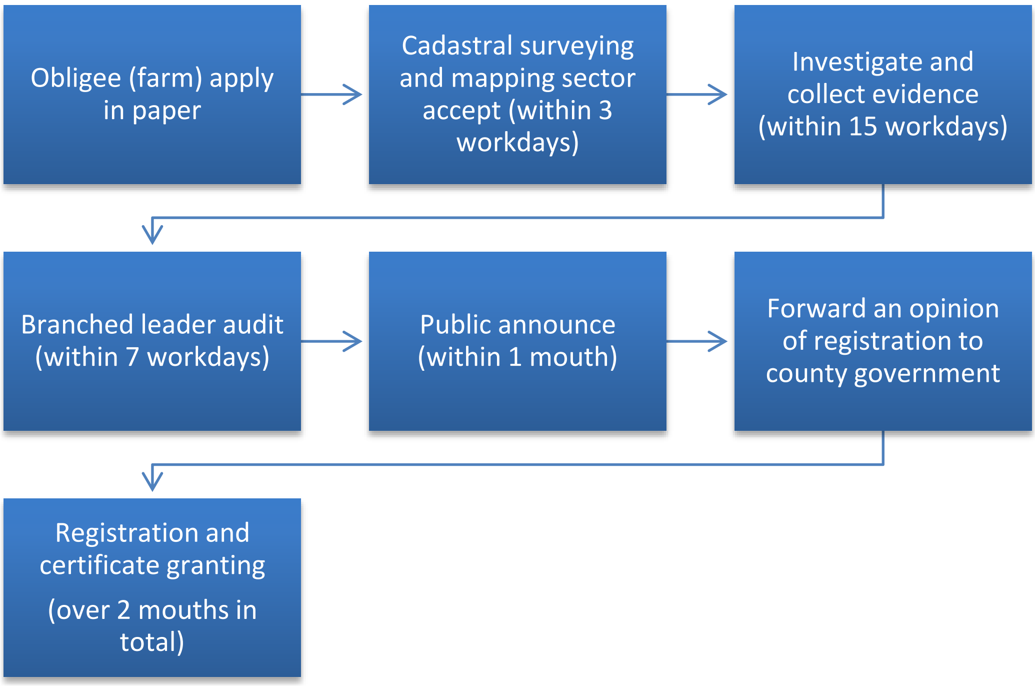


Figure 1 Flow chart of land registration

The workflow for registering rural land takes at least two months from the application until the awarding of certificates. It must go through two levels of government with low efficiency. Long waiting time is common in most instances, but further delays would transpire for places with no valid certification of land rights. Another weakness in the current system is the lack of geometry in urban villages with new buildings being constructed with high rates of urbanization.

Most urban villages have not been well documented. Since they are not considered as urban areas, land records cannot cope with updates of development. It is an imperative that a good system of registration be developed as soon as possible to provide land tenure security protection. The current system is inefficient because landowner is obliged to individually apply by themselves, which is time-consuming and difficult to implement with existing technical force in land administration departments.

A fit-for-purpose land record system (Enemark, Bell, Lemmen, & McLaren, 2014; Enemark, Bell, Enemark, & Bell, 2014; Zevenbergen, Augustinus, Antonio, & Bennett, 2013) could be a potential solution to the problems faced in registering land in China's urban villages. The system should be flexible and pragmatic to meet people's requirement of land rights, it may start from a simple approach to fit the new situation or problem to make it cheaper and faster, but it is a dynamic process which can be improved over time. A simple geometrical index is required to facilitate the recording proceedings. This approach allows the Land administration department to register the entire urban village and maintain an up-to-date land information system.

UAV are considered of potential value in supporting a fit-for-purpose approach in land registration. The use of UAV images for data collection may greatly shorten the time and costs involved. UAV is considered to be more flexible to supply some complex features which cannot be distinguished from satellite photo or oblique aerial photograph. Jing (2011) had investigated the application of low altitude remote sensing imagery in urban land rights adjudication of China, it showed that Low Altitude Remote Sensing Imagery (LARSI) provides a cheaper and time-saving chance to enhance the conventional adjudication. A mapping method which combined GPS and imaging technologies with UAV provided a new way to support land monitoring in Albania (Barnes, Volkmann, Sherko, & Kelm, 2014). This UAV-based mapping approach was developed to support land registration by improving the spatial data quality of cadastral records.

The aim of this research concentrates on the use of UAV in land recordation for urban villages where the terrestrial environment is more complex.

1.2. Research Problem

In China, the issue of urban villages has drawn significant attention at the beginning of the 21st century. Urban villages have risen in every megacity, such as Beijing, Shanghai, Guangzhou, Chongqing and Shenzhen. Ten years later, other big cities such as Xi'an, Nanjing, Chengdu and Zhuhai also experienced the rise of urban villages with rapid urbanization (Liu, He, Wu, & Webster, 2010). Development of urban villages is ongoing in many cities nowadays. Many urban villages have been changed into real urban areas, where old buildings being replaced by new commercial centres. The land has been transformed as state owned, have been correctly registered in the urban cadastral system. But thousands more are incorrectly being kept on the old system of recording. The old system of land records is no longer valid, and should be more reflective of the real land use situation in the urban villages.

Registration of rural land ownership is now conducted mainly using GPS, ranging telescope, and total station. These methods require substantial manpower and time to collect geographic data. The alternative could be with the use of aerial images for boundary mapping applications. The study conducted by (Mukendwa, 2015) showed promising results in Namibia.

Considering the size of urban villages, averaging area 6.1 hectares (Shanxi Government, 2015), UAV images have the potential to map land parcel boundaries in urban villages. This study aims to explore and develop a UAV based method for fit-for-purpose land registration of urban village in China.

1.3. Research Objectives

The main object of this research is to develop a land recordation approach for protecting the residents' land rights within the urban villages using UAV images. Sub-objectives and research questions are formulated below:

1) To analyse a proposed land recordation system for the urban villages
   a) What land rights need to be recorded?
   b) Who would be users of the system?
   c) What data are required for the system?
   d) How to capture spatial information of land rights?
   e) What are the processes or procedures feasible in the system?

2) To propose the integration of UAV in the recordation
   a) How can the use of UAV help improve the current recordation system?
   b) Can UAV images satisfy the accuracy requirements needed in the recordation system?
   c) What are the strengths and weakness of the developed system?
   d) What conditions and circumstances does UAV usage become more applicable and useful?
   e) What future developments can be made to better facilitate the use and feasibility of UAV in the recordation system?

1.4. Concept Framework

Figure 2 shows the concept framework of using UAV images to support land registration in urban villages. These are the three main aspects and their relationships between each other. Urban village is the particular phenomenon in the urbanization of China. The land use and building situation are very different from normal urban or rural area. To update the land records in urban village to the land recordation system, UAV image could be utilized to provide spatial data much more fast and affordable. This study would use UAV images in urban village to register their lands into the system.

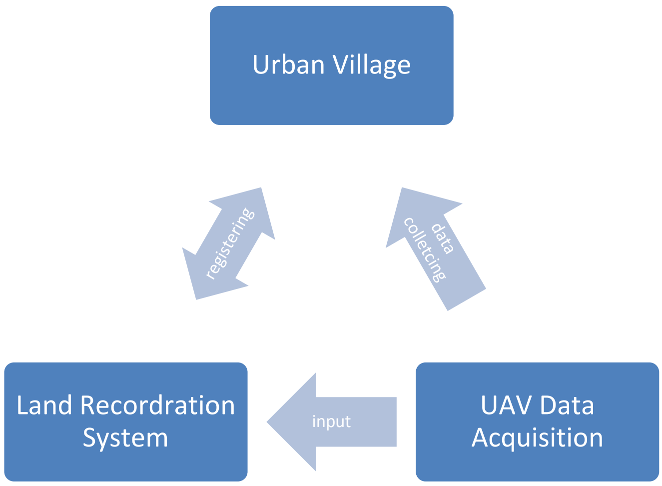


Figure 2 Concept Framework

1.5. Research Matrix

Research Objectives	Research Questions	Research Methods	Data Sources	Anticipated Results
To analyse a proposed land recordation system for the urban villages	What land rights need to be recorded?	Literature review; Legal document review	Relevant scientific journals, articles and work papers	Situation description about requirements and content of current land recordation in rural and urban area of China; Land laws, rule and regulation, local department files
	Who would be users of the system?			
	What data are required for the system?			
	How to capture spatial information of land rights?			
	What are the processes or procedures feasible in the system?			
To propose the integration of UAV in the recordation	How can the use of UAV help improve the current recordation system?	Interview; Image processing; Digitization	UAV images, POS data, Satellite image, Interview record	Orthophoto; Control points; Work base map; Digital boundaries; Cost budget; Land recordation from example
	Can UAV images satisfy the accuracy requirements needed in the recordation system?			
	What are the strengths and weakness of the developed system?			
	What conditions and circumstances does UAV usage become more applicable and useful?			
	What future developments can be made to better facilitate the use and feasibility of UAV in the recordation system?			

Table 1 Research matrix

1.6. Thesis Structure

Chapter 1: Introduction
This chapter provides the introduction of this research. It states the background and significance of the study. Chapter 1 discusses the research problem and objectives, the research questions to the objectives are also listed.

Chapter 2: Literature Review

This chapter discusses the main concepts which were the foundations of this research. Urban village and its formation, land registration system in China, land polices and history were discussed as well as unmanned aerial vehicle and its application in land administration.

Chapter 3: UAV Photogrammetric Procedures
This chapter theoretically explains the procedures in UAV image processing. It includes camera calibration, image orientation, surface reconstruction and orthoimage generation. These were operating principles behind the automatic software processing.

Chapter 4: Materials and Methods
This chapter presents the methods used to answer the research questions. It begins with the introduction of the study area and image data. Then detailed explains the steps of orthophoto generation in Pix4D. Orthophoto calibration and assessment were also presented before it used for boundary map.

Chapter 5: Results and Discussion
This chapter presents the results and discussion of the study. The first section presents the registration content in the optimized system including obligee information and land information. The second section presents the resulting map based on orthophoto. The third section presents the time and cost comparison in field survey between traditional method and UAV photogrammetry.

Chapter 6: Conclusions and Recommendations
This chapter concludes the study by discussing how the research objectives and questions were achieved and answered, and it was followed by recommendations for further research.

2. LITERATURE REVIEW

As explained in chapter 1 this research will focus on the following main concepts: urban villages, land ownership and land recordation, and UAU data acquisition for boundary mapping. This chapter will explain the main concepts based on a literature review. The part of UAV data acquisition will be described in the context of fit-for-purpose land administration. A complete description of the UAV procedures will be presented in a separate chapter 3.

2.1. Urban Village

2.1.1. Development of Urban Villages in China

Rapid development and urbanization gave rise to urban villages. Over 30 years of reform and opening up, the number of cities increased from 190 in 1978 to 661 in 2007. The urban built-up area has expanded from 7438 km^2 in 1981 to 32520.7 km^2 in 2005. The urban population of 173 million people in 1978 increased rapidly to 594 million in 2007 (Ailin, 2012). For the rapid development of the city, the land was expropriated from arable land in surrounding countryside. Arable land was expropriated, but the local farmers still remain in the original place of residence, keeping a piece of house site. What happened was that the village became surrounded by the city, and became "urban village".

Farmers benefitted from the situation of rapid urban growth by renting out their land. The rise of urban village comes with the rapid economic development and intensified city expansion (Yuting Liu et al., 2010). A huge number of migrants swarm into cities looking for work in industry and commerce to meet the large housing demand, local farmers try to overlay their houses to provide tenement as much as they can. Cheap rent in urban village provides relief to people who come without much money for accommodation. Rent has turned into the main income of the household (Song & Zenou, 2012). Consequently, as more lands are used for residential purposes and farmed land is disappearing. Massive construction projects built without approval and planning from urban planning department are seen consisting of narrow alleys, serried buildings and sinuous street network. This creates not only inconvenience for the inhabitants but also causes problems for land and housing management departments. Properties are not being adequately registered, and house leasing behaviour cannot be supervised by authority.

Urban village always comes after economic development in cities, so they would not from to the same in different places. Mainly in Beijing, Shanghai, Guangzhou, Shenzhen and some coastal city which are economy developed areas. Those cities were in the forefront of the wave of reform and opening up, they may depend on their advantage of history, geography or policy, gathering funds, resources and labour from that region. The housing construction made by government cannot keep up with the increasing labour that works for new business, urban village was come to offer an alternative chose for them. However, the development of urban village in various regions do not exhibit the same trend. Their position, size and distance away from the city and so on are not the same (Z. Jing, 2008).

Furthermore, the different cities show different situations in scale and density, like a lot of urban villages in Xi'an grew around universities. There are many colleges located in Xi'an. Students and fresh graduates are important components of the population in urban village, as shown in figure 3. But in Shenzhen, urban village is usually next to new central business district, most of the tenements there are employees who work nearby. For Beijing, most central lands have been developed, while the rest of the village grow naturally. In Shanghai, urban village start again at the new economic development zone – Pudong (shows in figure 4). The key point is that urban village will arise near labour gathering place where villagers still have their house site, the customary country style houses will "grow" to high-rise buildings.

Figure 3 Urban villages' distribution around universities in Xi'an （cyan marks represent to urban villages, yellow blocks represent for universities）

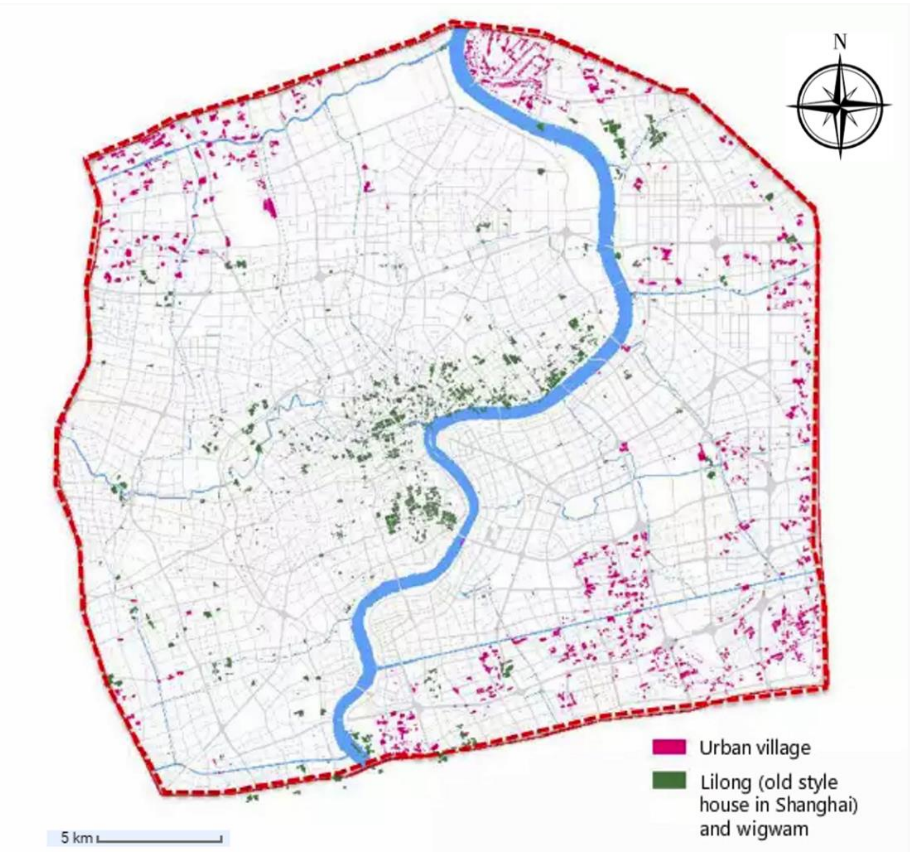


Figure 4 Distribution map of urban village, lilong (lanes and alleys in Shanghai) and wigwam in Shanghai (Cui, 2014)

2.1.2. Spatial Evolution of Urban Villages

According to Hao (2012), the growth of urban village can be divided into three phases: village expansion, densification and upward expansion (intensification). Village expansion refers to growth of land area. Village densification refers to built-up density increase. Village intensification refers to rising of floor area ratio, normally speaking is to build higher floor apartments. The spatial evolution of urban villages cannot be made overnight; it evolved step by step. Figure 5 illustrates the urban village development.

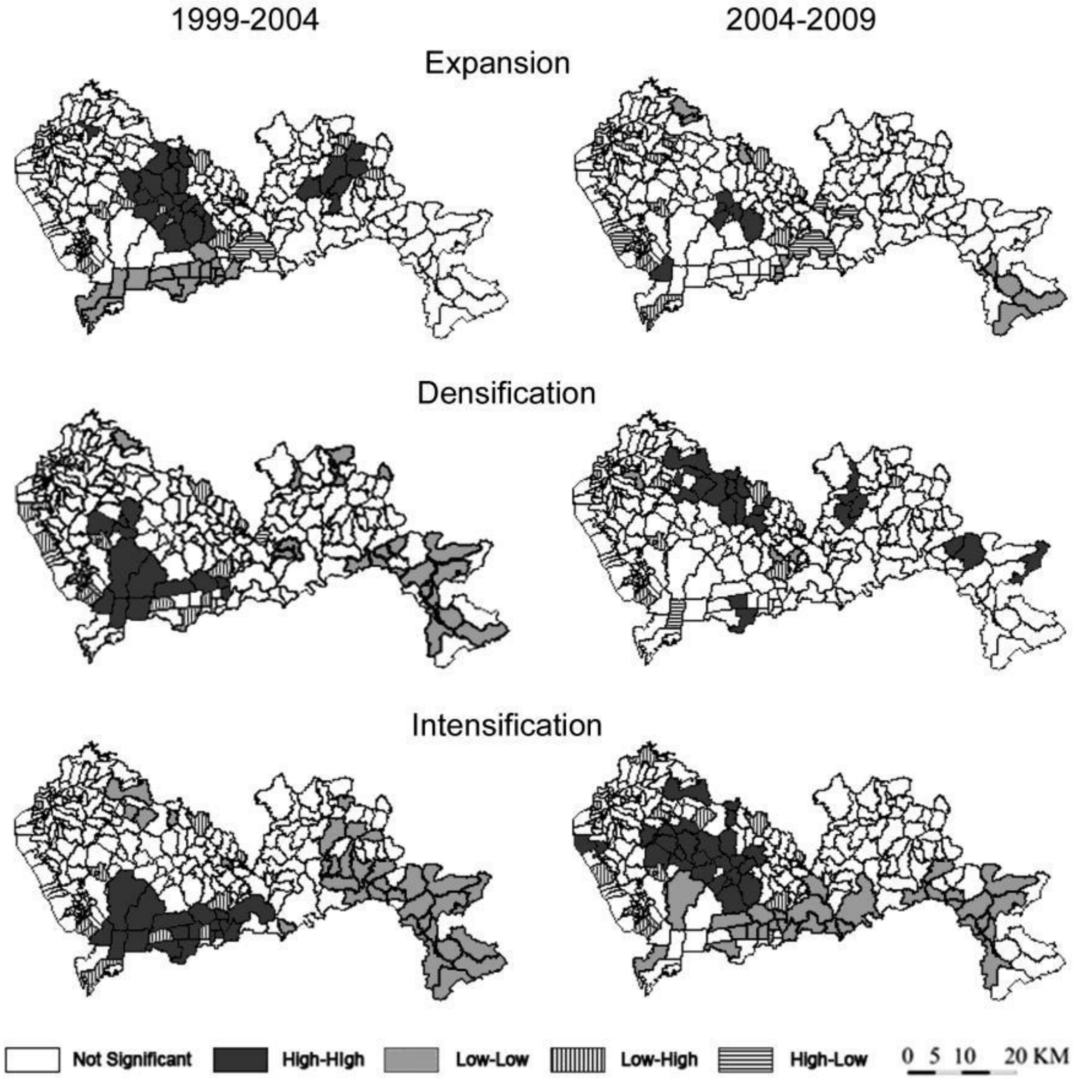


Figure 5 LISA cluster maps of urban village development in terms of expansion, densification and intensification, respectively (Hao, 2012)

In the first period, urban village development was concentrated on the city centre. The development moved to the outer districts in the second period because the land in inner districts was already occupied by housing units. For land expansion, two urban village groups which had good access to the city centre were clustered, but land expansion area was much more confined in the second period. Urban village densification was clustered in more peripheral locations than the ones in the first period. The trend also happened for intensification, the clusters of high active urban villages shifted from the city centre to outer district, and the city centre turned to be clustered low active urban villages.

Urban village in outer districts followed the urban villages in the inner districts to gone through a development process to produce more housing units. The urban village development pattern was expansion first and then densification and intensification. The development speed is determined by its location in the urban fabric. Though urban village developed in terms of different phases, they raised from the inner districts to the outer ones in the whole Shenzhen city.

2.1.3. Urban Villages and Urban Slums

Urban villages are a typical feature of rapidly growing Chinese towns. Urban villages are villages that appear on both the outskirts and the downtown segments of major Chinese cities, including Beijing, Shenzhen and Guangzhou, they are high-density low-cost rental housing as the main type of spontaneous construction area (Wang, Wang, & Wu, 2009).

Urban villages are not part of urban planning and management. Buildings are illegally constructed, unplanned, with lacking of basic infrastructure and poor sanitary conditions. The urban environment is extremely crowded and security is difficult to guarantee. Figure 6 shows the urban village in Guangzhou which belongs to the category of the city from a point geographic point of view. From the perspective of the social nature, it still retains elements of traditional rural areas, having the dual characteristics of urban and rural. Meanwhile, the urban villages have been considered to be Chinese slum by many, although it does not fully meet the definition (Min Jia, 2013).

Figure 6 Urban village in Guangzhou, China (Sack, 2012) and slum in Dharavi, India (The Global Grid, 2013)

According to the definition of the United Nations Human Settlements Programme: "A slum is a heavily populated urban informal settlement characterized by substandard housing and squalor (Un-Habitat, 2007)." But from the other index, urban village is quite different from slum (listed in Table 2).

	Urban village	**Slum**
Formation motive	passive	initiative
Building structure	storied house	bungalow
Population mobility	extremely high	low
Housing conditions	building	hut
Resident income	medium	low
Land ownership	collective owned	state owned

Table 2 Different between urban village and slum (Min Jia, 2013)

2.1.4. Government Interventions in Urban Villages

Urban villages located on the edge of cities were classified to urban area under the urbanization process, and became a part of the city. However, they cannot get rid of the inherent characteristics of the countryside, so they are the mixture of both. The conditions of urban villages land ownership was be divided into three phases:

1. Already "Dismantling Villages and Setting up Urban Communities", all the land have been expropriated by the state, the land is not owned by farmer collective any more, the village has been completely surrounded by the city, the original farmers have all been converted to citizens , but still retain the traditional rural lifestyle.
2. In processing of "Dismantling Villages and Setting up Urban Communities", most of the land has been expropriated by the state, land ownership is partly collectively owned, but the original farmers did not convert to citizens.
3. Not yet "Dismantling Villages and Setting up Urban Communities", the village has been included in urban planning but all land is still owned by collectives.

Urban villages are not included in the reconstruction plan which transforms lands into urban areas. It's still owned by villagers as a collective, and they would not be considered in the local city development planning. Urban village lands are recorded in the rural land management system. It has different legal rights from urban lands, and cannot be used for non-agriculture purposes. Their planning and management are designed for agricultural use. The property rights and attributes of urban villages need to be well recorded in the land management system.

2.2. Land Registration

2.2.1. Land Ownership in China

Land rights in China can be divided into three classes: land ownership, land use right and other rights. Land ownership is whether state ownership or the collective ownership, Chinese individuals cannot privately own land. However, individuals can obtain the land use right from the state. The land use right is called as "usufructuary right" under the Property Rights Law (L. Zhang, 2015), that allows the use right holder to legally possess, use, and benefit from property owned by another.

In the rapid economic development in China, land as an important carrier took place a series of changes in use rights and ownership. Since 1949, the land system has also experienced a change of times before its formation into its present form. According to Liu (2007), after the founding of our republic, the land system can be roughly divided into three stages: farmers' land ownership phase (1949 to 1953), cooperation and collective operational phase (1953 to 1978) and the household contract management phase (1978 to present).

First stage: in the second year of the founding, "People's Republic of China Land Reform Law" was promulgated. The main content is the abolition of the landlord class land ownership, and the implementation of farmers' land ownership. Basically, land reform was completed across the country in early 1953, greatly contributing to the economic recovery and development in rural areas (Jiang, 2001).

Second stage: From 1953 onwards, agricultural production cooperatives mode was separated. Rural land was under unified management, to concentrated power of people to deal with natural disasters, and made full use of tools and technology. At this stage, separation of the right of management from the right of ownership management rights began, land ownership transferred from farmer individual owned to collectively owned.

Third stage: As the reform and opening up extend to the countryside, the original land policy will become a stumbling block. In order to mobilize the peasants' enthusiasm for production, the household contract responsibility system began to appear .This mode of operation with a wide range of adaptability, not only adapt to the situation which is mainly manual labour and agricultural production, and also adapt to the potential requirements of modern agricultural production. To make this land system continually steadily implement, in April 1988, "The Constitution" Amendment provided that: Any organization or individual is allowed to occupy, trade or illegal transfer land in any other ways, but land use rights can be transferred by rule. Then in April 1993, "household contract management" was explicitly written into "the Constitution" to make it a basic national economic policy.

According to "Land Management Law of People's Republic of China", Article 2 states: "The People's Republic of China resorts to a socialist public ownership i.e. an ownership by the whole people and ownerships by collectives of land." (Congress, 2004) That is a so-called dualistic land ownership structure. "Land in the cities is owned by the state. Land in the rural and suburban areas is owned by collectives except for those portions which belong to the state in accordance with the law; house sites and privately farmed plots of cropland and hilly land are also owned by collectives." (Congress, 2004; National People's Congress, 2004), both "Constitution of the People's Republic of China" Article 10 and "People's Republic of China Land Management Law" Article 8 refers to this.

2.2.2. Dual Land Ownership

Liu & Yang (2004) indicated the dualistic household registration system, designed to limit migrating from countrysides to cities. The dualistic household registration system was established to limit rural-urban migration. People needed to be registered as agriculture account or non-agriculture account in the hukou system to identify e treatment. Citizens registered as non-agriculture account could enjoy a variety of welfare benefits guaranteed by the state financial subsidies. However, people registered as agriculture account who called farmer can only make live with their land, and they cannot easily move to cities or other places from their birth land. But the current situation defies the rule, with so many labourers coming into cities looking for work which then resulted in the creation of urban villages across the country.

The dualistic structure of land ownership in China is considered to be one of the root causes of the formation of urban villages (Liu & Yang, 2004). The dualistic ownership structure makes villagers get land use rights with low-cost or even free of charge. Villagers then build by themselves to earn rent as much as they can. The result of maximizing land and housing rent income further intensified urbanization in villages.

Many factors caused the formation of urban villages. Liu (Ying Liu, van Oort, Geertman, & Lin, 2014) explained that local governments usually acquire farmland rather than built-up land to save on costs. When all farmlands are transferred to the state owned land and used for various development purposes, the rest are involuntarily transformed into the urban village.

The structure of the urban villages business model generally consists of housing lease and some basic services like dining, food market, daily consumer goods, clothing stores and the like(Yuan, 2007). Low living costs and high population density have become the distinct feature of urban villages. Behind the low living cost is higher social governance management cost, and therefore further creates problems in land management. Messy construction and low utilization rate (Yao, 2013) are results by the current land policy, resulting in incomplete land records in most urban villages.

2.2.3. House Site Use Rights

House site is a specific kind of land for villagers' housing land and the necessary subsidiary sites. Including housing, kitchen, livestock fences, toilets, courtyard and a small amount of green land (Feng, 2003). "Land Management Law" (Standing Committee of the National People's Congress, 2004) stipulates that one rural housed hold can only have one piece of house site, with a limited area in the provinces standards. "The application for housing land after selling or leasing houses shall not be approved." Building construction on house site should conform to the local land use plans and use original land occupied by houses and open spaces of villages as much as possible to save land as well as make rational use of land resource. It means house site is provided to villagers for their housing demand, but the current situation in urban village is that villagers are losing their agriculture land for farming to make money, so they build higher houses to lend room for income. For the ownership of house site, it is still owned by collective, villagers can apply for use right of it.

After that villages could have use right and right of inheritance, but villages cannot lend, transfer to others or mortgage house site. On the other side, such appendices as buildings, trees, stockyard and washroom constructed by villagers are owned by themselves. The use right of house site is permanent but use limited, and only villagers can apply for house site use right in their own village group. The initial acquisition of house site use right is free. This policy gives an advantage to villagers but is also likely to cause farmers to misunderstand the relationship of house site ownership.

House site certificate, also called "collective land use certificate", is a land right certificate registered and issued by the people's government at or above the county level. A villager who wants land need to file an application for land registration to local land resources bureau, then surveyors from there would measure the parcel and fill out the questionnaire. The bureau officer need to check all the documents like: a) Application forms of house site use right and house ownership; b) Legally valid proof of identification of obligee (ID card, Hukou booklet, etc.), if the obligee commissions others to handle this issues, power of attorney and identity proof of trustee must provide too; c) Parcel map and real estate surveying report; d) Rights origin certification of house site use right and house ownership etc.

2.2.4. Land Registration in China

Land recordation system keeps the attribute and geographical information of land to describe who is the owner, what is the land right and where is the parcel. The records on these two aspects should be treated as integrated, but they are often separate to land registration and cadastre, not cooperate well. Land registration emphasize an official record of the land right, solidify with land title and land deed. Mainly concentrate on attribute information like owner and rights, land registration written the link between them down. However, cadastre aims at property state, shows the size, nature, value and land right of the parcel. Cadastre also includes geographical information of the parcel, their boundaries are recorded after survey.

Record consistency is a very important factor for land registration, the change history of land ownership and obligee replacement needed to find and produce. If obligee cannot provide it, land administration department should keep the record. A land record in urban village had been changed two times after issue and modification of Land Administration Law on 1987 and 1999 (Qingtian County Government, 2014), villagers got official documents like "Collective land use certificate" from local government with their land use right. On the other hand, all the changes are looked by people, there is another aspect needed to be concerned, which is information publicity. How does the obligee get land use right, where is the location of the parcel, what size is the land when does that happen, if these question could be answered anytime when people asked, keeping the land under all people's supervision, that would be the best guarantee of the land administration system. The cadastral database has been built in some land resource bureau. Anyone can see the relevant land information and know for him or herself, once database comes into service. People can see the latest developments related to their land, which opens the information to the public to prevent corruption, and to ensure smooth and stable operation of the system.

For system running, a fit-for-propose land recordation system design should consider the special situation of urban village. Different situations in urban villages make it impossible to have uniformity in scheduling. Allowing urban village to make its own investigation and registration plan with the land resource bureau would be more applicable. Since the village borders have been fixed decades ago, village by village registration could ensure the integrity of land records. Some urban villages have completely transferred to city area (Deng, 2014., Huang, 2013., Liang, 2014), their experience in land registration management is worth learning.

Before start registration, land management departments should make a detailed plan, to avoid duplication of work and improve work efficiency. Among them, a high-precision survey base map will bring great convenience, a carefully planned field work could be made on the base map. After the investigation, add up numbered land information which had been confirmed on the original base map, it would be a very good query tool -- index map.

Land registration is a legal act that the land registration authority records ownership, use, size, grade, and prices of land in the special database with the provisions of the program (Ministry of Land & Resources, 2007). According to Article 2 (Ministry of Land & Resources, 2008) , "Land Registration" refers to the act of "registering state owned land use rights, collective land ownership, collective land use rights, land mortgage right, easement and other land rights that need to be registered according to any laws and regulations on the land registers for the purpose of announcement".

From the state central policy documents, it only indicates the general direction and principles of treatment, did not make specific provisions for the registration of urban village, so the local government and land administration departments taking a different registration measures based on the actual situation within the jurisdiction of theirs (according to (Ministry of Land and Resources, 2007)), but the main registration details are similar, like oblige information, land description and above-ground structures situation these three main aspects. Registration details about the land contain location, building area, the area of legal use right and owner information.

Land Resources Bureau in China is a department which implements policies, laws and regulations by the national, provincial and local government about land, minerals, mapping, housing and real estate, property management and housing system reform; responsible for developing legal education program as well as publicity plan for all aspects of the above, and organize the implementation. Its related function includes land management, real estate market and property management, cadastral surveying and mapping management, housing system reform management, property regulation and housing industrialization management, law-enforcement monitoring, land requisition and demolishing management and land reserve management. It is related to most aspects of urban village such as development, regulatory, demolition, reconstruction.

2.2.5. Land Registration in Urban Villages

The authority power of land right countersign is held by Municipal People's Government in each city or district. Municipal People's Government is the executive branch of the General Assembly of the Municipal People's Congress. It leads the work of all sectors of county level governments. Institutions involved with urban village land registration are listed in figure 7. Implementation of national economic and social development planning and budgeting, management of urban and rural development and other administrative work under its jurisdiction areas. The main land recordation problem focuses on house site recordation in urban village, its original authority power is hold by the national and local government, and it is the final decision maker to grant land certification.

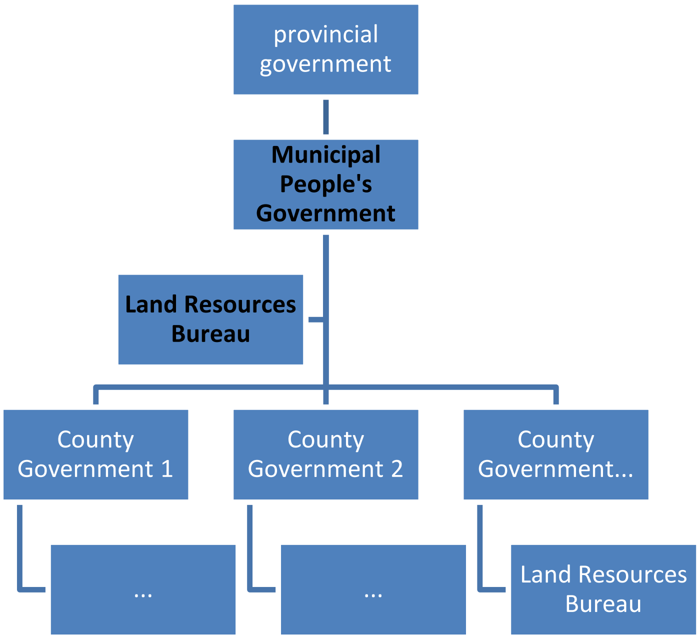


Figure 7 Urban village land registration related institution chart

The record object in this research is in urban village. The land is owned by the collective before urban village reconstruction. "Collective land use rights" includes collective construction land use right, right to use the house site and collective agricultural land use right (excluding the right to contracted management of land). Urban village has a different land structure. The land use in urban village has been used for housing build from agricultural land or other use. House site has a higher value than the rest of the land, where most of the disputes occur. Most of the villagers have no other income beside house rent. After they have lost their agricultural land, only small part of them will have an ability to make other business. Others live by collecting rent from tenants (Song & Zenou, 2012).

2.3. Fit-For-Purpose Land Registration and UAV

2.3.1. Fit-For-Purpose Land Registration

Urban village land in this research has its particularity. It is a transitional temporary phenomenon, will be converted into part of the city sooner or later. The registration system should be designed to be rapid, complete, and the economy as a primary consideration, instead of complicated as existing urban land registration system. It should fit for the purpose of urban village land registration, which is peculiar from normal rural or urban land registration.

The requirement of this recordation system are similar with the pro-poor land administration which contains eight core requirements: affordability of citizens and the state, layered tenures, preventative justice, implementation, spatial index map, transparency, inclusive and equity, joint management (Zevenbergen et al., 2013). From point view of poor aimed, the system should be set up with low cost and limit time, to provide basic protection to poor people's poverty profit rather than nothing. A good land administration system fit to the reality (economical, culture and history) of local people and the ability of the government, so as urban village land recordation system.

There are some aspects villages can learn, but with different consideration and residents. From the grassroots of the capacity point of view, the article is considered the affordability of low-income residents, so charge a symbolic fee as one dollar. In the case of urban villages, a small symbolic charge is worthy to take, mainly to promote the progress of investigations, and reduce the potential problem caused by the charge for villagers. Then, the cost falls on the other stakeholders of land registration, and the land management department is a subordinate agency of local government, does not run for profit, so the cost of the entire land registration procedures should support by the government.

A good way to reduce the cost is applying new technique to change work mode as efficient and cheap operation style. Such as the use of UAV image as input data which has high-resolution aerial photo in target areas. After correcting process, orthophotos or point cloud would be generated by software, interior work will be able to preliminary determine the border f parcels or houses. Then go to the field for verification and correction with interpretation result of interior work, it will greatly reduce time and costs in traditional method reliance on manual measurement. For the details on this technology it will be described in the next chapter.

The key requirements for a rapid land recordation system include functions, processes, people and technical tools (Zevenbergen et al., 2013). This research focuses on using new technology to improve land record process, in terms of making the system more efficient and cost-effective. It would help ease the complexity of property rights in urban villages. Using UAV images to support land recordation in urban village as spatial information collection resource, could sharply reduce the cost and time than the traditional survey method. And small UAV can take flights for aimed area anytime anywhere for urban village land recordation purpose.

2.3.2. UAV Application in Land Administration

UAV is defined as an aircraft system with complete autonomous control capability (Bailey, 2012), which can automatically take off and land, and flies on low-altitude on a designed route. It can be treated as an "aerial robot", working using flight control system, and using positioning & navigation module that feeds back the flying conditions to pilot control UAV. UAV for photogrammetry had been tested by many scientists (Colomina & Molina, 2014), some have used professional cameras (Ruzgienė, Berteška, Gečyte, Jakubauskienė, & Aksamitauskas, 2015) and others using a consumer-level camera (Uysal, Toprak, & Polat, 2015). Some researchers have even used smartphones on-board a UAV (Kim et al., 2013). They have sown very positive results, providing quality DEM and orthophoto-images generated from sensors on-board UAV.

The main focus of this research is to generate base maps for land survey and measurement using UAV technology. Data quality and accuracy are the necessary items for base maps, and generally employ high-resolution pan-images and airborne images (Shang, 2008). UAV images have been tried in cities in China for land rights adjudication (Y. Jing, 2011). Low altitude remote sensing images from UAV were utilized processes in orthophoto for investigation and surveying procedures. But for messy distribution buildings in urban village, UAV images could also be a good data resource for land recordation. The working base map for surveying should be of two kind format: digital map in electronic equipment and paper map which is easier to carry and identified by the property owner.

The most interesting aspect of that for land administration is land measurement or survey. For land boundary mapping, Mukendwa (2015) had a research to use UAV images mapping customary land. In relevant engineering work, UAV images were utilized for area measurement (Mesas-Carrascosa, Notario-García, Meroño de Larriva, Sánchez de la Orden, & García-Ferrer Porras, 2014). UAVs have been successfully used for land use change detection (Y. Zhang & Cui, 2011). Orthophoto for land plot measurement was tested in Spain (Mesas-Carrascosa et al., 2014), used for land policy monitoring. Using UAV image to mapping parcel boundary had been tested in Namibia (Mukendwa, 2015).

The last but not least point is the system management issues, the joint management method which mentioned in pro-poor land administration paper (Zevenbergen et al., 2013) is indeed an appropriate way. Since there are at least three stakeholders, but it is not normal equitable relation like person to person, one of them is the government, then how to protect villagers' rights become a big issue in this system. Normally, village leaders could represent most people because leaders are elected from villagers, so they are dealing with most issues with outside as representative. On the other hand, land resource bureau takes the responsibility of maintaining and handle the land recordation system as technical guidance, regulation executor and manager. In the end, government, village leaders and land resource bureau will play main roles on the table to run this land registration system.

Ten basic element (Zevenbergen et al., 2013)or principles were reiterated in the system optimization section to emphasize the factors needed to be consider in land recordation system design, some of them are also applicative in urban village. After assess the condition of urban village, it is needed and useful to design a new recordation system to register land there. Since they will be urbanizing soon, start to make records of villagers' property rights became an instant mission before that. Land recordation should be act in a whole village with unified process, registered by surveyor send from land resource bureau. Villagers need to provide certification to surveyor which may have different type from different period, if there is any dispute for the house site use right, the government need to act as a mediator. The government would check the survey documents and issue certification for the current land use situation, keep the classified records to land information database system with standard index.

2.3.3. UAV Regulation

In order to protect public safety, UAV flight must be regulated. In the end of 2015, the Federal Aviation Administration (FAA) of the United States officially opened network registration system for small unmanned aircraft systems (UAS). It requires UAV registered in real-name, and reporting position in real-time. The purpose of this UAV register system is to better manage the use of unmanned aerial vehicles, timely track UAV owner who violate flight safety rules, to effectively aviation security. According to the new registration requirements, small UAV weight between 0.25 to 25 kg need for registration, including its cameras and other airborne equipment.

FAA has been published a number of UAV flight management regulations policies before, that limit flight altitude under 120 meters, and require UAV cannot fly out of controller's visual field, flying within 8 kilometres to any airport need to get approval before taking flight. In terms of pilots, UAV operators do not need to obtain a pilot's license, but he must get UAV safety training, and pass the test every year. The basic principle of regulation is to guarantee aviation security.

The EASA (European Aviation Safety Agency) published the Technical Note "Introduction of a regulatory framework for the operation of unmanned aircraft" on December 18, 2015 for the operation of unmanned aircraft in the European airspace. Many member states have their national regulations, like France: DGAC DEVA1207595A, Germany: LBA NFL I 281/13 and UK: CAA CAP 722. Moreover, the Netherlands requires RPAS licenses for UAV pilots; the French DGAC requires type certificates for every operated drone on the French territory. The EASA will publish a final rule both in technology and management aspects before the end of 2010s.

China has some progress in UAV regulation. The Flight Standards Department in Civil Aviation Administration of China promulgated the "Light and Small Civilian UAV System Operation and Management Interim Provisions" Advisory Circular in November 2015, classified UAV in weight and fly speed, and to state clearly the responsibility and authority of civilian UAV captain, even mentioned about unmanned aerial vehicles drunk driving and other behaviours.

According to the "Provisional Regulations on Administration of UAV" promulgated by the Civil Aviation Authority of China in the end of 2013, the UAV can fly without approval only under the following three conditions: UAV indoor flight; UAV lighter than 7 kg flight within a visual field; UAV testing flight in sparsely populated areas. According to "People's Republic of China Basic Flight Rules", other flights need to get approval from the local air force headquarters and air traffic management bureau in the district where the flight would take.

There are many gaps between the use and supervision of UAV. China had been put out "Civilian UAV Air Traffic Management Regulations", "Civil UAV Airworthiness Management Meeting Minutes", "Civil unmanned aircraft systems driver management Interim Provisions" and other relevant laws and regulations after 2009. Unfortunately, because the entire UAV industry of the country is in the initial stage, it will inevitably be delayed in the management and punishment procedures and standards. With the rapid development of the UAV industry, regulations and supporting regulatory measures will be gradually perfected.

2.4. Summary

The concept of "urban village" was defined in this chapter. It also compared urban village with slum to highlight the peculiarity of urban village. Land ownership and house site use right in china were explained to analysis the requirement of land registration in urban village. To support the land recordation system in urban village, UAV was considered to collect spatial information of urban village land. The UAV photogrammetry theory was introduced in next chapter to expound how UAV could support land recordation system in urban village.

3. UAV PHOTOGRAMMETRIC PROCEDURES

This chapter states the principles in photogrammetry, explains how it works from the images to the result and the procedures in the Pix4D software used in the research. Photogrammetry is well used in survey and modelling from the time when photo shoot was invented. Images are utilized to represent the real world instead of points and lines. Different from the traditional method which measures the features by basic geometry elements, photogrammetry builds the model first, and measure the numbers we need in that reconstructed model.

UAV image quality would be influenced by many factors in the flight. Unlike satellite images, most UAV images were captured for a certain purpose, so a flight plan is needed. A good flight plan should consider many factors, first of all is the target area, after area confirmation (parcel corner coordinates are needed here), field investigation is required to confirm airspace and landing sites, and apply for flight permit. Then to the core of flight plan, flight altitude is limited by accuracy requirement, appropriate flight routes could reduce flight times to the minimum which is time and cost economic. Overlapping is an important factor need to be considered. Theoretically, a forward overlap of 50% is required for stereo pair coverage in an ideal flight. However, gaps would occur due to flying height variations, aircraft tilt and terrain variations, and there would be distortions caused by the camera. Images are used for photogrammetry control sometime, some points must appear in three photos. For these reasons, UAV images used for mapping normally require the frontal overlap between 60% and 65% and side overlap between 30% and 40% (Xing, Wang, & Xu, 2010). More overlap between images there are, more homonymy points could be found in image pairs. Camera equipment is the other constraint for image quality. The following sections introduced the office process contains image correction, matching, editing and output.

3.1. Camera Calibration

In order to measure the size of an object in world units, lens distortion must be corrected by estimating the parameters of a lens and image sensor of an image. The location of the camera in the scene could be determined after that. It could be used to detect and measure objects from images (MathWorks, 2016).

It can correct the camera distortion through calibration. The relation between the images and the real world can also be determined with calibration. Camera calibration is an important step to getting a high accurate representation of the real world in captured images. Primarily, it is about finding the quantities internal to the camera that affect the imaging process. The following are the factors need to be considered in camera calibration: ("Perpetual Enigma", 2014)

1. Principal point position: The principal points are the points where the principal planes cross the optical axis. Principal point position should be located at the center of the image, intersection point which in the middle of width and middle of the length.

2. Focal length: The focal length of the lens is the distance between the lens and the image sensor when the subject is in focus, usually stated in millimetres. The focal length of the lens essentially determines how 'zoomed in' the photos are; the higher the number, the more zoomed the lens will be.

3. Others: Skew factor refers to shearing. The image was calibrated from a parallelogram to rectangle. In order to correct that, the angle between adjacent sides needed to be calculated to make shear warp transformation. Lens distortion refers to the pseudo zoom effect near the center of image. The commonly encountered distortions are approximately radially symmetric which can be classified as barrel or pincushion distortions.

Distortion can either be irregular or can follow many patterns. The most commonly encountered distortions are radially symmetric approximately arising from the symmetry of a photographic lens. These radial distortions can usually be classified as either barrel distortion or pincushion distortions.

Pinhole camera model was used to explain how to map the 3D scene to a 2D image. It means that every point in the 3D world gets mapped to the 2D plane on our image. It basically describes the relationship between the coordinates of the 3D point and its projection on the 2D image. It is the ideal case where there is absolutely no distortion of any kind. Every camera is modelled based on this, and every camera aspires to simulate this as close as possible. But in the real world, we have to deal with aspects like geometric distortions, blurring and finite sized apertures.

Figure 8 shows as a camera model. The camera is placed at the origin O. The point P represents a point in the real world. It was required to capture onto a 2D plane. The "image plane" represents the 2D plane captured in the image. So basically, that is trying to map every 3D point to a point on the image plane. In this case, the point P gets mapped to Pc. The distance between the origin O and this image plane is called the focal length of the camera.

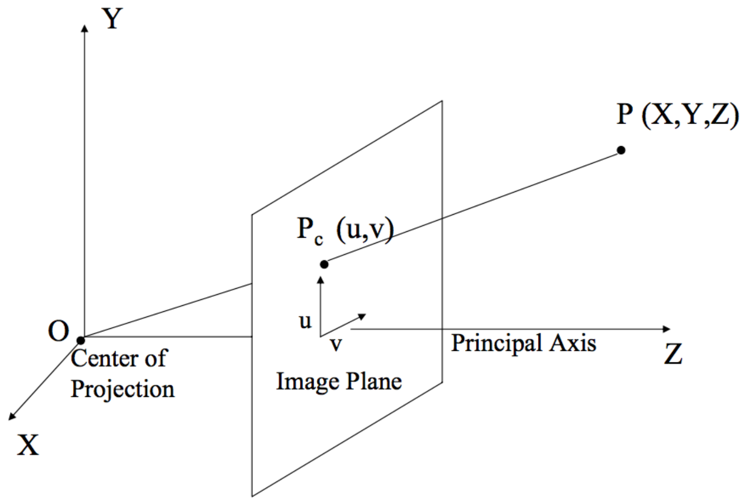


Figure 8 Pinhole camera model ("Perpetual Enigma", 2014)

In the above figure, the point P_c (u, v) was estimated from P (X, Y, Z). The focal length is denoted by 'f', and point P_c and P contain in a pair of similar triangles. This means that 'v' depends on the f, X, and Z; 'u' depends on f, Y, and Z:

$y = fX/Z$
$u = fY/Z$

Then, if the origin of the 2D image coordinate system does not coincide with the point which the Z axis intersects the image plane, P_c need to be translated to the desired origin. The translation is defined as (t_u, t_v), or like (x_0, y_0) in the figure 9. So now, u and v are given by:

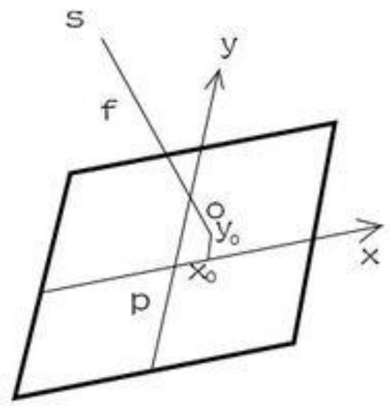


Figure 9 Elements of interior orientation in an image (Lin & Wang, 2013)

$v = fX/Z + t_v$
$u = fY/Z + t_u$

That is how point in image (u, v) translated from real point (X, Y, Z). The three parameters include focal length f, principal point skew coefficient (x_0, y_0), are called as intrinsic parameters. They are used to determine the relative position between lens center (projection center) and the image, to restore the situation of the bundle when the image was being shot. Basically, camera calibration parameters are used to transform a 3D point in the real world to a 2D point on the image plane considering aspects like focal length of the camera, distortion, resolution and shifting of origin.

3.2. Image Orientation

Image orientation aims to place images in the right location and orientation of the ground coordinate system. As for a single photo, it has an independent coordinate system. It can only determine the direction of the ground point even with the external orientation elements. To determine the spatial location of ground points, stereo image pairs captured by two camera positions with overlapping images are needed. Using stereo image pairs and its geometric relationship between the grounds, it can not only determine the ground point flat position, but also determine the elevation of ground points. GCPs are still required for scaling and geo-referencing.

For image orientation, there are several phases in the image processing procedure: inner orientation, relative orientation and absolute orientation. Interior orientation defines the internal geometry of a camera as it existed at the time of shoot. It is primarily used to transform the image plane coordinate system to the image space coordinate system. Intrinsic parameters got from camera calibration are utilized in interior orientation to determine the positional relationship between images and its space coordinate system. Then, positional relationships between images would be fixed in relative orientation.

To define the position and rotation of the camera of image and projection center, six exterior orientation parameters were needed. They are three object mapping coordinates of the projection center (U_0, V_0, W_0) also as (X_0, Y_0, Z_0) and three rotational parameters of aircraft yaw, pitch and roll which denoted by $\varkappa$, φ, and ω. These are called the extrinsic parameters of the camera. They are used to determine the relative position of the bundle in the ground coordinate system. A signal image is not enough for calculating the ground points' position. Orientation of a stereo pair for relative orientation and absolute orientation is required. A stereo pair is two photos taken from different positions for the same area, the two photo contain a certain rate of overlap (P. Bourke, 1999).

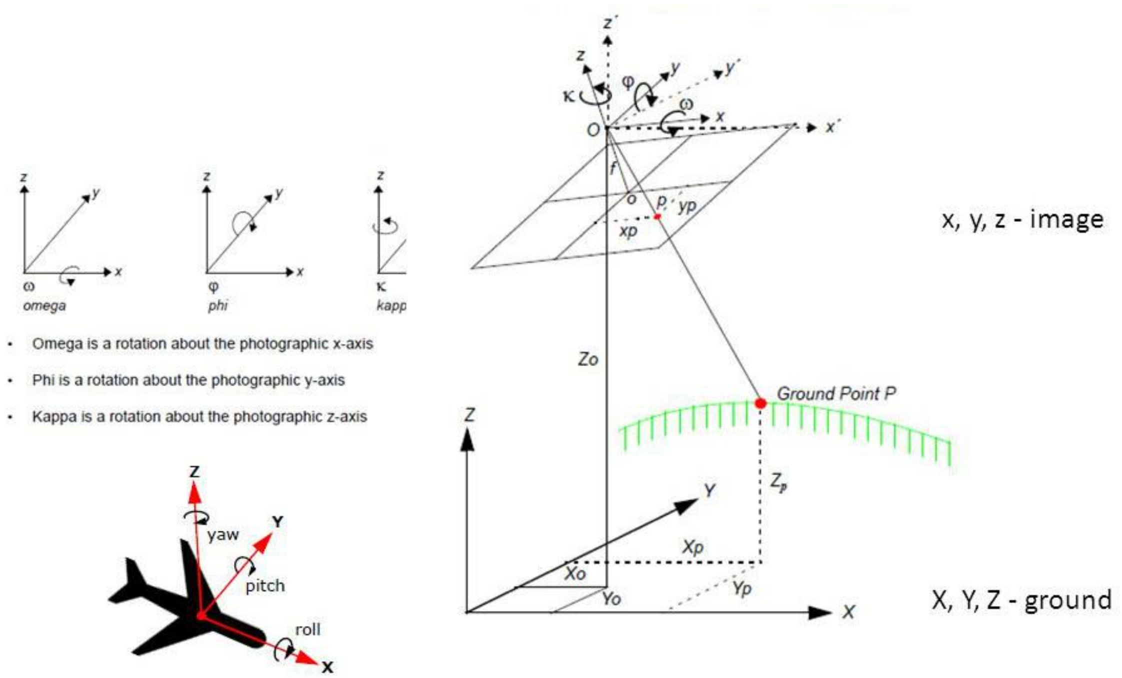


Figure 10 Elements of exterior orientation ("ERDAS LPS", 2010)

Relative orientation aims to orient two photos within a stereo images, and absolute orientation aims to orient and scale the stereo model to the ground. For relative orientation, it must find 5 parameters for rotation and direction, while 7 parameters are needed to do absolute orientation. It does not only determine the relative relation between two photos, but also fix them to the real distance scale between them. Next photo would make a stereo pair with the previous one. When all photos are taken part in the orientation, a whole image shoot is created.

3.3. Surface Reconstruction

A point cloud model was reconstructed digitally by dense image matching. It automatically identified conjugate points in two or more images. Keypoints were detected through image matching, then the normalized region around each keypoint was extracted. The normalized region in multiple images would be compared and computed the pixel matrix to find the matched keypoints. With the matched points from all image pair constituting the whole point cloud. The same image points picked out from multi-images were used to calculate the corresponding space coordinates. When those points were placed in the same coordinate system, it restored the scene of the shooting area by point could.

As point cloud was built, 3D model was generated. The point cloud is a set of data points in a three-dimensional coordinate system which is defined by X, Y, and Z coordinates. The color attribute of points is often intended to represent the external surface of ground features. If the density of the point cloud increases high enough close to infinite, then the point cloud is said to accurately represent the real features. So we can take the point cloud as a representation of the real world. To create a 3D model from the point cloud, making up the missing points is needed.

There are many techniques for converting a point cloud to a 3D surface. One typical approach is triangulation: building a network of triangles over the existing vertices of the point cloud. The surface result will be influenced by the point cloud density and triangle setting algorithm, the reconstruct surface would be more close to reality with more dense points. This process covers converting point cloud to triangular meshes: transforming a raw point cloud into a colored mesh. It starts from a colored point cloud which maybe non uniform, through subsampling, normal reconstruction, surface reconstruction, recovering original color as well as cleaning up and assessing to get the result needed (P. Cignoni, 2009).

Surface reconstruction from point cloud is often a sequential process with the following steps: 1) input point cloud; 2) remove outlier; 3) simplification to reduce the number of input points; 4) smoothing to reduce noise in the input data; 5) normal estimation and orientation; then 6) to do the surface reconstruction.

3.4. Orthoimage Generation

Orthophoto, also called as orthophotograph or orthoimage, is a geometrically corrected aerial photograph which can be used to measure true distances, areas, angles, and positions, because the scale of the orthophoto is uniform in any direction (Fernandez, Garfinkel, & Arbiol, 1998). An orthophoto is usually a high-resolution aerial image that combines the visual attributes with the spatial accuracy and map reliability. In an orthophoto, the terrain has been corrected without central projection limitation. The distances in the image center and image boundary are the same, which would not have obscured area appearing in the uncorrected aerial photo. But the normal orthophoto can only be used to measure at the terrain level. Building lean appears in the normal orthophoto, it shows the building facade which should not be there. And buildings' roof were projected not right above its bottom. It obscures some streets and other ground features, because normal orthophoto is projected on elevation model.

True orthophoto removes residual tilt of the buildings, all of the above ground features show in their proper elevation. In true orthophoto generation, any outstanding features at ground level would be captured, and it collects detail description data of feature tops. It is generated through intensive computation based on three-dimensional models. To make an orthophoto, the original aerial images are georeferenced and processed to remove virtually all the distortion due to terrain and camera position.

For generating dense point cloud, two important concepts Digital Elevation Model (DEM) and Digital Terrain Model (DTM) need to be explained here. DEM is a kind of earth's surface model which is used to remove distortions in the aerial photography caused by changes in land elevation like valleys and ridges. It may include treetops, rooftops, and tops of towers, telephone poles, and other features; or it may include the ground surface if there is no vegetative ground cover ("IGIC", 2004). That could be classified into Digital Terrain Model (DTM) and Digital Surface Model (DSM) by the difference of ground features.

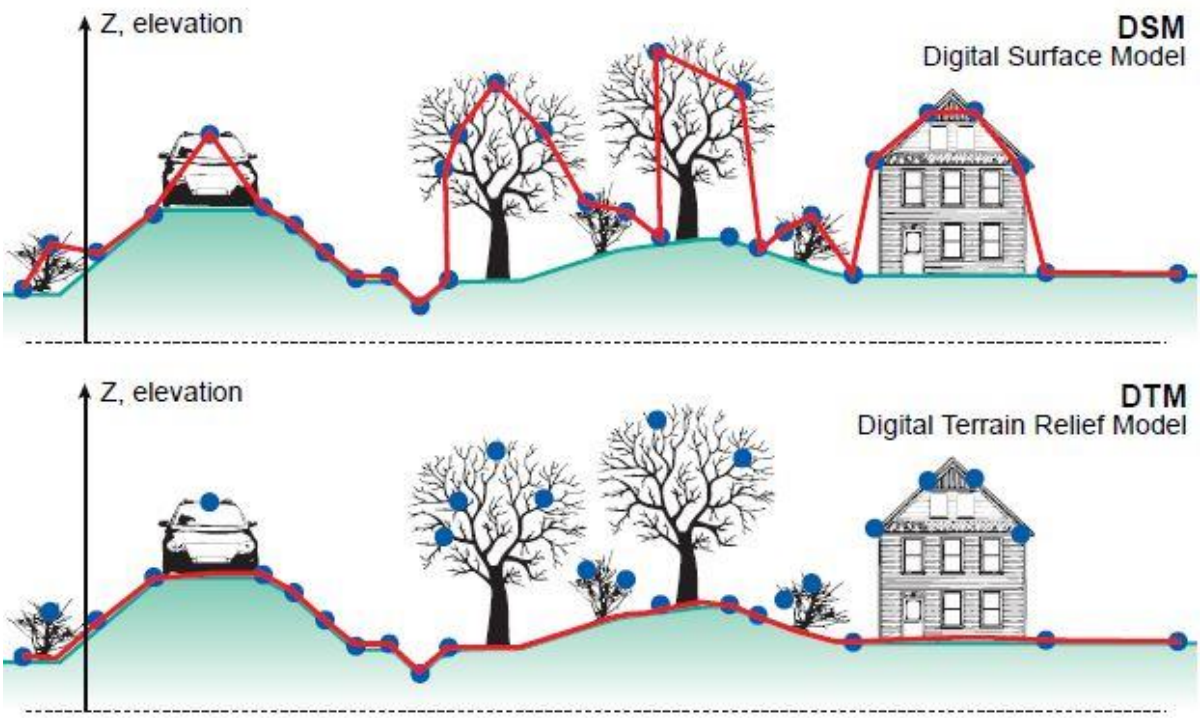


Figure 11 Difference between DSM and DTM ("CHARIM", 2010)

The DTM can be developed from aerial photography (E. Tate, 1998). The triangular irregular network (TIN) model is often used for a digital representation of the terrain. To form the TIN, a perimeter around the data points is established. Delaunay triangulation is then used to connect the interior points. Each triangulation results in a planar surface. A whole surface would be created by integrating all of the triangles over the domain. The TIN surface is used to orthogonally rectify the photos. By combining the data sources from different photos, each image pixel has a position and intensity value. In the rectification process, the intensity value for each pixel is re-sampled using a space resection equation to remove image displacements. The rest photos are then clipped and seamlessly joined together over the entire study area. The result is a digital image that combines the image characteristics with the geometric qualities.

3.5. Summary

In this chapter, orthoimage generation was introduced theoretically. The first step, camera calibration aims to reduce the distortion caused by the physical camera. Then image orientation aims to determine the location of each image, to combine them into one coordinate system. Dense image matching needed to be done after image orientation to construct point cloud. And 3D model would be built based on point cloud. In the end, an orthophoto would be generated to measure features in the study area. The research work done with Pix4D was described in next chapter, to show the image processing produces with research data in the study area.

4. MATERIALS AND METHODS

4.1. Study Area

The study area for this research is a typical urban village in a county-level city in the northwest part of China, Xinjiang province. The whole city covers an area of 7268 km^2, built-up area of it had expanded to 113 km^2 in 2013, the urbanization rate reached to 73%. The total amount of city GDP reached to 105 billion at the same time. It has the resident population of 55 million people, nearly 40 million people among that is floating population. It has three urban village groups as shown in Figure 12, surrounded by well-planned communities. The one in the north still has some farmlands, near underdeveloped areas. The main road lies adjacent to the village providing access to a nearby stadium and school. Minimal vegetation can be found in these urban villages, which strongly contrast with those well-managed communities with greener landscapes. The urban villages range from 9 to 22.5 hectares in land area. About 100 households live in each village group, with an overwhelming majority coming in as transiting migrants.

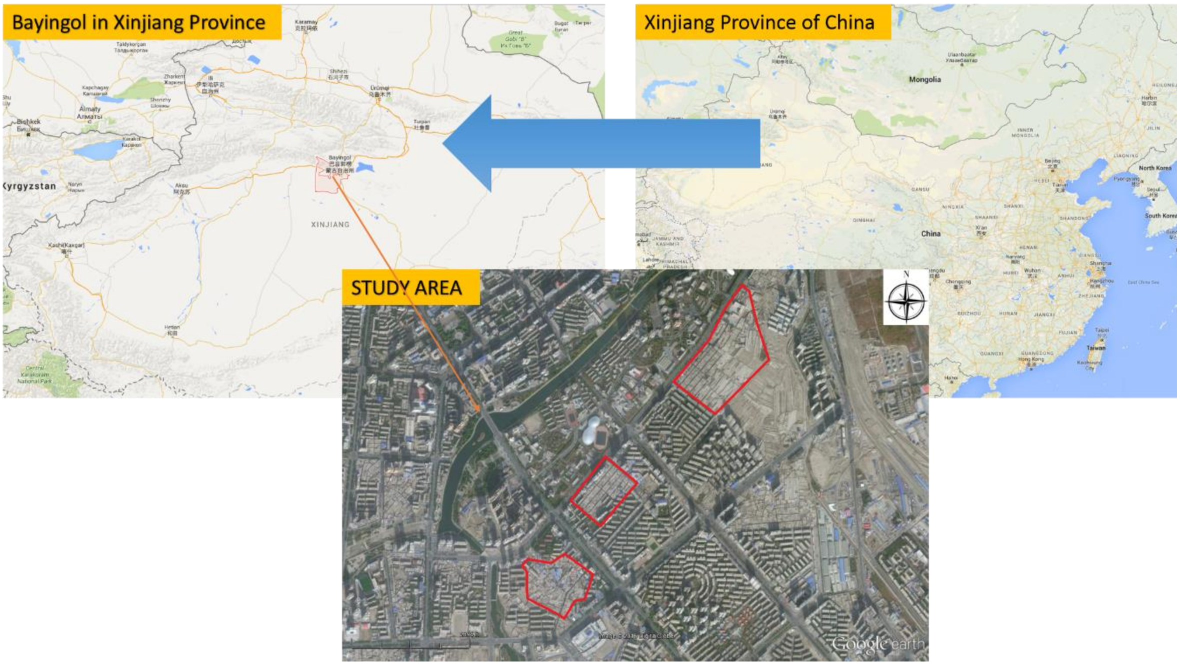


Figure 12 UAV image covered area

4.2. Data Source and Software Requirement

UAV images were provided by Chaofeng Ren, lecturer of Chang'an University. UAV images were used to assess the viability of UAV for land recordation system. The images for this research were captured by a CanonEOS 5D digital single-lens reflex (DSLR) camera, with fixed-wing UAV on the height of above 600m. Eleven photos (number 40-50) were used in this study from the total of 302 photos taken. For accuracy matching, additional 12 photos (number 75-86) located next to study area were select. The frontal and side overlaps reached the minimum 65% and 35% respectively.

Camera model parameters were provided within the images, they were contained in table 3. In this table, image width and image height are the dimension description count by pixel. Image width and image height times pixel size are sensor width and sensor height, they are represented by physical length. Pixel size refers to a minimum sensor unit. The principal point is the vertical projection point of the focal point in the image plane, the distance between these two points called focal length. Ground Sampling Distance is the distance between pixel centres measured on the ground. It is decided by flight height affected by the specifications of the camera. As GSD=H·Δx /f, H refers to flight height and f means focal length, x represent to pixel size. But it would be different between ground points caused by terrain fluctuation. Principal point x and principal point y are the distances between point and image boundary in two directions.

Camera model parameters			
Image Width [pixel]	**5616**	**Sensor Width [mm]**	**36**
Image Height [pixel]	**3744**	**Sensor Height [mm]**	**24**
Bands	**RGB**	**Pixel Size [µm]**	**6.41026**
Focal Length [pixel]	**5485.82**	**Focal Length [mm]**	**35.1655**
Principal Point x [pixel]	**2796.13**	**Principal Point x [mm]**	**17.9239**
Principal Point y [pixel]	**1875.97**	**Principal Point y [mm]**	**12.0254**
Average Ground Sampling Distance (GSD) [cm/pixel]			**6.11712**

Table 3 Camera model parameters

Images were analysed and processed to make work base map for investigation and for geo-referencing. According to "Specifications for office operation of low-altitude digital aero photogrammetry - CH/Z 3003-2010" (State Bureau of Surveying and Mapping, 2010), ground resolution of the images needs to be equal or greater than 0.05m. To perform the analysis and processing, several software packages like Pix4D and ArcGIS were used.

4.3. Method: Generating Orthophoto

4.3.1. Image Processing

In this research, a Canon EOS 5D digital single-lens reflex (DSLR) camera was used for capturing images. The spectral specification of this camera is RGB (The RGB additive color model added red, green, and blue light together to reproduce a broad array of colors.) Before starting a project in Pix4D Mapper, configuring camera settings is needed. It is able to process images taken from many kinds of a camera like lightweight compact cameras, DSLR cameras and large format cameras with perspective or fisheye lens.

Then in the initial processing, Pix4D Mapper allows the user to select how to reconstruct the camera external and internal parameters. It works in the Automatic Aerial Triangulation (AAT), Bundle Block Adjustment (BBA), and camera self-calibration steps multiple times, to get an optimal reconstruction. There are different calibration method options for aerial nadir images which like fields with accurate geolocation and low texture content, or the very accurate image geolocation and orientation project. Users also need to choose which camera parameters need to be optimized. For internal parameters optimization, it is suggested to optimize all the internal parameters because small camera used with UAV is very sensitive to temperature or vibrations, which would influence the camera calibration. The values of internal parameters come from the camera model chosen. And all the external camera parameters include the position and orientation of the cameras are optimized by default. External parameters values are taken from the Automatic Aerial Triangulation (AAT) during initial processing. After that, the optimized values for the internal and external parameters are saved. The initial and optimized values for the internal parameters were displayed in the quality report. Moreover, the results of the AAT, BBA, and optimized internal and external camera parameters could also be saved.

In the camera model parameters section, users can see and edit all camera parameters. It could be estimated from the exchangeable image file format (EXIF) data, which usually created when a photograph is exposed and written to disk. EXIF data records information about the images taken like the shutter speed, ISO, and aperture settings, as well as lens and camera brand. In the other way, camera parameters could also change to the optimized values from the result after initial processing has been completed.

For the images in the project of this research, internal camera parameters for perspective lens shows as table 4. In among of these parameters, the image width and height were read from image files, its value cannot be edited by users, and they are usually displayed in pixels. Corresponding to sensor width and height, they are usually in millimeters. The pixel size could read from the EXIF data or calculated from the ratio sensor width / image width. The pixel is the basic unit of programmable color in an image, the physical size of a pixel equals the physical size of the dot pitch.

There are some distortions in this camera model shows in table 4. Users can choose how many distortion parameters are taken into consideration. Five parameters include radial distortion and tangential distortion, just three radial distortion parameters, or it is possible to even ignore them. Radial distortions arise as a result of the shape of the lens, whereas tangential distortions arise from the assembly process of the camera as a whole. The lenses of real cameras often noticeably distort the location of pixels near the edges of the imager. With some lenses, rays farther from the center of the lens are bent more than those closer in. Radial distortions usually be classified as either barrel distortions or pincushion distortions. Tangential distortion is due to manufacture defects resulting from the lens not being exactly parallel to the imaging plane, since it is usually small compared with radial distortions, users may only choose radial distortions.

Distortions in Camera model			
Radial Distortion R1	**-0.0980648**	**Tangential Distortion T1**	**-0.000442229**
Radial Distortion R2	**0.149028**	**Tangential Distortion T2**	**-0.00018282**
Radial Distortion R3	**-0.0720936**		

Table 4 Distortions in camera model of this research project

In the quality report, camera optimization result for the perspective lens would be judged as good if the difference between initial and optimized focal length is less than 5%. The focal length transformation parameters vary with temperature, altitude, and time. The calibration process starts from an initial camera model and optimizes them with respect to the images. An initial camera model should be within 5% of the optimized value to ensure a fast and robust optimization. For perspective lens, users should note that the principal point should be around middle, and that the radial distortion values R1, R2, R3 normally are smaller than 1. Otherwise, this may lead to global distortions.

To orient a project in Pix4D, image importing has to be completed. Then, importing the coordinates and the orientation of the images. The geolocation information may be stored in the images' EXIF data, it could be loaded automatically. In this research, 11 photos have their position and orientation data in a txt file, it was imported and showed in image properties table. It can also come from a general geolocation file or a flight log. After all importing, the software calculate the model like figure 13. In the quality report, orientation constraints table displays the computed angular error in degrees. Normally, the mean error is close to 0 when the angular accuracy for the orientation constraint is correct.

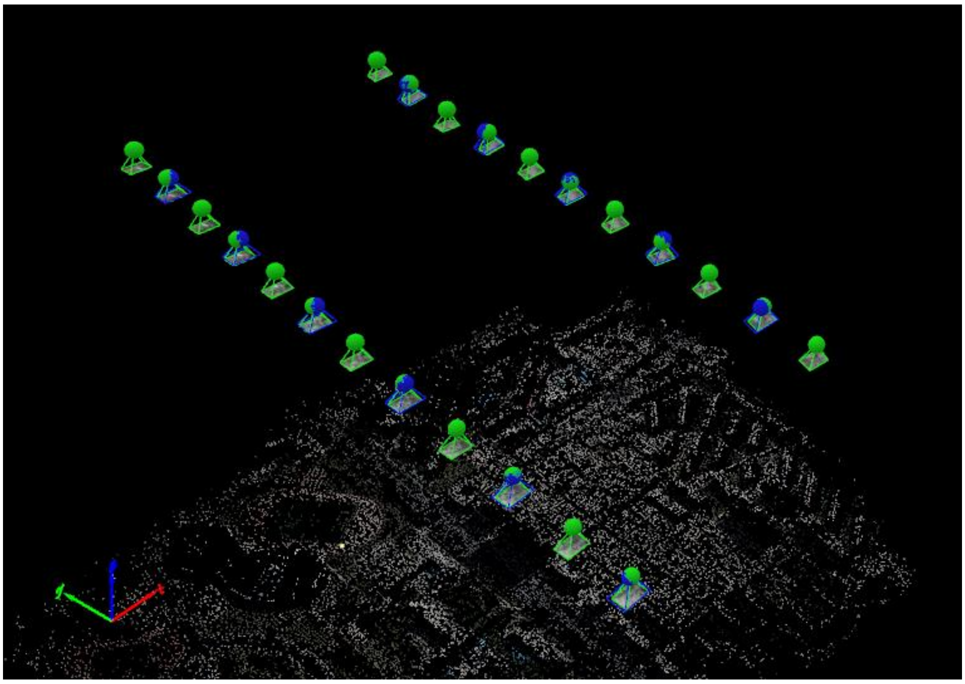


Figure 13 Camera position and point cloud produced in the project

Pix4D Mapper could automatically process images to highly precise 3D triangle mesh models with photorealistic texturing which are customizable and timely. It has many processing templates designed for different types of terrain/ object which needed to be reconstructed. The 3D modelling function is used for outdoor and indoor buildings, urban areas, tunnels as well as large vertical objects like power towers, wind turbines, etc. But this research focus on the orthophoto generated by Pix4D, so we don't discuss 3D modelling too much here.

The final step in Pix4D Mapper was DSM and orthomosaic generation. After point cloud building, an orthomosaic was generated using the DSM that comes from the 3D Densified Point Cloud. Therefore, errors in the point cloud would affect the orthomosaic. The altitude of the points will not be perfectly estimated when the 3D point cloud was computed, there is always some error and noise were minimized. Some points which are supposed to be at the same altitude may display incorrectly caused by this error, like some edge of building roofs.

Pix4D Mapper was used to generate the orthophoto. Without the need for human intervention, it can produce professional, precise two-dimensional maps and three-dimensional models from thousands of images. Its image data range from UAV images, aerial photo, oblique photo or close-range photogrammetry images. Images captured by different cameras could even be processed together, to build 3D model, DOM, and DSM. To increase image accuracy, Ground Control Points (GCPs) can be used to tie the image with known points on the map. GCPs are points with known coordinates that have been measured with traditional surveying methods.

The exterior orientation of the image was automatically calculated by pix4d mapper with aerial triangulation. Some POS data were used for georeferencing. For image orientation, block adjustment was used, which came with precision reports for result quality assessment. Precision of aerial triangulation and block adjustment were all provided in the report. Orthophotos would automatically be generated after mosaicking, where all the data would be stitched into one large image. The image result can be displayed by the GIS and RS software.

Pix4D Mapper could automatically find thousands of common points between images. Characteristic points which can be detected on the images are called keypoints. When two keypoints on different images are same, they are called matched keypoints. Each group of matched keypoints generates one 3D point. If there is high overlap between two images, the common area would be large. The larger the common area, the more keypoints can be matched together. The number of keypoints directly impacts the resulting accuracy. To generate an orthophoto in pix4d mapper, the first thing is to create a project. There are three items needed: select image geolocation, camera model, and image data input. The study area in this research is a county-level city in the north-west of China. "CGCS2000 / 3-degree Gauss-Kruger CM 87E" was selected as input and output coordinate system. Only 11 out of 23 selected images have geolocation POS data. They were all added into the project with position and orientation. Due to the privacy policy, the image geolocation POS data were in an independent coordinate system, and cannot be projected in the right place in map view. But their relative positions are correct. 3D Maps template was chosen to generate a DSM, and an orthomosaic as the typical aerial images input project. When processing a project, the following steps are recommended to be followed: 1). Initial Processing; 2). Analysing the Quality Report; 3). Point Cloud and Mesh; 4). DSM, Orthomosaic and Index.

In the initial processing step, keypoints were extracted with double image size feature scale. Because there were only a few images can be used, the higher processing set was chosen to improve the result quality as possible. Orthomosaic preview (figure 14) was generated in quality report after the first step, helping user to decide whether it is good or not to continue. Users also need to choose which pairs of images are matched and how. The default setting is fit for aerial mapping in this project, but users can use geometrically verified matching if necessary. It can be slower, but also more robust. An automatic way to select which key points were used did not restrict the number of key points. Key points were selected to do the calibration. The optimization step consists of running the Automatic Aerial Triangulation (AAT), Bundle Block Adjustment (BBA), and camera self-calibration steps. It was run multiple times until an optimal reconstruction was found. Cameras used with UAVs are very sensitive to vibrations, could influence the camera calibration, so all parameters of external or internal should be taken into consideration including position and orientation of the cameras.

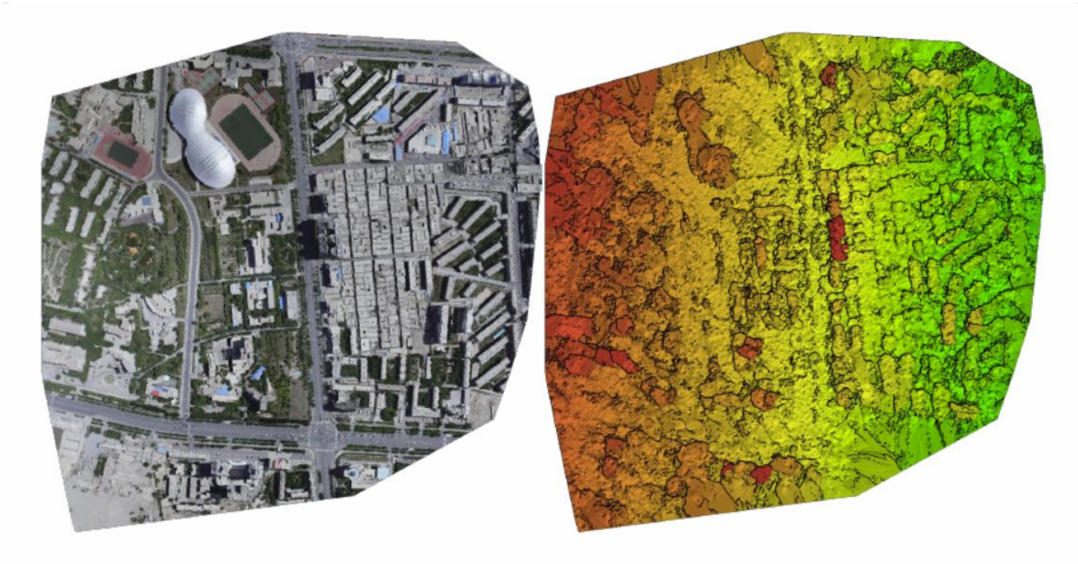


Figure 14 Orthomosaic and the corresponding sparse Digital Surface Model (DSM) before densification

The densification is an image matching algorithm using image orientation to match pixel by pixel. The selected key points were used to build dense point cloud, to increase the density of 3D points of the 3D model computed in Initial Processing step and Point Cloud and Mesh step would lead to a higher accuracy for both the DSM and orthomosaic. After densification, the point cloud was filtered. Compared to the default setting, more points were computed especially in areas where features can be easily matched. High point density was chosen, means each 3D point was computed for every image scale pixel. The minimum number of matches of each 3D point limited at 3 refers every point has to be re-projected in at least 3 images. The higher setting in this section was selected to improve the results at the range of hardware at hand.

DSM and Orthomosaic Generation was used to generate the result needed to measure urban village land. In this step, the spatial resolution was defined as one GSD (6.11712cm/pixel) for DSM and orthomosaic. Surface smoothing DSM filter was used to keep sharp features such as edges and corners of buildings. The interest area lay in the centre of the right half, which has less deformation than the marginal part.

4.3.2. Orthophoto Calibration and Assessment

The generated orthophoto based on converted POS data cannot be projected in the right place on the map, and was not scaled properly. A length of the track was measured to be 49m, about a half of the real. But the relative relations between features in the image were correct, which were based on keypoints in images. In order to make an accurate map to help land recordation in urban village, the scale problem must be resolved. One possible solution is to collect some points with known coordinates which locate in the result image area, then use these points to calibrate the orthophoto. These points should be randomly distributed in the image area, and can easily to be identified.

In order to find those points, Google Earth was chosen to use as a reference. Google Earth data comes from a variety of commercial satellite and aerial photographs, which are free and open for public use. People can use it for personal, non-commercial entertainment, or other purposes. If a more accurate map could be obtained, or some local control point data from mapping departments are available, they will be able to provide a better reference. So what had done was that 12 points which have obvious characteristics and randomly distribute in the target area were selected, got their latitude and longitude and find them on the orthophoto. Then use ArcGIS to open the orthophoto, in the georeferencing function, use the above 12 points as control points, and place them to right positions by directly entering coordinates. When all control points placed in the orthophoto, save and exit. A corrected image which modified with control points was obtained. After placing of control points, other points on the image will be recalculated according to the mutual positional relationships between 12 control points, the main purpose is to measure in the orthophoto with the actual ratio of the size.

Mentioned about measurement, accuracy problems must be taken into the considered. The general urban cadastral map has the scale of 1: 500, precision error of 0.05m for the boundary point to nearest control point, maximum potable point error in cadastral maps of 0.1mm. Because there is no actual field measurements or any data can be used for reference, so the discussion of the accuracy force on the resulting image. In order to detect the accuracy of the image after calibration, other check points which relatively locate in the interest area were selected, then got their coordinates in the orthophoto with ArcGIS and compare the coordinates of those points in Google earth which consider as reference coordinate system.

Generated orthophoto was used to support land recordation system by measuring the parcel boundary and building boundary. In orthophoto digitizing, the boundaries were saved as polygons, then polygon vertices were recorded as boundary point with their coordinates. Parcel area and location were obtained from these data, and registered in the system.

4.4. Summary

This chapter begins with the introduction of the study area and research data. Then explain the procedures of image processing in Pix4D. It started from initial processing, point cloud generation and meshing go next if the result quality after initial processing is fine. An orthophoto was generated in the last step and output as a TIFF (Tag Image File Format) file which can be edited in ArcGIS. The orthophoto was used as a work base map in the following work, features on the ground would be identified to mapping the boundaries. The result of orthophoto and digitizing work were showed in next chapter, to check whether it is qualified to support land recordation in urban village.

5. RESULTS AND DISCUSSION

This chapter discusses the results of this research. The necessary information in land registration was summarized after analysis of current situation in the study area. For the other part, orthophoto was generated, and quality of it was reported. Then, georeferencing and quality assessment were done. In the end, time and cost were compared between traditional survey method and UAV photogrammetry.

5.1. Land Registration Content in Optimized System

This special system is optimization designed for the current situation in urban village, aimed to complete record house site usage there. The main obligee is house site use right holders, in this research specific refers to villagers in urban. Then the main registered object is house site which became complicated in rapid grow of urban village

5.1.1. Obligee Information

The registration of obligee is one of the most important part of the whole system, land use right is held by the obligee, the correct information of obligee certainly should be recorded properly. China implemented the second generation ID card in 2004, which has a unique identification in the national database. The cardholders' information can be automatically read by card readers and search the cardholder in the national database. From the ID number, only one person could be traced, there would be no problem like obligee duplication or deletion. Then the identification information could input to the land recordation system. Right holder's name, contact details, address and other basic information have to be registered in obligee information part.

5.1.2. Land Information

Land information associates attributes and spatial data as cadastral records, it should be accurate, current and reliable. Boundaries and land use information are captured to do land administration by local government. In this research, land in urban village is the principal object in registration. Geographical attributes like area, location, and four direction boundaries are recorded. Building distribution in the study area is highly dense. There are almost no gaps between houses in the same columns, with some houses even sharing the same wall. It is easy to identify the location, shape and boundaries of houses in the generated orthophoto because there is no physical boundary that can be identified from the orthophoto. Alley is still owned by village collective, which cannot be contained in any house site parcel. There are some neighbouring parcels are too close to have a gap between them. In these case, house site land boundary would be registered as same as the building boundary. Other parcel with gap between neighbours need to measure the midcourt line, mark it on the orthophoto and then check the real case during the investigation.

Aside from geographical attributes of land, ownership information also needs to be filled through investigation. This registration system focuses on the house site in urban village. Land in urban village is all owned by the village group, an individual villager could apply the use right of one house site. Villagers can only use it as housing land for themselves. The difference information between house sites records is the use right obtain time, transfer history records, landowner information and parcel number. They should all register in the new record with a certificate of the land right source.

5.2. Orthophoto Map

5.2.1. Generation

After the generation of orthophoto, a quality report was generated for users. It contains the parameters to evaluate the whole processing. In this project, the median of keypoints is 25350 per image; all of 23 images had been calibrated for the reconstruction of the model, with 1.66% relative difference between initial and optimized focal length. The median of matches is 9857.58 per calibrated image. The parameters above were all evaluated as good in Pix4d Mapper criterion. But only image geolocation had been used for georeferencing, and no GCPs were used. Figure 15 shows the location of the final selected images. But they cannot be projected in the right place on the map, because the POS data had been converted for confidentiality.

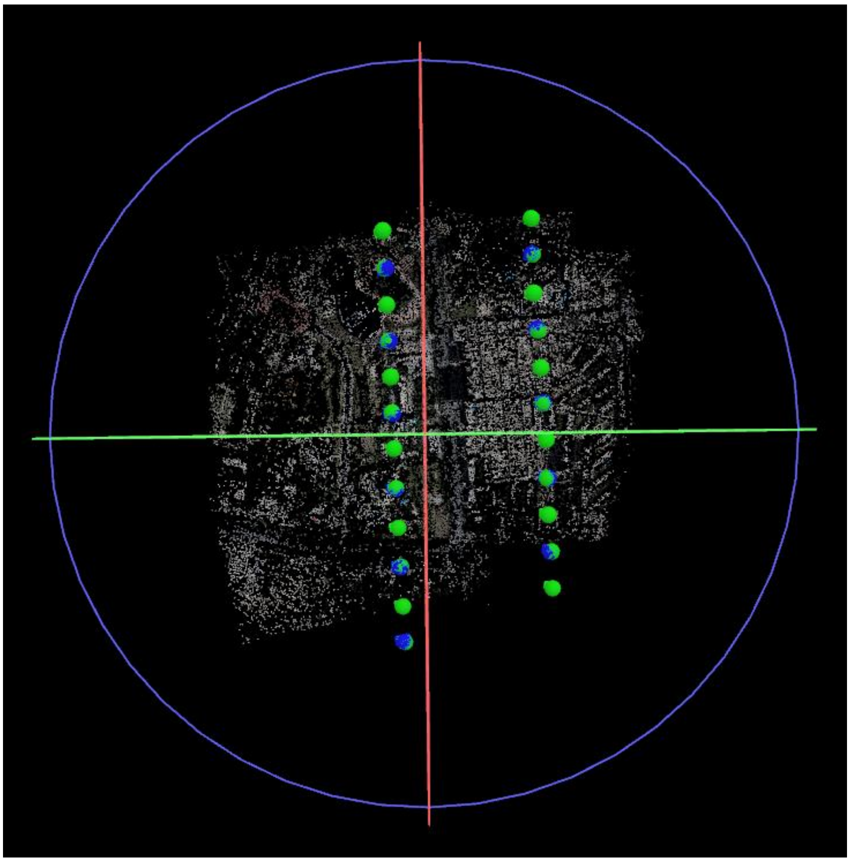


Figure 15 Camera location of selected images, green points refers camera locations

Image overlap had been shown in figure 16. Red and yellow areas indicate an overlap of fewer than 3 images for every pixel, poor results may be generated in these areas because of the low overlap. Good quality results may well be generated in green areas where overlap over 5 images. Key point matches are sufficient for these areas. There were 218951 tie points used for the bundle block adjustment, they were automatically matched on at least two images. The number of 3D points that have been generated by matched 2D points on the images was 87466, and the average of the reprojection error reached to 0.177136 in pixels. The mean reprojection error refers to the distance between the initial 2D keypoint position and the re-projection position of computed 3D point in image. After initial processing, some parameters in camera model from EXIF were optimized through camera calibration and used for processing, they had been shown in table 5. In combination with figure 17, the study area in this project had good overlap, but links between images in different flight route are weak.

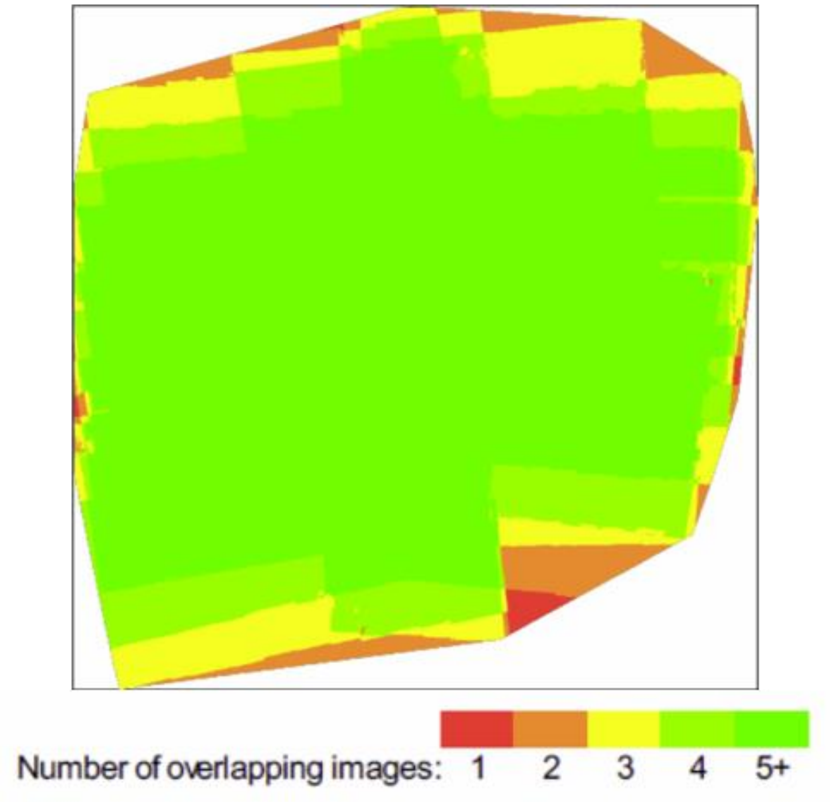


Figure 16 Number of overlapping images computed for each pixel of the orthomosaic

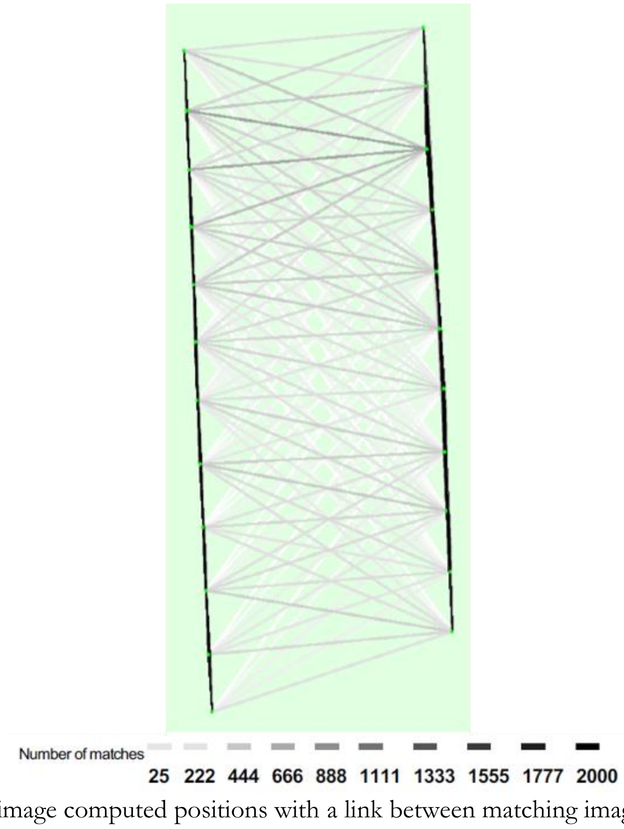


Figure 17 Top view of the image computed positions with a link between matching images (The darkness of the links indicates the number of matched 2D keypoints between the images. Bright links indicate weak links and require manual tie points or more images)

	Focal Length	Principal Point x	Principal Point y	R1	R2	R3	T1	T2
Initial Values	5485.820 [pixel] 35.166 [mm]	2796.130 [pixel] 17.924 [mm]	1875.970 [pixel] 12.025 [mm]	-0.098	0.149	-0.072	-0.000	-0.000
Optimized Values	5394.596 [pixel] 34.581 [mm]	2799.498 [pixel] 17.946 [mm]	1859.888 [pixel] 11.922 [mm]	-0.108	0.162	-0.034	-0.000	-0.001

Table 5 Internal camera parameters

There was no ground control point data in this project, so no report of that part was generated. But other geolocation details were provided. In absolute geolocation, none out of 11 geolocated and calibrated images had been labeled as inaccurate. The geolocation error is the difference between the initial image positions and computed image positions, shows in table 6, but they do not correspond to the accuracy of the observed 3D points. Table 7 displays the percentage of geolocated and calibrated images with a relative geolocation error. In this project that without GCPs, there were more than 99.6% of the geolocated and calibrated images had an error between -3 and 3, the geolocation accuracy was not overestimated. The relative geolocation error follows a Gaussian distribution in this project. Geolocation RMS error of the orientation angles shows in table 8, it was given by the difference between the initial and computed image orientation angles.

Min Error [m]	Max Error [m]	Geolocation Error X [%]	Geolocation Error Y [%]	Geolocation Error Z [%]
-	-15.00	0.00	0.00	0.00
-15.00	-12.00	0.00	0.00	0.00
-12.00	-9.00	0.00	0.00	0.00
-9.00	-6.00	0.00	0.00	0.00
-6.00	-3.00	0.00	0.00	0.00
-3.00	0.00	45.45	54.55	45.45
0.00	3.00	54.55	45.45	54.55
3.00	6.00	0.00	0.00	0.00
6.00	9.00	0.00	0.00	0.00
9.00	12.00	0.00	0.00	0.00
12.00	15.00	0.00	0.00	0.00
15.00	-	0.00	0.00	0.00
Mean [m]		-0.000396	0.000026	-0.000997
Sigma [m]		0.656350	0.560828	0.292216
RMS Error [m]		0.656350	0.560828	0.292217

Table 6 Absolute geolocation variance error

Relative Geolocation Error	Images X [%]	Images Y [%]	Images Z [%]
[-1.00, 1.00]	100.00	100.00	100.00
[-2.00, 2.00]	100.00	100.00	100.00
[-3.00, 3.00]	100.00	100.00	100.00
Mean of Geolocation Accuracy [m]	5.000000	5.000000	10.000000
Sigma of Geolocation Accuracy [m]	0.000000	0.000000	0.000000

Table 7 Relative geolocation variance error

Geolocation Orientational Variance	RMS [degree]
Omega	0.273344
Phi	0.354735
Kappa	0.190702

Table 8 Geolocation RMS error

In point cloud generation, the processing options were chosen as high quality as possible to generate a good result. Original image size and high point density were used for the point cloud densification. The minimum number of matches per 3D point was 3, it represents the minimum number of valid re-projections of this 3D point on the images. 3D textured mesh had been generated in this project. The maximum number of triangles used was 1million and the texture size was 8192×8192. 7×7 pixels grid was used to match the densified points in the original images. The densification area and annotations were taken into account as well. In that way, 3 processed clusters and 9 tiles were generated for the densified point cloud. Figure 18 shows the point cloud in the study area, there are some building facades has hardly any point. About 64 million 3D densified points were obtained in this project, it means 91.87 points were obtained per cubic meter in average.

Figure 18 Densified point cloud in the urban village of study area

In the third step of processing, DSM and orthomosaic were generated with the resolution of 1×GSD (6.12 [cm/pixel]). Noise filtering and surface smoothing were not used in this project. Inverse distance weighting method which is recommended for buildings had been used to generate the DSM and the DSM tiles have been merged into one file. The DSM result shows as figure 19, the orthophoto was generated based on that.

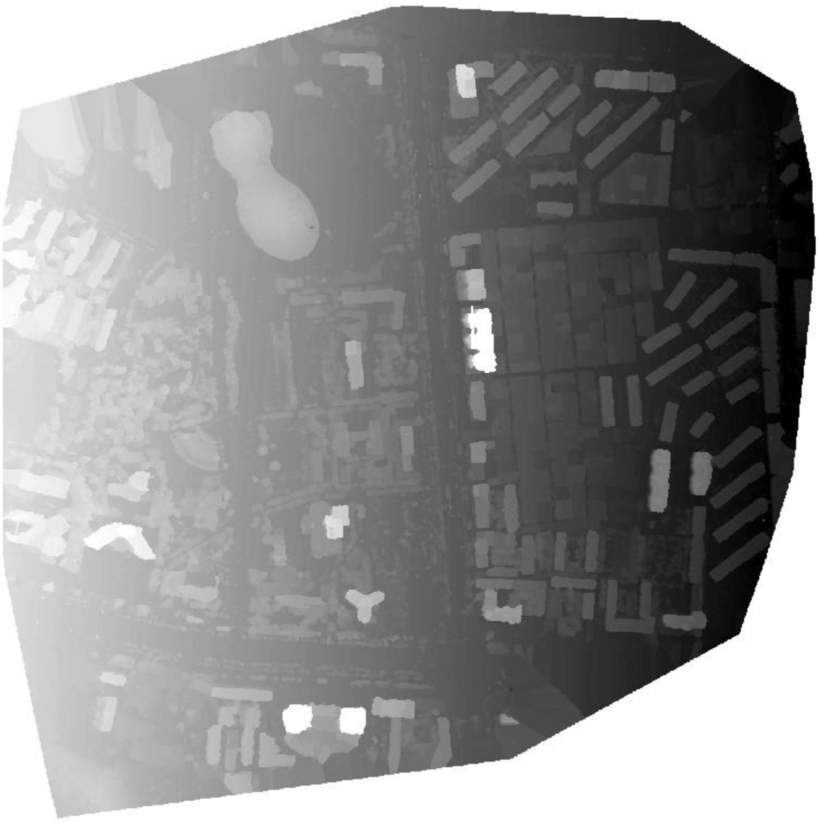


Figure 19 DSM

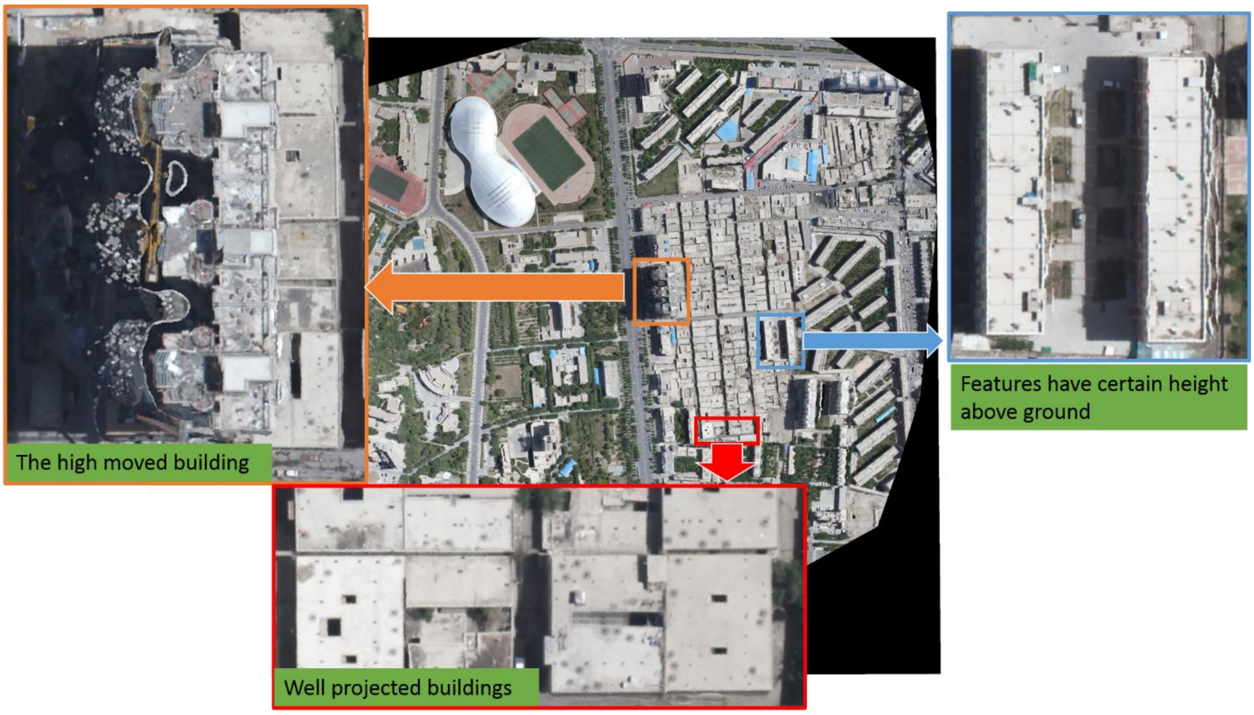


Figure 20 Generated orthophoto

Features are shown with different classes. The features on the ground are clear in the orthophoto (figure 20). But features located at a certain height above ground are fuzzy. Especially for buildings which have altitude difference, the roof of these buildings are shown completely but the little circle around the roof were obviously different to ground. The UAV images used in this processing were 23, only 11 of them shot the urban village of the study area. And these 11 images were taken within one line, they were not from various visual angles. Like the high moved building in figure 20, the images only shot the sunny facets. There were few keypoints matched in shade facets, cannot build a dense point cloud in that region. So the shape of that building was wrongly generated in the 3D model, and it leads a bad result in the orthophoto in the end. This kind of wrong projection would interfere with identification of other features. Most urban village areas were clearly visible in the generated orthophoto.

Shadow in the orthophoto may interfere with the identification of urban village buildings. Buildings in the study area urban village have approximate heights, the shadow of them shows in alleys between buildings. It does not matter for building identification. But some taller buildings near the border of urban village may be problematic. Their shadows may cover the roof of other low building in the orthophoto. Figure 21 shows these kinds of shadow.

Figure 21 Two kinds of shadows in urban village area

5.2.2. Georeferencing

Control points collected from google earth image (from Image © 2016 DigitalGlobe, 4/9/2015, resolution: 0.5m) were used for orthophoto georeferencing. Due to the security policy of geographical information in China, the POS data was projected in an independent coordinate system which was unknown to us. Without other control methods, the orthophoto was wrongly projected. In order to correct it as the right scale for measurement, 12 points which can be easily identified in both satellite image and the orthophoto were placed in their position by the coordinates from Google Earth. These points are the intersections of road mark or corners of some structure. The distribution of control points shows in figure 22. The georeferencing result shows in table 9, residual of them range from 0.01 to 0.36, most of them fasten on range of 0.13 to 0.27. The total RMSE was 0.201574 m, larger than 3 times of pixel size.

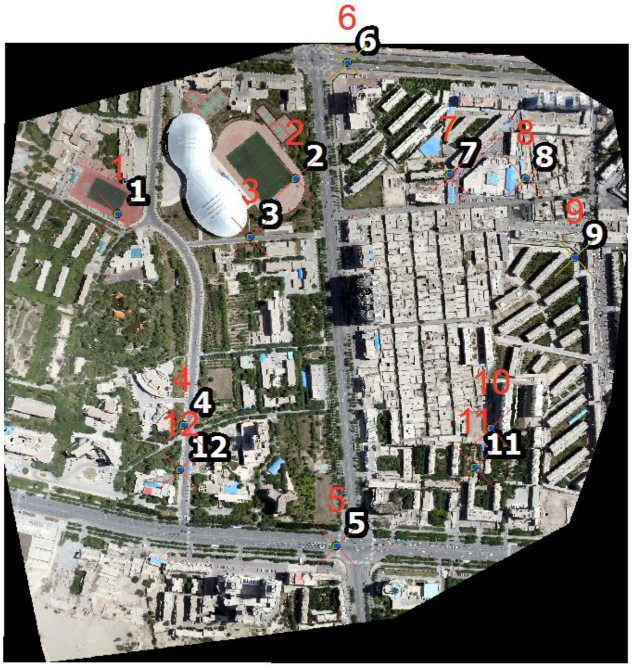


Figure 22 Location of scale points in the orthophoto

Link

Total RMS Error: Forward:0.201574

	<Link>	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
☑	1	60682.894726	47525.737921	429685.332124	4624865.685592	-0.143801	0	0.143801
☑	2	60848.167319	47558.767946	429947.851065	4624696.063516	0.0699107	0	0.0699107
☑	3	60806.037880	47503.936630	429821.524045	4624677.700595	0.0856056	-0.241214	0.255954
☑	4	60743.808419	47326.905625	429512.052476	4624524.323459	0.314429	0.184081	0.364351
☑	5	60887.261754	47214.248675	429558.287074	4624190.081348	-0.0101514	0	0.0101514
☑	6	60896.533956	47667.167181	430151.208275	4624777.035348	0.132898	0	0.132898
☑	7	60991.858426	47562.251318	430143.287956	4624515.429084	-0.20829	0.11029	0.235688
☑	8	61062.745451	47558.853432	430233.381526	4624419.495714	-0.109865	0.123109	0.165003
☑	9	61109.104735	47485.194944	430200.901092	4624262.000213	0.103015	-0.165208	0.194694
☑	10	61031.163712	47325.278631	429892.101499	4624151.442045	-0.0176071	0.178577	0.179443
☑	11	61016.013727	47288.406612	429824.749773	4624121.924386	0.0483749	-0.12898	0.137753
☑	12	60740.995984	47285.718902	429454.947435	4624473.242479	-0.26452	-0.0645138	0.272273

Table 9 Referencing links result

In order to get a better result in the main study area, another 12 control points were selected from the building corner in urban village (figure 23). The orthophoto used for urban village georeferencing was generated without POS data to eliminate the error from camera position. Referencing links with less residual were showed as table 10, from 0.03 to 0.23, total RMSE as 0.142, much better than the orthophoto generated with POS data.

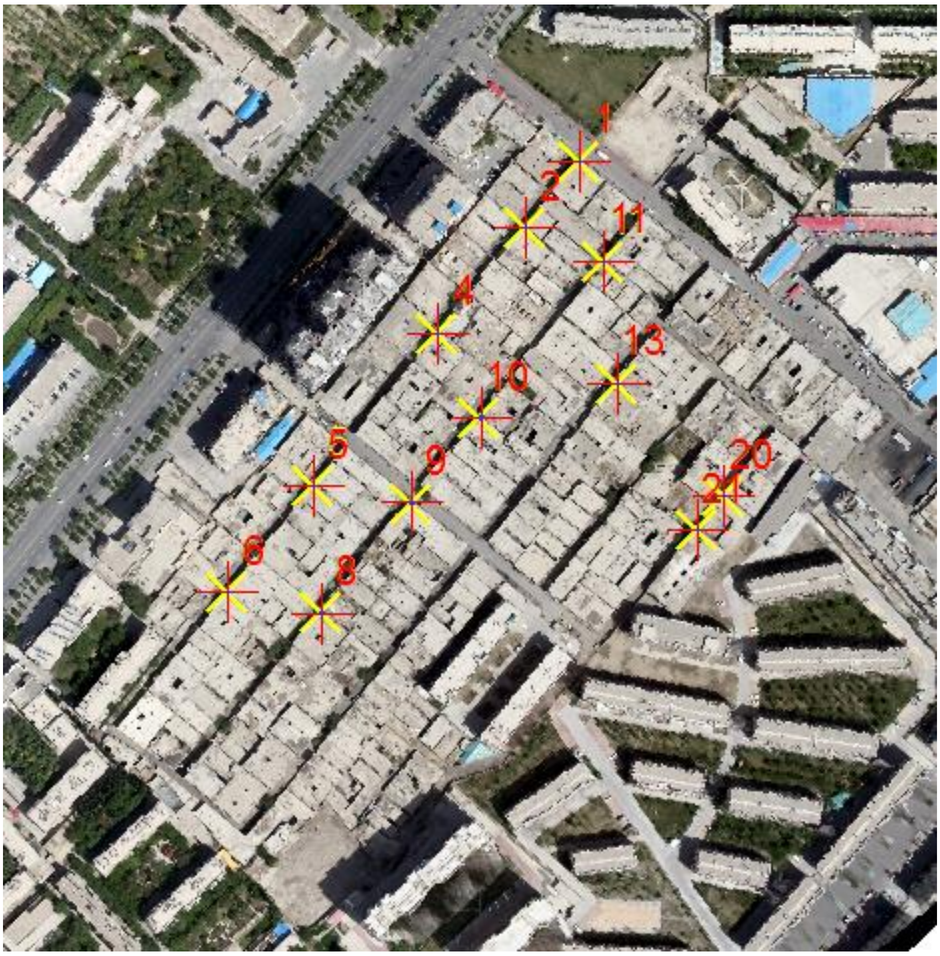


Figure 23 Location of scale points in the orthophoto without POS

Link

Total RMS Error: Forward:0.141797

	Link	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	<Residual>
✔	9	-67.784512	-21.104094	429926.488...	4624362.08...	0.0396268	0.225453	0.228909
✔	10	-65.117387	-41.075519	429963.078...	4624406.89...	0.217778	0	0.217778
✔	4	-48.474609	-46.108686	429940.420...	4624451.62...	-0.16961	0.068648	0.182976
✔	13	-77.807421	-63.722123	430034.999...	4624425.21...	-0.0939046	-0.112819	0.146786
✔	5	-52.949907	-10.162421	429874.530...	4624371.01...	0.117593	-0.0867078	0.146104
✔	21	-107.658206	-55.874724	430077.367...	4624347.62...	-0.132331	0	0.132331
✔	20	-106.646582	-63.693042	430091.935...	4624365.20...	0.117457	0	0.117457
✔	1	-43.320918	-86.828176	430015.346...	4624542.77...	-0.0436829	-0.103312	0.112167
✔	6	-56.536904	14.749289	429829.414...	4624314.28...	-0.0911937	-0.0470688	0.102624
✔	2	-45.445034	-70.885617	429986.365...	4624506.98...	0.0510973	0.082088	0.0966921
✔	8	-71.070873	4.823028	429878.800...	4624303.66...	-0.0311703	0	0.0311703
✔	11	-59.759979	-77.196036	430027.683...	4624489.62...	0.0183417	0	0.0183417

Table 10 Referencing links result for orthophoto without POS

5.2.3. Accuracy Assessment

The accuracy of the georeferenced orthophoto was assessed by calculating the difference value between check points coordinates (shows in figure 24) in the georeferenced orthophoto and Google Earth. The difference between X coordinates and Y coordinates were listed as table 11. The total RSME was 0.112, still large than 0.05 cm. That was caused by two main reasons, GSD in orthophoto was 6.12 cm/pixel, the map accuracy based on that cannot be better. The other reason attribute to the control points, they were collected from satellite image which resolution was 0.5m. These two aspects could be improved in other processing test using better data. Lower altitude (600m for image source) flight and good ground control points would be helpful to reach the accuracy standard in urban cadastre survey.

Figure 24 Check points distribution

Id	X	X`	Y	Y`	dx	dx2	dy	dy2
1	429970. 699030	429970. 788698	4624489. 143610	4624489. 129140	−0. 08967	0. 00804	0. 01447	0. 000209
2	429786. 721872	429786. 760911	4624261. 100410	4624261. 038000	−0. 03904	0. 00152	0. 06241	0. 003895
3	429846. 597200	429846. 564463	4624264. 361840	4624264. 285980	0. 03274	0. 00107	0. 07586	0. 005755
4	430057. 929205	430058. 018408	4624453. 690600	4624453. 785500	−0. 08920	0. 00796	−0. 09490	0. 009006
5	429993. 379343	429993. 321903	4624372. 915800	4624373. 028160	0. 05744	0. 00330	−0. 11236	0. 012625
6	429961. 302559	429961. 229138	4624333. 906960	4624333. 919740	0. 07342	0. 00539	−0. 01278	0. 000163
7	429898. 057674	429897. 994271	4624226. 396600	4624226. 306870	0. 06340	0. 00402	0. 08973	0. 008051
8	429998. 121123	429998. 031281	4624315. 197250	4624315. 365760	0. 08984	0. 00807	−0. 16851	0. 028396
9	430042. 707712	430042. 771147	4624369. 058060	4624368. 943890	−0. 06344	0. 00402	0. 11417	0. 013035
10	430088. 992766	430088. 983752	4624425. 619040	4624425. 538500	0. 00901	0. 00008	0. 08054	0. 006487
11	430154. 286507	430154. 352436	4624428. 127290	4624428. 149590	−0. 06593	0. 00435	−0. 02230	0. 000497
12	430119. 589758	430119. 511957	4624399. 757970	4624399. 845210	0. 07780	0. 00605	−0. 08724	0. 007611
						0. 06701		0. 08932
		RMSE (X)		RMSE (Y)				RMSE
		0. 06701		0. 08932				0. 111658

Table 11 Adjusted value for check points

5.2.4. Boundary Digitizing

In order to take measurements in orthophoto for land recordation, features were digitized in ArcGIS. The main needed features were buildings in urban village as shown in figure 25. 186 buildings in urban village were digitized as polygons based on the orthophoto. Then, the area of buildings and coordinates of corner points can be registered in land recordation system.

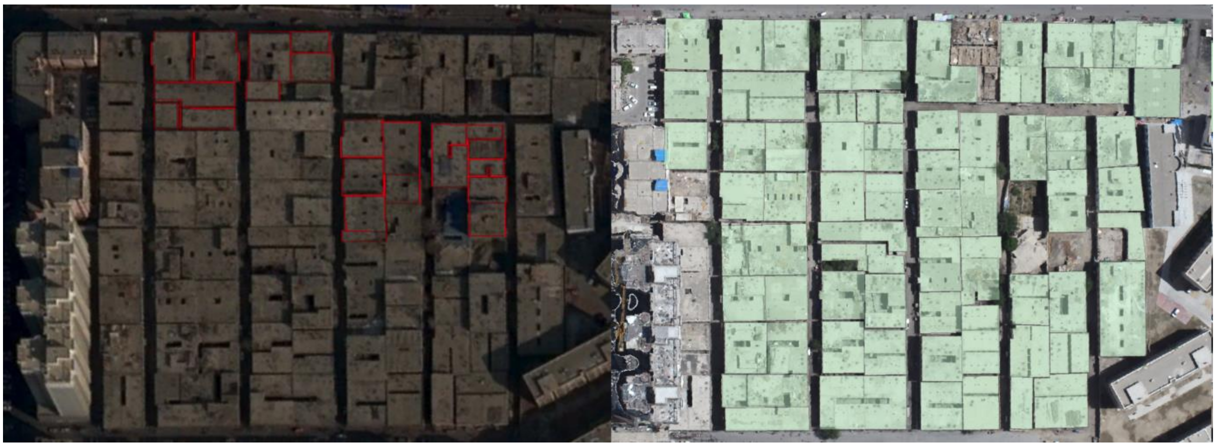


Figure 25 Comparison of boundaries in satellite image and orthophoto

Parcel boundary can also be identified in orthophoto as a polygon, but different classes have different identification strategy. Gaps between buildings in satellite image can be identified viewed as zigzag lines. But in orthophoto, those gaps can be zoom out enough to draw three almost parallel lines as boundaries of parcel and building (figure 26 a). In this situation, the middle line between buildings was considered as a shared parcel boundary of adjacent house sites. For some other situation, the shared wall would be considered as parcel boundary. Those are identification strategy of parcel boundary between buildings. For boundary between building and alley, parcel boundary is the same as that of buildings. Different cases are shown in Figure 26 b. After the boundary was identified as polygon, parcel area and building area could be calculated, as well as the coordinates of boundary points. This geographic information are needed to be registered in the new land recordation system. An example of "House Site Use Right and House Ownership Registration Application Form" was attached in the appendix.

Figure 26 Different boundary cases in satellite image (a) and in the orthophoto (b)

5.3. Evaluation of the New Method

The cost and time of the new method were evaluated. For a survey project in urban village, the first step is to take control points of aimed area. There was no information acquired with regards to the cost and time needed for control points, and so it was not calculated in this research. The field investigation was not changed in the new method, and was not analysed either. The cost was planned for a survey project in the study area; the area was about 80000 m^2 with roughly 200 households.

The time period of land recordation consists of three parts: application to respond pried, survey and investigation time and examine and approve the end to certificate issue. The main difference between traditional and rapid system is the survey method, so the time and cost comparison would focus on that part. The information about this part was arranged from distance interview with Ms. Dong, Project Manager of Tianbang surveying and mapping company. The survey project budget was arranged for the study area, it contains the salary of surveyors and support staff, instrument rent, board and lodging expenses, transportation and so on. On the other side, time was divided into fieldwork and office work, because fieldwork may be delayed due to the weather. Project plans were compared to analysis strength and weakness for each method.

Time

1) Traditional survey: 3 survey groups were planned to accomplish the field survey work in 3 days. Each group has one observer and one recorder. In the meantime, one driver and one support staff give assistance to their job. Eight people in total. Survey average 25 households per day per group. Field survey work would be delayed by the weather, total field survey work count as 4 days. Office work took two days to map the collected points. 7days in total.

2) UAV photogrammetry: a flight group consisted of one pilot and one observer. The flight was done within 2 hours including prepare time. The orthophoto was generated on the following day. It requires two days to digitize the orthophoto by one mapper. 4days in total.

Money (unit: ¥)

1) Traditional survey: the cost of a traditional field survey case is the summation of staff salary, board and lodging expenses and instrument rent. According to the interview, the current market price for staff daily salary as follows: observer 140, recorder 260, driver 210, and supporter 100. Board and lodging expenses count as 130 for each person per day. The instrument includes total station, laser range finder and tape, the rent of a set instrument is 300 per day. Vehicle rent of 260 per day is also a part of instrument rent. The total cost linearly increases with time/area.

2) UAV photogrammetry: the cost of the field survey by UAV is consist of staff two parts. The salary for pilot and observer took 2000 including orthophoto generation. The salary would not increase with the area because flight time would no longer than one day for an urban village area, it is fixed spend for every project. Because the field work could be done within one day, there is hardly any board and lodging expenses. The UAV rent count as 300 per day, it is the market price for DJI 3 Pro, and vehicle rent counts as 260. In this new method, the only changing cost is the salary of mapper (270 per day), because mapping work increases with the area.

From the results of two methods, UAV photogrammetry was shown to use only half time of the traditional survey, and cost only a third, for that specific area. The cost and time detail chart attached in th appendix. Within urban village, the ratio between them does not differ much, but the ratio changed from three to nine times when the area was increased to 300000 m^2. UAV cost much less from this comparison, it has a great potential in urban village survey.

Comparison	The traditional survey	The UAV photogrammetry	The ratio	The increase ratio
Time (this case)	**4+3 days**	**2+2 day**	7:4	7:2
Money (this case)	**¥10450**	**¥3100**	**3:1**	**10450/540≈20:1**
Time (30 ha. case)	**(4+3)*4 days**	**2+2*4 day**	3:1	**-**
Money (30 ha. case)	**¥10450*4**	**¥2560+540*4**	**9:1**	**-**

Table 12 Comparison of time and cost in two cases

5.4. Summary

This chapter presents the results of the study. For the land registration in urban village, a new register approach was developed to fit the requirement of house site land and its property above. The service object focuses on the single used land for housing in the special urbanizing rural area – urban villages. That is a rising phenomenon between Chinese dual land structures, the old land recordation system is not fit for it. The new land registration content was redesigned for house site use right and house ownership registration, taken urban village situation into core consideration, made it independent out of normal land registration cases. Using UAV images to quicken the land spatial information collection, then speed up the whole land records update in urban villages. Urban villages will be managed under the urban land system soon, so it needs to keep current with land information.

The accuracy of urban village land records needs to be insured as well as the current. UAV image photogrammetry was tested as an alternate method for mapping the boundaries of land and buildings in urban village. The image processing results were presented and checked to be used as work base map in land registration, ground features were successfully extracted from the orthophoto map by digitizing in ArcGIS. In the end, time and cost were calculated and compared between traditionally field survey method and photogrammetry method using UAV images, it shows the great advantage both in budget and speed.

6. CONCLUSIONS AND RECOMMENDATIONS

This research aimed to develop a land recordation approach for protecting farmers' land rights within the urban villages using UAV images. It was reached by two sub-objectives which would be summarised in conclusion part. The research was presented in six sections, the first chapter stated the background and research problem, objectives and questions; and then the second chapter explained the main concepts in this research and introduce some work done by earlier researchers. The third chapter presented the photogrammetry theory when UAV images were utilized. The method and data used in this research were introduced in chapter four. Finally, the results were presented in two aspects: land registration content and the orthophoto as work base map in chapter five. This chapter presents the conclusions and recommendations.

6.1. Conclusions

This research aimed to develop a new land recordation approach for urban village in China using UAV images as spatial information data source. First, the conclusions of the two research objectives will be presented, followed by the final conclusion.

Objective 1: To analyse a proposed land recordation system for the urban villages

This objective aimed at analysing the requirement of the land registration system for urban village in China. Urban villages are villages located in the urban area where developed from rural areas or suburban district in decades. These urban villages have particular characteristics that need to be considered when developing a land registration system. In most urban villages, from capital cities or other big cities, agricultural land was partially or fully requisitioned. The remaining lands are used to build apartment to meet the rising requirement of new labour. But the self-build apartments are not under the urban planning and management, they may not be registered in the land recordation system. The urban village buildings distribution is messy and its land use situation cannot be supervised by the government, because urban villages are still managed by rural land management department which has a low standard and update cycle. This research aimed to support the land recordation system in urban village. One of the basic elements is land right. Ownership of land, house site use right and house ownership need to be registered to make clear relations between land and village collective, land and villagers, as well as property above the ground. Villagers in urban villages are the main service objects of the system, the national land management department is the executor of the system, and there are village committees and local government as other participants and users. To achieve the registration function of this system, there are two types of data required for land recordation system: land rights information and land spatial information. The right owner, right duration, right object and other right descriptions are classified as certain types; area, location, coordinates of parcel and buildings need to survey. In order to fit the urban village situation, currency and survey cost were two key points to be considered. The use of UAV images for photogrammetry to capture spatial information of land (Mesas-Carrascosa et al., 2014) is considered to be a good tool. And it was tested in this research, for buildings spatial information capture in urban villages. This method in supporting of land registration for urban villages is found to be justified, and it is expected to speed up the land registration procedure.

Objective 2: To propose the integration of UAV in the recordation

To achieve this objective research was carried out with the aim to test the usability of UAV images to produce work base map for land recordation in urban villages. A method was developed and tested for using UAV to capture aerial photos of a certain selected area, then generating orthophoto and making work base map from that for spatial information record. This new method, using UAV for work base map generation could save over half time and cost compared to traditional field surveying work in China. It is faster and cheaper than ground surveying by a total station and other optical instruments. However, it requires higher instrument using skills for surveyors. The limitation of this method is that can only capture the image from outside in the airspace, which means no information indoor can be recorded by UAV images. The method applied in image processing and orthophoto digitizing, proved feasible for land recordation in urban villages and UAV images could be considered as high qualified spatial data source.

The main object of the research was to develop a land recordation approach for protection of the farmers' land rights within China's urban villages using UAV images. The research resulted in a method for making a work base map using UAV images. This method can optimize registration content for urban villages and can contribute to a faster and cheaper approach of land recordation. It supports the registration of low-income groups in urban villages to protect their profit in land rights. UAV images can further be used to respond to rapid change situations common in urban villages. The tool and the method are specifically fit for the typical characteristics of urban villages in China, which is different from the normal urban area, and contributes to solving the land registration problem in an urban village.

6.2. Recommendations

This research developed a new land recordation approach for urban village in China using UAV images. It proved the feasibility of using UAV images as spatial information data source in support of fit-for-purpose land registration. However, more research is needed to support the claims and further develop the method. Future studies should test different UAV types, study the different UAV types for diverse areas, study the optimal flight plan and choice of cameras. Important is also a deeper understanding of the UAV and camera combinations, to compare the image quality and evaluate the costs. Then, find the conditions and circumstances for which combination fit best.

On the other side, land recordation using UAV is also promising for land registration in other urban areas with rapid development and fast changes. Using UAV to update the land records in urban districts could also meet the currency requirement of that. But the accuracy standard and building distribution need to be considered as it would not be the same with this research case. Moreover, 3D cadastre is rising in land administration. UAV images can be used to structure 3D area models too, that is the future direction of land and housing management which needed more research.

Using UAV in land registration of urban villages in China could have an impact on practical procedures and formal regulations. Before implementing the new method, the impacts need to be known and regulations need to be changed accordingly.

LIST OF REFERENCES

About Orthophotography. (n.d.). Retrieved April 3, 2016, from http://www.igic.org/projects/orthos/aboutorthos.html

Ailin, J. (2012). *Study of Harmonized Development of Industrialization, IT application, Urbanization and Agricultural*.

Bailey, M. W. (2012). Unmanned Aerial Vehicle Path Planning and Image Processing for Orthoimagery and Digital Surface Model Generation. Retrieved from http://etd.library.vanderbilt.edu/available/etd-11302012-151303/

Barnes, G., Volkmann, W., Sherko, R., & Kelm, K. (2014). Drones for Peace : Part 1 of 2 Design and Testing of a UAV-based Cadastral Surveying and Mapping Methodology in Albania Paper prepared for presentation at the " 2014 WORLD BANK CONFERENCE ON LAND AND POVERTY " Copyright 2014 by Grenville Barnes , Walter V. *The World Bank Conference on Food and Poverty*, 1–28.

China, C. C. of. (2008). Zhonggong zhongyan guanyu tuijin nongcun gaige fazhan ruogan zhongda wenti de jueding. *National Land & Resources Information*, 4–12.

China, M. of L. and R. of the P. R. of. Measures for Land Registration (2007). Retrieved from http://www.mlr.gov.cn/xwdt/zytz/200801/t20080103_97843.htm

Colomina, I., & Molina, P. (2014). Unmanned aerial systems for photogrammetry and remote sensing: A review. *ISPRS Journal of Photogrammetry and Remote Sensing*, *92*, 79–97. http://doi.org/10.1016/j.isprsjprs.2014.02.013

Congress, S. C. of the N. P. (2004). Land Administration Law of the People's Republic of China (2004 Amendment). Retrieved October 26, 2015, from http://en.pkulaw.cn/display.aspx?id=3673&lib=law#menu1

Dahlberg, R. E. (1984). The public land survey system: The American rural cadastre. *Computers, Environment and Urban Systems*, *9* (2-3), 145–153. http://doi.org/10.1016/0198-9715(84)90013-9

Digital Elevation Models | CHARIM. (n.d.). Retrieved April 3, 2016, from http://www.charim.net/datamanagement/32

Digital Orthophotos. (n.d.). Retrieved April 3, 2016, from http://www.ce.utexas.edu/prof/maidment/grad/tate/research/orthophotos.html

District, T. people's government of L. G. (2013). Land registration apply workflow. Retrieved February 6, 2016, from http://lfgy.gov.cn/html/zxfw/zwfw/grbs/tdgl/bslc/20131225/93.html

Enemark, S., Bell, K. C., Lemmen, C., & McLaren, R. (2014). *Fit-For-Purpose Land Administration*. *International Federation of Surveyors (FIG)*. Retrieved from

Enemark, S., Bell, K., Enemark, S., & Bell, K. (2014). Building Fit-for-Purpose Land Administration Systems Building Fit-for-Purpose Land Administration Systems, (June), 16–21.

Fernandez, E., Garfinkel, R., & Arbiol, R. (1998). Mosaicking of Aerial Photographic Maps Via Seams Defined by Bottleneck Shortest Paths. *Operations Research*, *46*(3), 293–304. http://doi.org/10.1287/opre.46.3.293

Government, S. (2015). Urban village reconstruction plan. Retrieved February 6, 2016, from http://www.shanxigov.cn/n16/n8319541/n8319612/n8322008/18667085.html

Hao, P. (2012, April 25). Spatial Evolution of Urban Villages in Shenzhen. University Utrecht. Retrieved from http://dspace.library.uu.nl/handle/1874/237052

Jing, Y. (2011). Assessing Larsi-Integrated Participation Procedure for Urban Adjudication in China, (May), 105. Retrieved from http://www.itc.nl/library/papers_2011/msc/la/jing.pdf

Jing, Z. (2008). exploring village self-urbanization process in P.R.CHINA.

Kim, J., Lee, S., Ahn, H., Seo, D., Park, S., & Choi, C. (2013). Feasibility of employing a smartphone as the payload in a photogrammetric UAV system. *ISPRS Journal of Photogrammetry and Remote Sensing*, *79*, 1–18. http://doi.org/10.1016/j.isprsjprs.2013.02.001

Li, L. H., Lin, J., Li, X., & Wu, F. (2014). Redevelopment of urban village in China – A step towards an effective urban policy? A case study of Liede village in Guangzhou. *Habitat International*, *43*, 299–308. http://doi.org/10.1016/j.habitatint.2014.03.009

Liu, Y., He, S., Wu, F., & Webster, C. (2010). Urban villages under China's rapid urbanization: Unregulated assets and transitional neighbourhoods. *Habitat International*, *34*(2), 135–144. http://doi.org/10.1016/j.habitatint.2009.08.003

Mesas-Carrascosa, F. J., Notario-García, M. D., Meroño de Larriva, J. E., Sánchez de la Orden, M., & García-Ferrer Porras, A. (2014). Validation of measurements of land plot area using UAV imagery. *International Journal of Applied Earth Observation and Geoinformation*, *33*, 270–279. http://doi.org/10.1016/j.jag.2014.06.009

MeshLab Stuff: Meshing Point Clouds. (n.d.). Retrieved March 29, 2016, from http://meshlabstuff.blogspot.nl/2009/09/meshing-point-clouds.html

Mukendwa, M. (2015). Innovations in Boundary Mapping: Namibia, Customary Lands and UAVs.

National People's Congress. (2004). Constitution of the People's Republic of China (2004 Amendment). Retrieved October 26, 2015, from http://en.pkulaw.cn/display.aspx?id=3437&lib=law

Presentation "Leica Photogrammetry Suite LPS 2010 ERDAS. LPS Introduction Digital photogrammetry program that allows for – triangulation and – orthorectification of." (n.d.). Retrieved April 3, 2016, from http://slideplayer.com/slide/4531969/

Pouliot, J., Vasseur, M., & Boubehrezh, A. (2013). How the ISO 19152 Land Administration Domain Model performs in the comparison of cadastral systems: A case study of condominium/co-ownership in Quebec (Canada) and Alsace Moselle (France). *Computers, Environment and Urban Systems*, *40*, 68–78. http://doi.org/10.1016/j.compenvurbsys.2012.08.006

Ruzgienė, B., Berteška, T., Gečyte, S., Jakubauskienė, E., & Aksamitauskas, V. Č. (2015). The surface modelling based on UAV Photogrammetry and qualitative estimation. *Measurement*, *73*, 619–627. http://doi.org/10.1016/j.measurement.2015.04.018

Sack, P. (2012). Xian Village. Retrieved February 8, 2016, from https://xianvillage.wordpress.com/page/2/

Shang, H. (2008). Land Use Survey Base Map Production Methods. *China Science and Technology Information*.

Song, Y., & Zenou, Y. (2012). Urban villages and housing values in China. *Regional Science and Urban Economics*, *42* (3), 495–505. http://doi.org/10.1016/j.regsciurbeco.2011.06.003

State Bureau of Surveying and Mapping. (2010). *Specifications for ofiice of low-altitude digital aerophotogrammetry*.

Stereo Pair Photography. (n.d.). Retrieved April 3, 2016, from http://paulbourke.net/stereographics/stereophoto/

Stoter, J., Ploeger, H., & van Oosterom, P. (2013). 3D cadastre in the Netherlands: Developments and international applicability. *Computers, Environment and Urban Systems*, *40*, 56–67. http://doi.org/10.1016/j.compenvurbsys.2012.08.008

The Global Grid. (2013). Urban Slums and Developing Migration | Sustainable Cities Collective. Retrieved February 8, 2016, from http://www.sustainablecitiescollective.com/global-site-plans-grid/164156/looking-planet-slums-mike-davis

Understanding Camera Calibration | Perpetual Enigma on WordPress.com. (n.d.). Retrieved April 3, 2016, from https://prateekvjoshi.com/2014/05/31/understanding-camera-calibration/

Un-Habitat. (2007). What are Slums and why do they exist. *Sustainable Urbanization: Local Action for Urban Poverty Reduction, Emphasis on Finance and planning 16 - 20 April 2007, Nairobi, Kenya What*, (April), 7623151–7623153.

Uysal, M., Toprak, A. S., & Polat, N. (2015). Dem generation with uav photogrammetry and accuracy analysis in sahitler hill. *Measurement*, *73*, 539–543. http://doi.org/10.1016/j.measurement.2015.06.010

van Oosterom, P., Lemmen, C., Ingvarsson, T., van der Molen, P., Ploeger, H., Quak, W., … Zevenbergen, J. (2006). The core cadastral domain model. *Computers, Environment and Urban Systems*, *30*(5), 627–660. http://doi.org/10.1016/j.compenvurbsys.2005.12.002

Wang, Y. P., Wang, Y., & Wu, J. (2009). Urbanization and informal development in China: Urban villages in shenzhen. *International Journal of Urban and Regional Research*, *33* (4), 957–973. http://doi.org/10.1111/j.1468-2427.2009.00891.x

What Is Camera Calibration? - MATLAB & Simulink - MathWorks. (n.d.). Retrieved April 3, 2016, from http://cn.mathworks.com/help/vision/ug/camera-calibration.html

Yao, J. (2013). Problem and Solution Discussion in "Urban Village" Reconstruction. *China Economist*, 47–49.

Zevenbergen, J., Augustinus, C., Antonio, D., & Bennett, R. (2013). Pro-poor land administration: Principles for recording the land rights of the underrepresented. *Land Use Policy*, *31*, 595–604. http://doi.org/10.1016/j.landusepol.2012.09.005

Zhang, L. (2015). China : Real Property Law, *6462* (October 2014).

Zhang, Y., & Cui, H. (2011). Techniques of UAV system Land use changes detection application. *Photonics and Imaging for Agricultural Engineering (Proceedings of SPIE)*, *7752*, 77520X–77520X–6. http://doi.org/10.1117/12.889162

House Site Use Right and House Ownership Registration Application Form (Example)

Case number:

Obligee Information	Name	ID number	Contact information
	John Chen	3503071978XXXX0625	Tele: 133XXXX6320
Postal address	No.131, East gate lane, Gaochengcun, Xinjiang province		

Parcel Information				
	Location	North corner of Gaochengcun		
	Parcel number	4203645XX	Parcel area (m²)	423.40
	Collective land owner	__XX___ Township (Town), Street ___XXX___ Village Committee		
	Parcel boundary points	(see coordinates below)		

Parcel boundary points:

	X	Y
1	430000.732	4624524.771
2	430030.099	4624500.44
3	430022.756	4624491.062
4	430002.434	4624507.799
5	430004.209	4624509.972
6	429994.958	4624517.697

Building Information				
	Construction type	Brick structure	Property right type	personal
	Building area (m²)	385. 43	Build time	Oct. 1997
	Building points	(see coordinates below)		

Building points:

	X	Y
1	430000.475	4624524.475
2	430029.881	4624500.166
3	430023.084	4624491.505
4	430003.261	4624507.64
5	430005.213	4624510.008
6	429995.467	4624518.317


土地权属证明书

Certificate of land right source

Cadastral Sketch Map

House Site Use Right and House Ownership Registration Application Form (Example)

Traditional survey	Field work	Office work	Work rate	Surveyor salary	Board and lodging expenses	Support fee	Instrument and car rent	Mapping	Total in ¥, exchange rate to € ≈ 7
	3+1 d	3d	3000 m^2/d	1600	130*8*4	(210+100 +260)*4	(300+260)* 4	270*3*2	6560+2240+1650=10 450
UAV photogrammetry	Flight	Orthophoto generating	Mapping	Pilot salary	Orthophoto generating	Mapping	UAV rent	Transpor tation	Total
	1 d	1d	2d	1000	1000	270*2	300	260	1000+300+260+1000 +540= 3100

Cost and time in detail of two methods