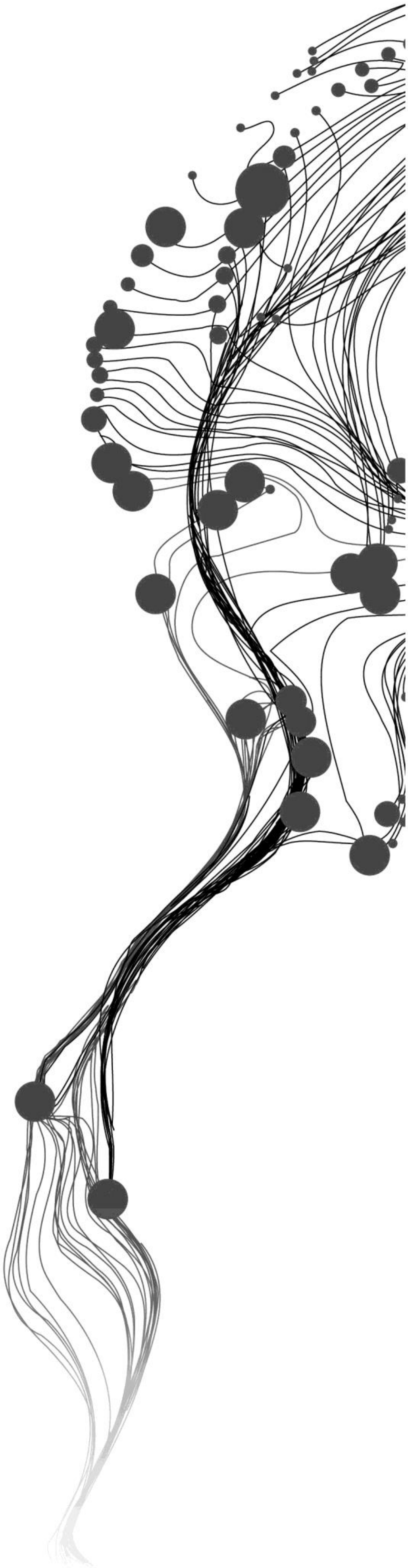
ASSESSING FEASIBILITY OF INTEGRATING UAV TECHNOLOGY IN RURAL ADJUDICATION IN CHINA

YUANGEN JIANG
March, 2016

SUPERVISORS:
Dr., M.N., Koeva
Dr., F.C., Nex
Dr., Yun Yang



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YUANGEN JIANG

Enschede, The Netherlands, [February, 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., M.N., Koeva
Dr., F.C., Nex
Dr., Yun Yang

THESIS ASSESSMENT BOARD:
Prof. Dr. J.A. Zevenbergen (Chair)
Dr. Ir. C.H,J. Lemmen (External Examiner, Kadaster)

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ABSTRACT

Adjudication is the first step of land registration, which plays an important role in ensuring the tenure security for the citizens. Conventional adjudication procedures require extensive ground measurements in cadastral surveying and mapping process, resulting in the process being time-consuming, labour-intensive and costly.

Unmanned Aerial Vehicle (UAV) technology provides a great opportunities in saving time and reduce cost in cadastral surveying and mapping process of adjudication procedure. This research focus on assessing the feasibility of integrating UAV technology in rural adjudication. The assessment was carried out by comparing the conventional adjudication procedure to the new procedure based on three criteria: time, cost and accuracy.

This research included literature review for the current adjudication procedure and questionnaires designed before fieldwork. Fieldwork was conducted to collect the questionnaires and technical data. The data collected was used to assess the new procedure. The results revealed the test accuracy (0.552m) for agricultural lands in rural areas can satisfy the accuracy requirement (1m) while saving time and reduce cost.

The conclusion is that the new procedure has been shown to save time, minimize require manpower and reduce cost , while the required accuracy still can be achieved for agricultural lands, which means UAV technology has good potentials in rural adjudication, specifically for the use right adjudication of agricultural lands of larger areas.

Keywords: Rural Adjudication, UAVs, Boundaries, Assessment

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisors Dr Mila Koeva, Dr Francesco Nex, Dr Yun Yang for their wholehearted support and encouragement during my research. I am very grateful to your valuable guidance and suggestions. Your patience and encouragements really inspired me, your trust and concern helped me to finish this research.

I would like also to thank University of Twente, Faculty of ITC for giving me this chance to study in this institution. I am also grateful to the staff who gave lectures and help during the modules. Further thanks to the Chang'an University: Dr Wei Zhang gave me this opportunity to join the programme with ITC and helped to provide data for this research.

It is my honour to appreciate the Zhejiang Surveying and Mapping Institution: the Director Zhenli Wang and staff- Mingshen Luo, Mian Zhou, Kun Zhang. They provided the data and support for the relative technical issues.

I would to show my sincerest thanks to my friends in ITC: Chenxiao Tang, Matthew Oliver Dimal who supported me in thesis writing, really grateful for your time and concern.

Finally, I would like to thank my family. Without their selfless support, I cannot study here. Thank you so much.

Yuangen Jiang

February 2016

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1. INTRODUCTION

Adjudication is the first step in land registration, which is an integral government system in ensuring tenure security for its citizens. Conventional adjudication procedures have been time-consuming, labour-intensive, and costly, because the cadastral surveying and mapping processes require extensive field measurements. This study will assess the feasibility of integrating UAV technology in cadastral surveying and mapping process to improve the adjudication procedure in rural areas of China.

1.1. Background and motivation

People in many parts of the world still do not have access to formal systems that secure their land rights. In 2014, the World Bank and the International Federation of Surveyors (FIG) published a report entitled 'Fit-for-Purpose Land Administration', which noted that 75 percent of the world's population has problems safeguarding their legal land rights because of the absence of a formal registration. Hence, building an affordable and sustainable systems is urgent (Kelm, 2014).

China started the First National Land Survey Project in 1984 and ended in 1997. The output quality was insufficient because of logistical constraints and of its high dependency on the skilled manpower. The procedure required had been time consuming and labor intensive. The output was in paper format, which meant inconvenience for data updating and sharing. In order to achieve the goal of obtaining land resource information for all communities and to satisfy the need of national land resource management, China set out the Second National Land Survey Project in 2007-2009. Global positioning systems (GPS) using real-time kinematic (RTK) capabilities, total station and geographic information systems (GIS) were employed. The use of advanced techniques made it more cost- and labor- efficient, compared to the First Project, but several major constraints still lingered. The main problem has been that the required groundwork remain to be labor-intensive and costly (Jing, 2011).

The unmanned aerial vehicle (UAV) technology can provide a new way to produce cheap and fast spatial data during the process of cadastral surveying and mapping. UAS can deliver up-to-date spatial data with high accuracy, faster and less labor-intensive. Moreover, it can satisfy the special needs of certain areas. For instance, the tests done in Albania (Kelm, 2014) have shown the use of UAV in accelerating the production of spatial data. The tests were done in three different areas covering rural, urban, and peri-urban area. Results of the tests showed UAV technology to be flexible and reliable, which meant it can satisfy special needs for special area (Mumbone, 2015). There are numerous advantages of using UAV. For instance, UAV can acquire extremely high spatial resolution. It can be cost-efficient to generate images for large expanses of land. On the other hand, there are certain disadvantages of UAV (Paneque-Gálvez, McCall, Napoletano, Wich, & Koh, 2014). For example, the payload is small and the endurance of flight is low. Other problems include the possibility of collisions, poor geometric and radiometric performance, and safety, security and ethical issues.

This research will focus on rural area in China to test whether the UAV technology is functional in specific area in China. The situation of many rural areas in different places in China are quite different, for instance, the rural parts of Southern and Eastern China are more developed, which means the problems here are more severe. Complicated boundary relationships compound the situation including overlapping boundaries, fuzzy borders, and land parcels with several certificates. Rural adjudication are different to urban adjudication due to different utilities, which includes adjudication for usufruct of curtilage and adjudication for the right to rural land contractual management according to ("Land Administration Law of the People's Republic of China," 2004). In 2013, China started a comprehensive rural land registration project, which contributes to accomplishing adjudication for the right to rural land contractual management within 5 years and accelerating the adjudication for usufruct of curtilage ("The No. 1 Document from the National Central Government of 2013," 2012). Figure 1 shows rural areas in China.

Figure 1 Rural area

1.2. Research problem

In China, the procedure of adjudication is preparation, cadastral surveying and mapping, land right investigation, data compilation and verification. The major problem is that the procedure of cadastral surveying and mapping are time consuming, labor intensive and costly.

It is still unknown whether UAV technology can be integrated in cadastral surveying and mapping process to improve the adjudication procedure and provide up-to-date land information in rural area of China.

1.3. Research objectives and questions

1.3.1. Overall objectives

To assess feasibility of integrating UAVs in cadastral surveying and mapping process to improve adjudication procedure in rural area of China.

1.3.2. Specific objectives and questions

Objective 1: To examine the current requirements regarding conventional adjudication procedure in rural areas of China.

Question 1: What are the procedures, regulations and policies of current adjudication procedure in rural area of China?

Question 2: What are the advantages and disadvantages of the current procedure in China?

Objective 2: To evaluate whether the current UAV technology would be applicable for land adjudication in rural areas of China.

Question 1: How suitable is the usage of UAV technology for adjudication procedure in rural areas of China?

Question 2: What would be the new adjudication procedure that would integrate UAV technology?

Objective 3: To evaluate the impact of using UAV in cadastral surveying and mapping in adjudication procedure in rural areas of China.

Question 1: What are the criteria to assess the adjudication procedure and what are the obtained results?

Question 2: What are the advantages and disadvantages while applying the new procedure compared to the conventional adjudication procedure?

Question 3: What are the recommendations for future development?

1.3.3. Conceptual Framework

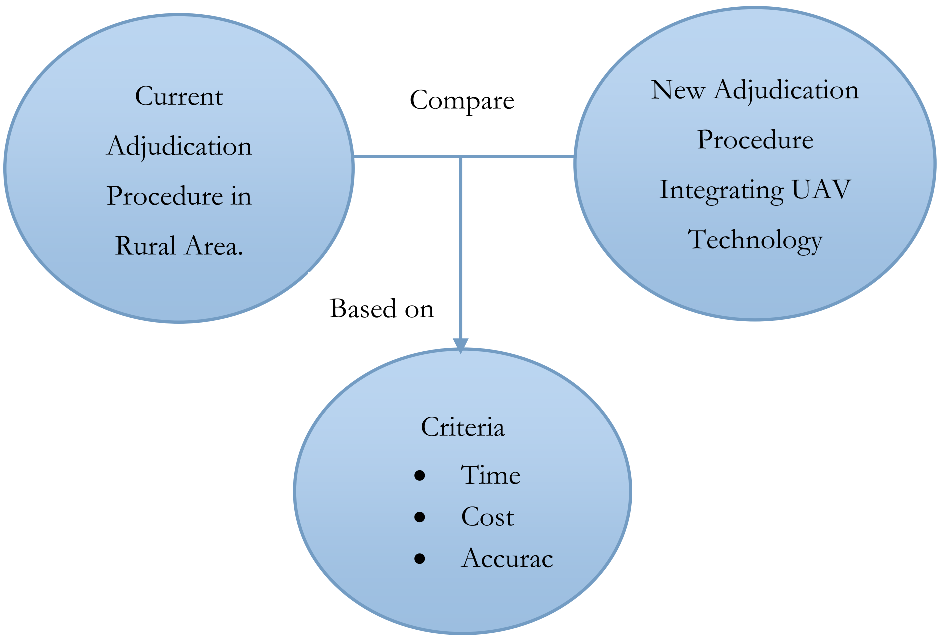

Figure 2 Conceptual Framework

1.4. Hypotheses

Integrating UAV technology in cadastral surveying and mapping will greatly improve land adjudication procedures by reducing time, labor and cost.

1.5. Research Matrix

Research Objectives	Research Questions	Research Methods	Data Sources	Anticipated Results
1. To examine the current requirements regarding conventional adjudication procedure in rural areas of China.	Q1: What are the procedures, regulations and policies of current adjudication procedure in rural area of China?	Literature review Interview	• Local documents • Legal documents • Interview management and technical staff in Land and Resources Bureau	• Clear description on the requirements and content of the current adjudication procedure in China; • List of legal, policy and regulation documents.
	Q2: What are the advantages and disadvantages of the current procedure in China?			
2. To evaluate whether the current UAV technology would be applicable for land adjudication in rural areas of China.	Q3: How suitable is the usage of UAV technology for adjudication procedure?	Literature review and legal document review, Interview, fieldwork	• Interview management and technical staff in Land and Resources Bureau • Literature • Legal materials • Interview local land owner • Pen for delineation • Data from local department	• Information of time and costs • Orthophoto w/ delineated boundary • UAV imagery and POS data • Flight specification • Camera parameter • Cadastral map of study area • Example of certificate • Notes and Records of Interview
	Q4: What would be the new adjudication procedure that would integrate UAV technology?			
3. To evaluate the impact of using UAV in cadastral surveying and mapping in adjudication procedure in rural areas of China.	Q5: What are the criteria to assess the adjudication procedure and what are the obtained results?	Literature review, Fieldwork output analysis	• Output data of fieldwork • Existing data • Literature Software: ArcGIS, Pix4DMapper	• Orthophoto production of Choose area • Digitized cadastral map of Choose area; • Time, cost and accuracy results; • Evaluation of results; • Further recommendation.
	Q6: What are the advantages and disadvantages while applying the new procedure compared to the conventional adjudication procedure?			
	Q7: What are the recommendations for future development?			

2. LITERATURE REVIEW

This section introduces the relevant terms and concepts about land registration and cadastre, adjudication, boundaries, boundary delineation in international context and in China. The UAV technologies and applications are also introduced.

2.1. Theoretical concepts in international context

2.1.1. Land registration and cadastre

Land registration is described as a process of official land right recording (Zevenbergen, 2004). It is the official process of recording and recognizing interests in land, including who owns the land and how it is done (Dale & McLaughlin, 1988). Cadastre is a public inventory of properties data within a certain country or district, which is arranged methodically based on boundary survey. Such properties are identified by some separate designation systematically (Zevenbergen, 2004). The outlines or boundaries of the property, together with registers, may show the parcel's value, size, nature, and legal rights. It answers the questions "where" and "how much" (Henssen, 2010). Land registration and cadaster achieve the social goal with strong relation and function, which should be treated as an integrated system (Zevenbergen, 2002). This system can be described static or dynamic.

The static model of land registration system can be represented in a simple connection among owner, property rights and parcel (Henssen, 1995). The owner represents the rightful individual or group of people to whom ownership is ascribed; the parcel represents the object of ownership; and the right gives the answer to question 'how' by representing a certain legal relation. The dynamic land registration system has three main functions: adjudication, subdivision, and transfer (Zevenbergen, 2002). The mushroom encompassed the static model. The situation of unregistered land tenure are transformed to registered station through adjudication from left side to right side. The transfer and subdivision are two main activities of registered land tenure, which can be seen as updating. On Figure 3, the dynamic model of the system of land registration are shown.

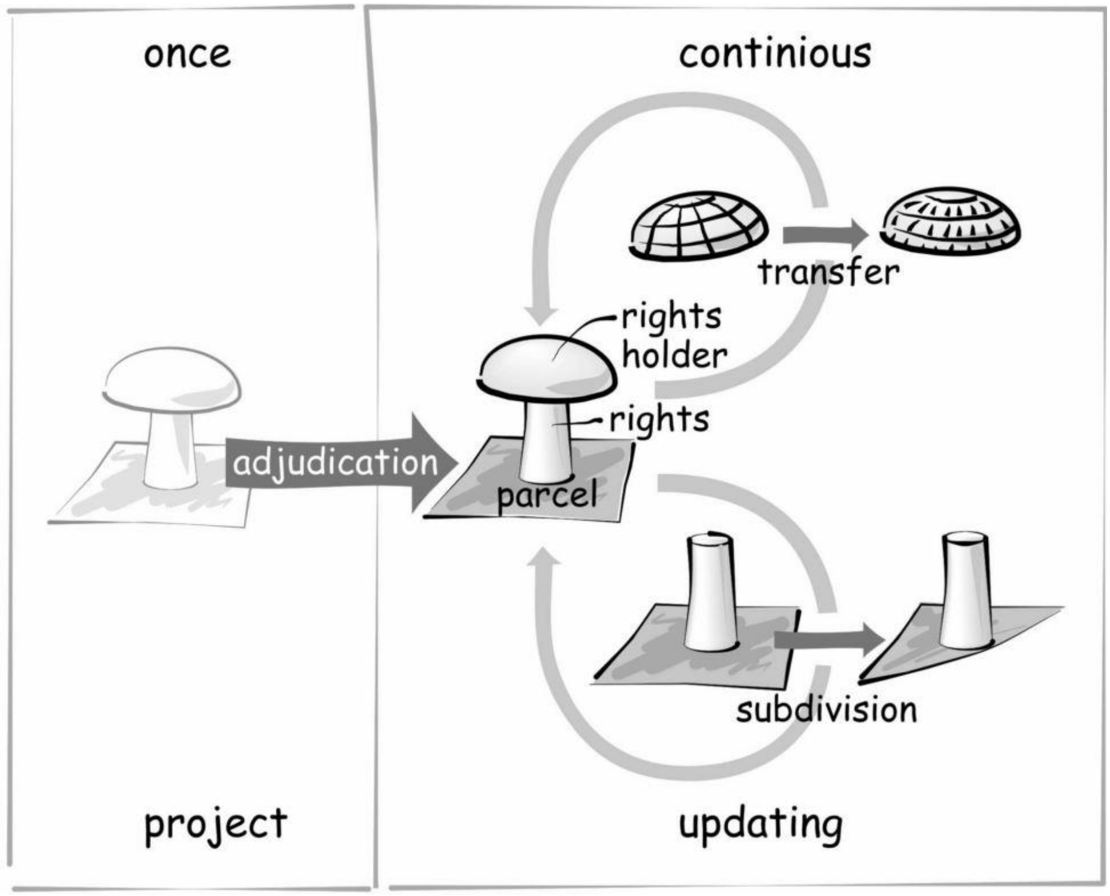

Figure 3 Dynamic model of the system of land registration (Jaap Zevenbergen, 2002)

2.1.2. Adjudication

Parcel boundary adjudication is an important process in land registration, which includes legal and physical boundary adjudication. Adjudication is the process of acknowledging existing rights by government (Lemmens, 2011). Dale & McLaughlin (1999) describe adjudication as the first stage in the registration to determine what rights exist to the land. Zevenbergen (2002) defines adjudication as the first of three functions in land registration system. This research aims at improving the adjudication part in land registration, focusing on the cadastral and mapping part of this process.

2.1.3. Boundary

The definition of boundary is perceived in two aspects: legal and common aspects. It refers to an imaginary line dividing neighboring estates in legal aspect, while common aspect means division line of the physical object (Dale & McLaughlin, 1999). Normally, the legal boundary will be a vertical boundary. Its actual physical location is normally demarcated by point features or linear features (Commission, Europe, & Nations, 2004). Boundary means dividing line or 'line of allocation' between two object ("Boundaries - The Canadian Encyclopedia," 2006).

The boundary can be divided into fixed boundary and general boundary. The main difference is that fixed boundary can be an accurate surveyed boundary, which allow the surveyor to replace any corner monument that might be lost, while the precise line of general boundary between adjoining parcels can be undetermined (Zevenbergen, 2002). Fixed boundaries are located by surveyed coordinates which means it is determined to a high accuracy standard (Kaufmann & Steudler, 2001). The exact location of the boundaries are fixed (Henssen, 2010). According to (Enemark, Clifford, Lemmen, & McLaren, 2014), in advanced land information systems, the fixed boundaries has significant effect to interoperability between legal and physical objects and it can be used for specific purposes. General boundaries are the approximate boundaries lines that the precise details can be confirmed by further investigation (Dale & McLaughlin, 1999). General boundaries are not surveyed accurately and the boundaries are the approximately lines. Enemark et al., (2014) discuss the general boundaries are the ones whose position has not been precisely determined in the present context and it would be sufficient for most land administration purposes.

2.1.4. Boundary delineation

Boundary delineation is important for geo-information related activities, such as semi-automatic mapping, object-based multispectral classification and stereo-matching (Mathias & Lemmens, 1996). People will have problems obtaining reliable object outline during feature extraction from aerial and space imagery, which means the method of boundary delineation is crucial (cite#$).

Multispectral segmentation method was introduced in a study regarding boundary delineation of agricultural fields in remote sense images (Rydberg, Borgefors, & Member, 2001). The procedure in this study was divided into three parts, which includes multispectral edge detection, unsupervised classification and merge regions. Random sets were introduced for modeling agricultural parcels and delineation of the field boundaries (Esfahani, 2014). ## What did they show / prove? What are the results?

2.2. Theoretical concepts in China

2.2.1. Land tenure system in China

There are two main types of rights in land tenure system in China: land ownership, and land use right. Two types of land ownership are (1) state-owned land, where ownership belongs to the general public, and (2) collective-owned land, where the land belongs to the 'collective' (which is the local population living in that specific rural region). "Land Administration Law of the People's Republic of China" (2004) states that the country implements socialist public ownership. It indicates that land ownership includes state-owned land ownership and collective-owned land ownership. Land in urban areas are owned by State. Land in rural and suburban areas are owned by collectives except on some special types of land. Land use right includes state-owned land use right and collective-owned use right.

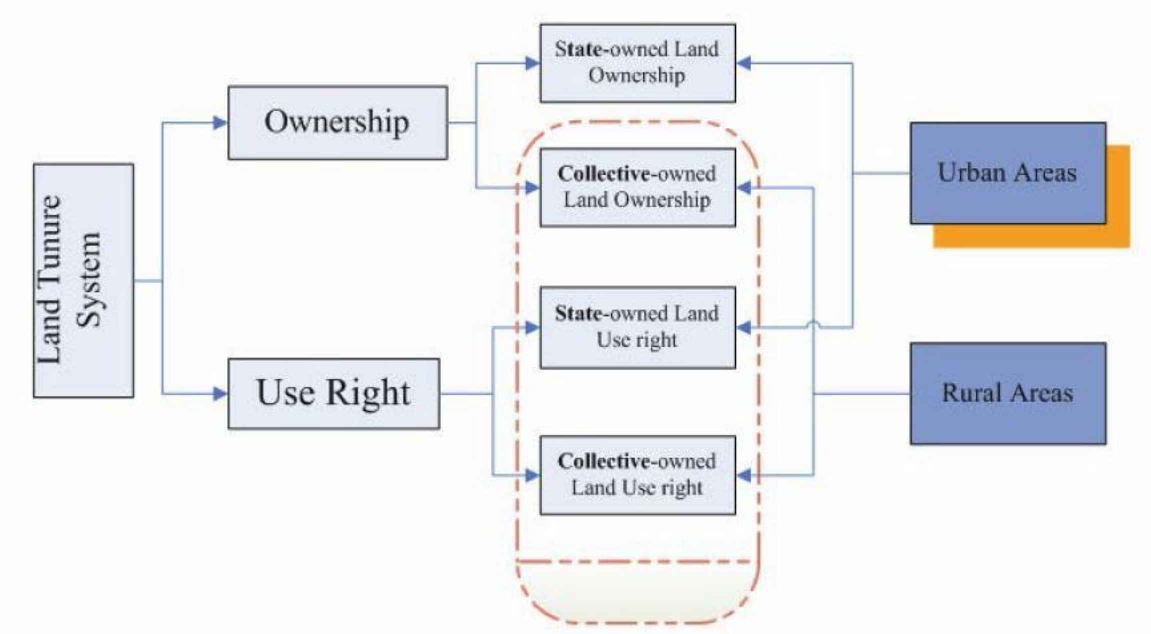

Figure 4 Land Tenure System Framework in China (Jing, 2011)

There are three adjudication for land rights in China: state-owned land use right, collective-owned land ownership and collective-owned land use right. The study area is rural, which means land ownership belongs to different collectives in different area. On Figure 4 the China land tenure system are shown.

There are some advantages and disadvantages in the current land tenure system for rural areas in China. According to Wen (2006), agricultural productivity and total output increase when collectively owned land are distributed to households with exclusive use rights. Major disadvantage is the incompatibility of the system with the market economy, since rural land is not tradable (Wen, 2006). Most people in rural area still have little confidence on tenure security even if improvements on legal rights have been initiated since 1978 ("China book | The Nature Conservancy," 2014).
This research mainly provides a new way for rural land use right adjudication. Land ownership in rural area are owned by Collectives in certain area. Land use right in rural area are owned by villagers.

2.2.2. Land adjudication in China

There are two types of land adjudication in China, urban land adjudication and rural land adjudication. Land adjudication only applies to land, and not including buildings and other appendages on or under the land.

Rural adjudication is a major undertaking in China for years to come ("The No. 1 Document from the National Central Government of 2013," 2012). China is said to focus on reforming the system of rural collective property right, to ensure the legal right of people in rural area. This entails accomplishing adjudication for the right to agricultural land (rural land contractual management) and adjudication for rural residential land use (usufruct of curtilage) are considered important.

Many researches has shown the significance of standardization rural land adjudication for rural sustainable development. Standardization rural land adjudication could increase agricultural productivity and maintain social stability (Chen et al., 2014). There are some major problems during the past rural land adjudication before 2010, which includes incomplete polices, inefficient organization and local difference (Fallis, 2013).

Rural land adjudication and registration focus on ensure the legal and complete land right of rural people, which will lead transformation of rural land management institute (Fallis, 2013). Li, (2015) discussed that rural land adjudication were not only a fundamental work, but also involves the improvement of rural economic institute.

2.2.3. Boundary in China

Boundary in China means fixed boundary according to (Congress, 2012). This regulations states that every boundary point should be surveyed accurately. Parcel boundaries should be identified by the land owners and the neighbors. The boundary would has legal effect after verified by the government.

2.2.4. Parcel

Parcel means the basic unit in land registration. It is also the basic unit for cadastral survey in China. One parcel of land is one unit to be adjudicated. Parcel is the piece of land consisting of closed land boundaries. Internationally there is no common terms used on parcel .On Figure 5 the parcel samples are shown.

Figure 5 Parcel sample of rural land

2.2.5. Accuracy requirement

The requirement of accuracy for different purpose of use of rural land are different even though they are all rural lands. The accuracy requirement of curtilage (residential area) is 5cm (level one), 7.5cm (level two). The accuracy requirement is the same for all the acceptable scale, which includes 1:500, 1:1000, and 1:2000 according to(“Specifications for surveying and mapping 1 500, 1 1000, 1 2000 digital topographic maps,” 2014) .

The accuracy requirement of agricultural lands is lower. The common use scale for agricultural land is 1:2000 according to (“Investigation Code of Practice for the Right to Rural Land Contractual Management,” 2014).The requirement is showed in the table 1:

Table 1 Accuracy requirement of agricultural lands

Unit: meter

Scale	RMSE	
	Plain, Hill	Mountains
1:500	±0.25	±0.37
1:1000	±0.50	±0.75
1:2000	±1.00	±1.50
1:5000	±2.00	±3.00

2.3. Technical concepts

2.3.1. Adjudication technologies

The general adjudication process is similar all over the world, which includes boundary identification, surveying and mapping, and output verification (Kaufman, 2002). But the methods and instrumentation used in cadastral surveying and mapping are different in different countries and change over time. There are two main approaches: terrestrial survey, and photogrammetric survey. This research compares the accuracy, time and cost between the terrestrial survey (ground survey using Total Station) and Photogrammetric survey (UAV imagery) in cadastral surveying and mapping process of rural adjudication procedure in China.

- **Terrestrial survey**

Terrestrial survey has been used for many years in cadastral surveying. With the development of technologies, the technical tools have changed from theodolites to GPS RTK and Total Stations.

According to Persson, (1995) the strength of the modern terrestrial survey are: the accuracy of the result is high, comparing to remote sensing used in photogrammetric based method, it is close to the objects and the work are uncomplicated and the equipment are inexpensive.

- **Photogrammetric survey**

During the past years the application of photogrammetric techniques have been increasing (Vassilopoulou et al., 2002). Adopting photogrammetry techniques has been helpful to identify the boundary by interpreting the outline of objects from the photographs.
One of the methods described by Siriba (2009) stated that ortho-rectified photographs used to identify the boundary are sufficient for cadastral purposes. And it is current considered in the renewal of cadastral maps in some countries (Al-ruzouq & Dimitrova, 2006).

During the data acquisition of cadastral boundary, orthophotos can be used well as a basis (Lemmen et al., 2009). The existing traditional boundary survey method is time consuming and it will easily cause different sources of errors because of many steps of process (Rugema, Verplanke, & Lemmen, 2015). The innovation of photogrammetric technology provides a new way in data collection-digital pen. The digital pen has the capability to record spatial data directly with attribute data. it is a good way of acquiring the cadastral data because it reduces errors and saves time compared to the conventional way (Rugema et al., 2015).

2.3.2. Unmanned Aerial Vehicles (UAV)

Military needs are the primary driving force of innovation in aerial techniques, which urges the application of small aircraft that can fly by themselves and gather information with little human intervention (Observation, 2015). These aircrafts are drones, unmanned aerial vehicle (UAV).

UAVs can be divided into fixed-wing and multi-rotor UAVS (Observation, 2015). The fixed wing UAV is suitable for surveying larger areas while the multi-rotor UAV is better for surveying small areas (Khairul Nizam Tahar, 2012). Due to the different flight theory, the endurance of fixed-wing aircraft is times of rotary`s, which means fixed-wing aircraft provides longer flight duration comparing to rotary's and are more ideal for capturing images over lager area. In the same time, higher altitude means lager ground size with a certain visual angle (Soergel, Michaelsen, Thiele, Cadario, & Thoennessen, 2009). With the steady flight path (Arifianto & Farhood, 2015), fixed-wings could capture consecutive qualified images in a settled height under a good flight plan. But to control the aircraft, there must be a skillful pilot on ground.

Recently, UAV are applied in many different areas that benefit a lot because UAV can satisfy certain requirement at a low cost and quick response. For instance, UAV has a significant impact on disaster management. UAV can extract a wide range damage features and reveal damage effectively that is not easy identified in the original image data (Galarreta, 2014). It also avoids the risks for pilots entering some dangerous places. UAV technology can also be helpful in agriculture area by obtaining accurate information guiding the producers to make the framing more effectively and efficiently. Use of UAV can greatly improve the data collection process of wireless sensor networks, which is helpful for monitoring agriculture (Ahir & Patel, 2014). UAV can be used to produce orthophoto for customary right registration (Mumbone, 2015), which is a good example for this research.

There are also some disadvantages of using UAV. For instance, during the process of building detection using UAV images, the 3D points generated could be noisy and contain gaps (Vetrivel, Gerke, Kerle, & Vosselman, 2015). The information provided by UAV images are not enough for the detail feature extraction, but the revival of applying oblique image would help provide additional information and make the feature extraction more reliable (Nex, Rupnik, & Remondino, 2013).

2.3.3. UAV Application in cadastral mapping

The development of spatial technology has provided new opportunities for cadastral mapping. UAV can provide high resolution imagery to optimize the fieldwork and makes it more efficient to define property boundaries (Volkmann & Barnes, 2014). Jing (2011) investigated feasibility of integrating UAV technology in urban adjudication in China and concluded that UAV technology could achieve cost and labor efficient even though the accuracy cannot satisfy the requirement of urban standard, but it could benefit rural adjudication in China. UAV application was conducted in Namibia for mapping customary parcel boundaries turned out to be functional because the UAV mapping approach provide high accurate orthophoto maps (Mumbone, 2015). Maurice, (2015) used UAV imagery to produce orthophoto for basemap updating in an efficient way that was proved successful.

With the rapid development of urbanization, UAV technology are tested in rural adjudication in some places in China recently. UAV technology takes obvious advantages of measurements in small area, and special topographic area with low flight attitude because it is effective, high accurate and flexible (Xu, 2015). Song, (2014) discussed the apply direction of UAV technology in rural cadastral surveying process and analyzed the advantages of applying UAV technology, concluding that UAV technology improves the efficiency, reduces cost and the accuracy is satisfied comparing to the traditional method.

Most of researches of the UAV application in cadastral mapping above shows the opportunities of integrating UAV technology in cadastral mapping because UAV technology can provide a new way that is efficient, cheap, accurate and flexible. There are also some limitation of applying UAV technology because accuracy requirement in some areas are high.

2.4. Chapter Summary

In this chapter adjudication related terms in international content were introduced, which includes land registration, cadastre, adjudication, boundary and boundary delineation. China's land tenure system were introduced and the exact meanings of the adjudication related terms in China were explained. The accuracy requirement standard of rural adjudication was shown.

Adjudication technology were introduced, including territorial survey and photogrammetric survey. UAV technology is a potential tool that could be integrated in adjudication procedure according to many researches all over the world. UAV applications are tested in some rural areas in China, which has shown the promising benefits in saving time and reducing cost compare to ground survey. But the accuracy requirement would be a limitation in certain areas in China.

3. RESEARCH METHODS

The previous sections discussed the relevant concepts that are used in this research. This part of the study discusses the workflow of research design, research approach and techniques used to answer the research questions.

Figure 6 shows the workflow design used in this research. The study was divided into three main parts, each part seeking to address the various sub-objectives of the research.

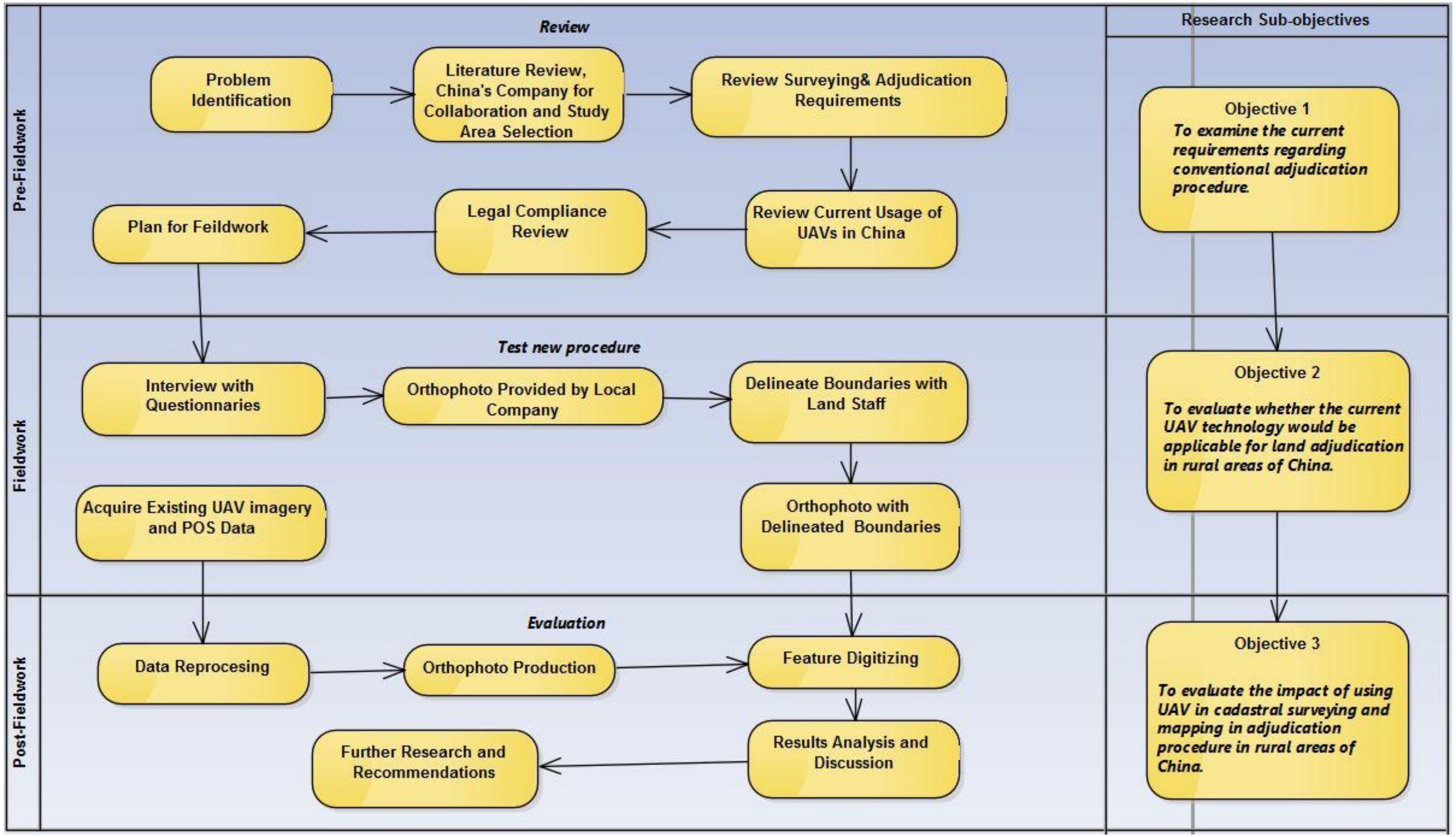

Figure 6 Workflow of research design

3.1. Research Approach

This research compares the conventional adjudication process to new adjudication procedure that integrates UAV technologies, based on three aspects: time, cost and accuracy. The data on conventional adjudication method were obtained from review of related works, while measurements concerning the proposed procedure were obtained through the fieldwork.

3.1.1. Pre-fieldwork

The current adjudication procedure was analyzed, which revealed overt and latent advantages and disadvantages of the method. Literature review on the practicability and suitability of UAV technology for survey applications was also performed. Legal compliance review is necessary to determine the feasibility of new adjudication procedures. For UAVs, there is no explicit regulation limiting its usage. The closest document to a guide for UAV use for civilians is the "Measures for Civil UAV 2009", which provides recommendations on usage but are not legally enforceable (Tang, 2015).

With the rapid development of UAV applications, the standardization of UAV usage are expected. In December 2015, Civil Aviation Administration of China proposed temporary measures to collect suggestions to start in January and become enforceable in February of the next year (Yang, 2015; Han, 2016).

The questionnaires were prepared and translated to Chinese prior to fieldwork. A teleconference was settled with Director of Zhejiang Surveying and Mapping Institution to discuss the availability of data needed for the research, which included the UAV images, POS data, digital cadastral map, orthophoto and flight specification. For security issues, the ground control points (GCP) cannot be provided. Moreover, specific details of the study area cannot be revealed.

Parts of the data were provided before fieldwork including information of UAV and the flight specification. The imagery provided for this study was captured on March, 2015 by a fixed-wing UAV-Albird KC2000. POS data recorded the longitude, latitude and height of the UAV imagery. The UAV carried a 12.8Mp resolution Canon camera (Canon 5D mark III). Figure 7 shows the UAV.

Figure 7 Albird KC2000 (Image from the Zhejiang Surveying and Mapping Institute)

The flight specification was designed based on the area's topographical characteristics. There are some mountains in the study area, which meant the flight height cannot be lower than the highest mountain. Since the area is adjacent to the sea, wind was also a factor influencing the projections of the UAV's flight stability. Figure 8 shows the flight specification and flight route.

Flight Height	614m
Resolution	16cm
Forward Overlap	75%
Side Overlap	50%
Length of Photogrammetry Baseline	154m
Distance of Different Flight line	461m

Figure 8 Flight specification and flight route

3.1.1.1. Study area

The study area was chosen mainly due to the availability of data. The study site is a village in Xiangshan County, Ningbo city, Zhejiang Province, China, located in the Eastern part of Zhejiang Province in China. More than 70% of the region is mountainous, the highest mountain being 810.8 meters above mean sea level. The total area is 60 square kilometers covered by 1062 UAV images. Figure 9 shows the location of the study area.

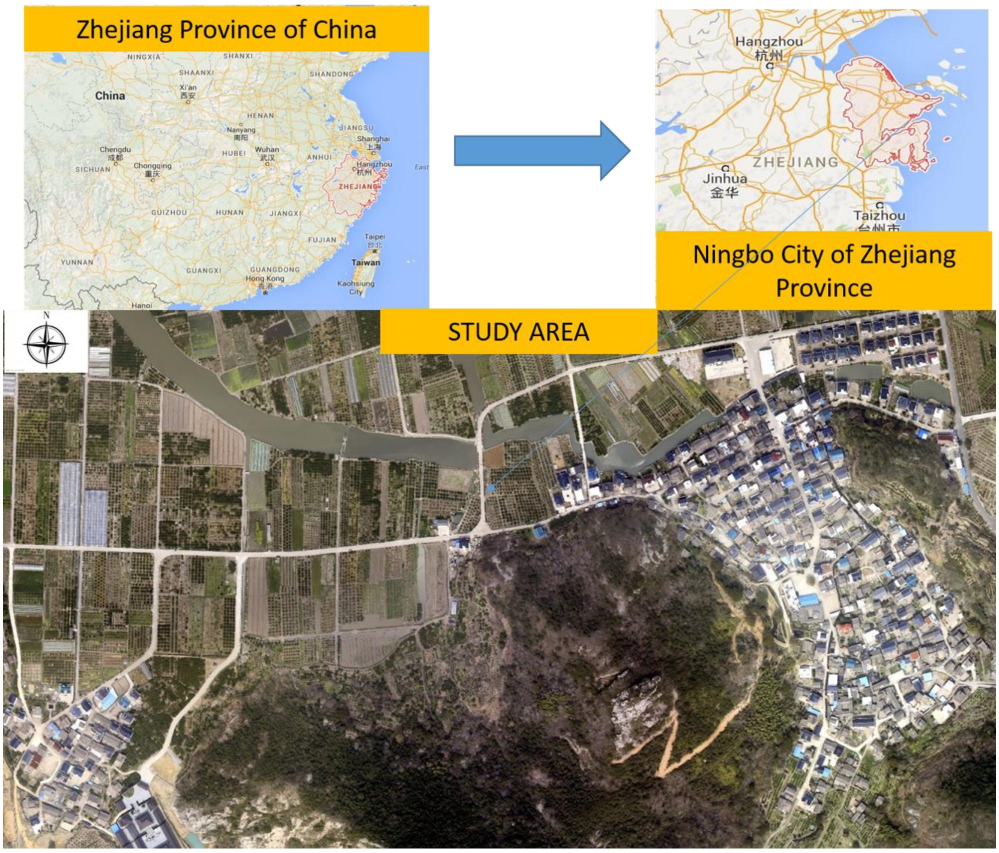

Figure 9 **Location of the study area**

3.1.2. Fieldwork

Field work was conducted to collect cadastral and technical data needed in answering research questions. Questions related to objective 2 were answered in this stage. On Figure 10 the overview of fieldwork were shown.

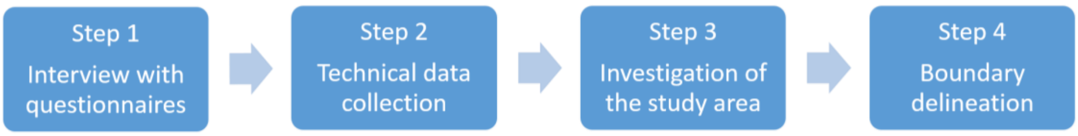

Figure 10 **Overview of fieldwork**

- **Interviews**

Land staff in Zhejiang surveying and Mapping Institution were interviewed as part of field work. This institution is part of the Zhejiang Geological Exploration Bureau, which undertakes basic provincial survey-mapping projects. Started in 1958, the bureau has Grade A survey-mapping qualification. The director of Surveying and Mapping Institution, Mr. Zhenli Wang, discussed the current adjudication procedure and the feasibility of new procedure. Shaoze Shen, the project manager of the study area was interviewed about topographic situation and overview of the study area. The UAV technology was applied to produce 4D product, DLG (Digital Line Graphic). It was the first time UAV technology was used for land administration by the Zhejiang Surveying and Mapping Institution. Fifteen (15) land staff were interviewed regarding details using conventional methods of land surveying and that of UAV use. Table 2 shows summary of those interviewed.

Table 2 Interview list

Name	Duty	Responsibility
Zhenli Wang	Director	Manage all the things
Shaoze Shen	Project Manager	In charge of the surveying project
Yan Yang	Technical Manager	In charge of technical aspects
Mian Zhou	Surveying Manager	In charge of surveying in the field
Mingsheng Luo	Land Surveyor	Field survey and land investigation
Kun Zhang	Land Surveyor	Field survey and land investigation
Jing Sheng	Land Surveyor	Field survey and land investigation
Changlong Yu	Land Surveyor	Field survey and land investigation
Fei Yang	Land Surveyor	Field survey and land investigation
Ganlin Fan	UAV pilot	In charge of UAV flight and data analysis
Binqian Jin	Land officer	Data compilation
Yilin Sun	Land officer	Data compilation
Yuxia Zhang	Land officer	Data compilation

- **Technical data**

After the interview procedures the technical part followed. The UAV imagery and POS data collected were used to produce orthophoto of the study area. The Digital Cadastral Map was used as reference data for accuracy comparison. This map was finished in 2013 and was verified by the local government. Table 3 shows all the provided data from Zhejiang Surveying and Mapping Institution.

Table 3 Collected Data in Zhejiang Surveying and Mapping Institution

Data Type	Remarks
UAV Imagery	Be used to produce Orthophoto
POS Data	Be used to produce Orthophoto (record Longitude, Latitude and Height of UAV imagery)
Orthophoto Produce by Local Institution	Be used for delineation
Digital Cadastral Map	Reference Data for accuracy comparesion
Laws, Policies, Regulations and Measures	Current adjudication procedure analysis
Example of Cadastral Form	Current adjudication procedure analysis
Example of Registration Form of Land Use Right	Current adjudication procedure analysis
Flight Specification	Proof of Results analysis

- **Investigation and boundary delineation**

The next step was to delineate parcels with the orthophoto provided by Zhejiang Surveying and Mapping Institution. Land investigation procedure was proposed to do in a workshop. But according to the director and the experiences of investigation in study area, it was impractical for rural areas. Instead of doing workshop, because of their limited capacity, parcel delineation was done in the office, choosing parcels that were very much visible on the orthophoto.

3.1.3. Post-field Work

The main tasks of post-fieldwork session were to analyze the current adjudication procedure, to produce an orthophoto of study area and to compare the current adjudication procedure with the new procedure integrating UAV technology according to accuracy, time and cost. On Figure 11 the steps are shown.

Figure 11 Steps of post-fieldwork

3.1.3.1. Orthophoto production and digitizing

POS data, recorded the coordinates where the images that were taken, including longitude, latitude and height, combing 1062 UAV images that provided by Zhejiang Surveying and Mapping Institution, are used to produce an orthophoto. Pix4Dmapper was used to process the UAV images and POS data. This software is an advanced photogrammetric software uses images to produce photo-mosaics, it can automatically converts images taken by UAV and delivers highly precise, geo-referenced maps.("Pix4D - UAV Mapping Software," 2016). On Figure 12 the workflow of the procedure are shown.

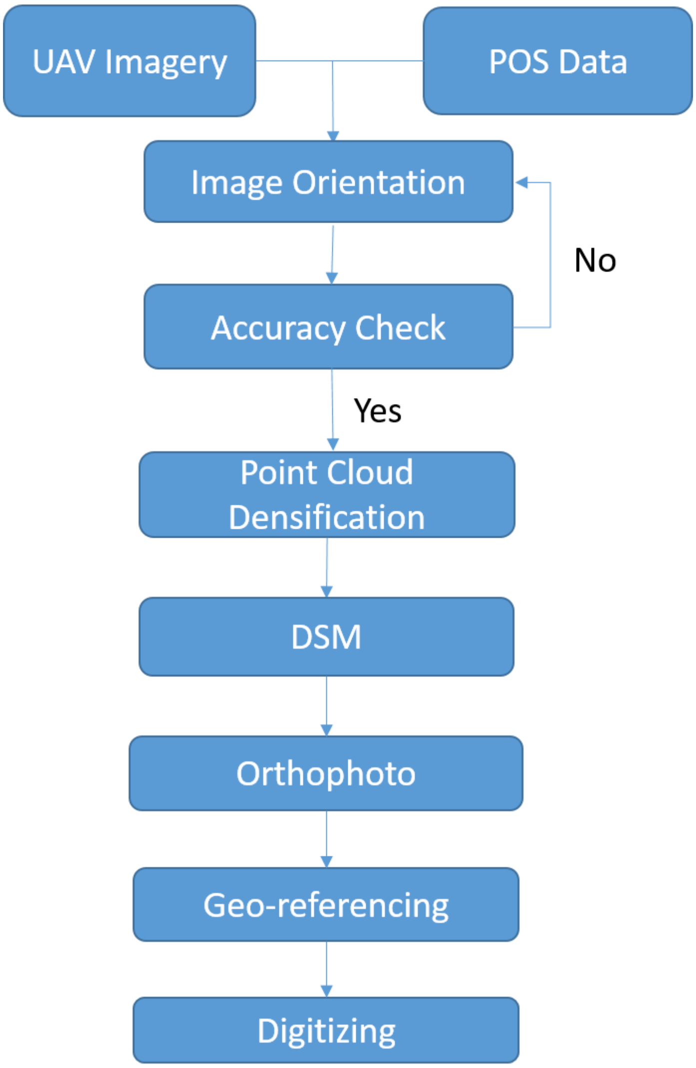

Figure 12 Workflow of the process

Creating a new project with 1062 UAV images and POS data choosing the output coordinate system as China Geodetic Coordinate System2000 120E (CGCS2000 120E) in Pix4Dmapper. CGCS2000 has been adopted as the national geodetic reference system that referred to ITRF 97(International Terrestrial Reference Frame 1997) since 2008 in China (United, Regional, & Reports, 2009).

The initial processing was the step performed in Pix4Dmapper, which used the property of images and camera geometry to perform the image orientation and calibration. This process detected the key points in all images to calculate their matches and perform calibration. The image scale value was one, which was a recommended image scale value. It would be helpful for generating enough features (www.pix4d.com, 2016a). The quality of initial processing was given in a report, which would show the results of median key points per image, image calibration, camera optimization, median of matching points per calibrated image and georeferencing.

In order to acquire more dense key points to reconstruct the object geometry, the dense point could generation followed. This step increased the density of key points cloud in the process of initial processing to generate more accurate points clouds. Scale Invariant Feature Transform (SIFT) is the most commonly used algorithm in this process.

For the purpose of obtaining high quality result, the parameters were selected as the highest standard. The image scale of point cloud densification was chosen as original image for the purpose of computing more points, especially in areas where features can be easily matched (e.g. cities, rocks, etc.) (www.pix4d.com, 2016). The point density was optima and the minimum number of matches were three.

After generating densified point clouds, the DSM and orthomosaic generation followed. The inverse distance weight method was chosen due to this method can produce better results in flat areas compared with other options provided in the software (www.pix4d.com, 2016). The orthomosaic was saved into a GeoTIFF file. The merge tiles option was chosen to generate a single orthomosaic GeoTIFF file containing the whole of the selected area by merging the individual tiles.

The output orthophoto was too large in size to process in ArcGIS. Thus 146 UAV images were used to produce an orthophoto that covers a smaller area in the study area. The orthophoto production was imported into ArcGIS and used transform tool to geo-reference the orthophoto from the original CGCS2000 120E to CGCS2000 121E which was used by the digital cadastral map provided by Zhejiang Surveying and Mapping Institution.

For the security reason, the GCPs cannot be used in this research because the coordinates of the GCPs were not provided. The reference dataset of digital cadastral map was approved by the provincial departments, which means it could be used to geo-reference the orthophoto. Import the digital cadastral map into ArcGIS and defined the coordinate system as CGCS2000 121E. Well visible and distributed points were chosen to do the geo-reference, including road corner points, corner of parking lots, corner points of lakes. The value of residual should not greater than half pixel (16cm) according to Stepanov & Aniskoff (2011). On Figure 13 the examples are shown.

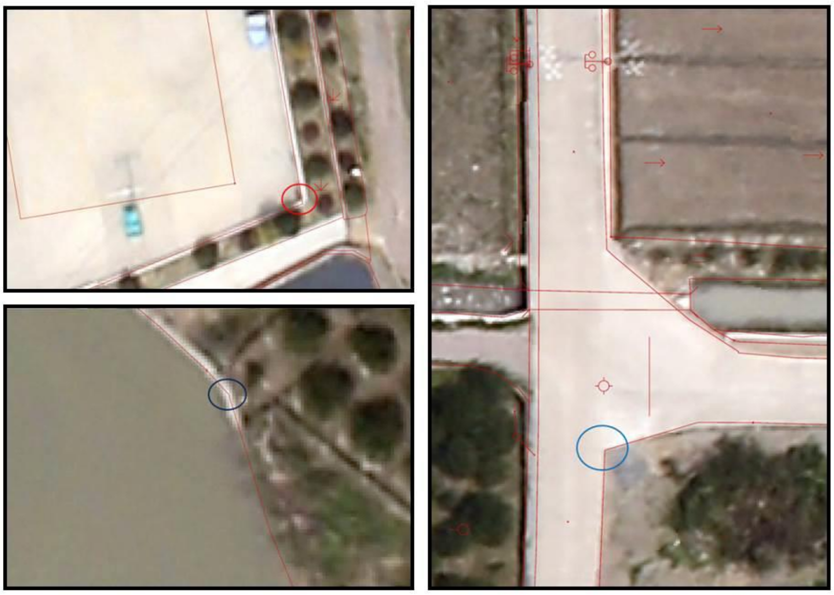

Figure 13 Sample points in the orthophoto

After geo-referencing the orthophoto the digitizing of study area followed. The digitizing contains three different parts of the study area, agricultural lands, regularly distributed houses and irregularly distributed houses. After digitizing these three parts, their accuracy would be checked by comparing coordinates of digitized and digital cadastral map. The RMSE calculations would be used to assess the quality.

3.1.3.2. Comparison-accuracy, time and cost

Accuracy:

The accuracy assessment of the study area are divided into three different parts based on the specificity of rural areas in this study area, which includes *regularly distributed houses* and *irregularly distributed houses* in residential area, *agricultural lands*. The reasons are: the accuracy requirement of residential area and agricultural are different.

The parcel boundary of regularly distributed houses are easier to be distinguished than the irregularly distributed houses, which means the accuracy result will be affected.

Compare the parcel point coordinate of these three different character of rural lands between digitizing and field surveying using RMSE calculation to test whether the parcel points of digitizing can satisfy the accuracy requirement.

Time:

The interview questionnaires were analyzed to compare the difference of cadastral surveying and mapping between the traditional adjudication procedure and the new procedure that integrating UAV technology.

Cost:

Based from interviews with the staff and personnel of Zhejiang Surveying and Mapping Department, the difference of costs was computed between the traditional adjudication procedure and the UAV method.

3.2. Chapter Summary

In this chapter research design and method were introduced. This research was divided into three part, which includes pre-fieldwork, fieldwork and post-fieldwork.

During the pre-fieldwork section, current adjudication procedure was analyzed. Practicability and suitability of UAV technology for cadastral surveying were reviewed. Legal compliance was reviewed to determine the feasibility of new adjudication procedures. A teleconference was settled with the Director of Zhejiang Surveying and Mapping Institution to discuss the needed data for this research that they can provide. Questionnaires were translated prior to fieldwork in order to collect enough information for this research.

The questionnaires were used to interview the staff in Zhejiang Surveying and Mapping Institution and the technical data were collected during fieldwork section. The orthophoto was used to do the boundary delineation in the office. All the data needed were collected during fieldwork.

The data collected during fieldwork were analyzed and processed during post-fieldwork section. Questionnaires were analyzed to reveal the overt and latent advantages and disadvantages of current adjudication procedure. The UAV imagery and POS data were used to produce an orthophoto with software Pix4D Mapper. The parcel boundary were digitized after producing the orthophoto. The accuracy, time and cost were compared between the traditional and new adjudication procedure.

4. RESULTS

4.1. Current adjudication procedure analysis

4.1.1. Procedures, laws, policy and regulations

According to the interview of Director of Zhejiang Surveying and Mapping Institution, the conventional adjudication procedure comprises:
(1) Preparation (information collection, study area analysis, make the design sheets); (2) Cadastral surveying and mapping (horizontal control and vertical control measurement, produce the parcel boundary map);
(3) Land right investigation;
(4) Data compilation;
(5) Verification.

After preparation for the surveying project, surveyors will need to set GNSS control network that covers the whole area, then measure parcel boundary points to produce the parcel boundary map. The parcel boundary map is used to do the land right investigation.

The relevant regulations, polices and laws of current adjudication procedure are as follow:
Land Administration Law of the People's Republic of China (2004 Amendment)
Land Administration Law of the People's Republic of China was established in 1986 and amended in 2004. It is the fundamental law of land administration with highest authority. The other policies, regulations and laws should comply with this law. This law stipulates land tenure system, land use planning, protection of cultivated land, land registration, usage of construction land and legal responsibility.

Measures for Land Registration
Measures for Land Registration was enacted in 2008 base on Land Administration Law of the People's Republic of China, Property Law of the People's Republic of China, Real Estate Management Law of the People's Republic of China and Enforcement Regulations of Land Administration Law of the People's Republic of China. This Measures focus on standard land registration and it can protect the legal right of land owners.

Regulations for Land Right Adjudication
Regulations for Land Right Adjudication was established in 1995 for land ownership and land use right adjudication before land registration based on relevant law, regulations and laws. This regulations reveal that the land ownership and land use right are adjudicated by county level or above government and land management department shall specifically undertake the implement. It specifies affiliation of the land ownership and land use right of different types of land, which is a good guide for land adjudication.

Cadastral Survey Regulations for Cities and Towns
Cadastral Survey Regulations for Cities and Towns were established in 2012 for urban and rural cadastral survey. It stipulates the content, procedure, methods, requirement, results management

and informative construction of cadastral survey. These regulations provide the specific procedure of cadastral survey and requirement of accuracy of different types of land in different areas.

Investigation Code of Practice for the Right to Rural Land Contractual Management
Investigation Code of Practice for the Right to Rural Land Contractual Management was enacted in 2014 for land registration of right to rural land contractual management. It specifies the tasks, content, procedure, methods, indicators, results and requirement of investigation of right to rural land contractual management. It has the specific regulations of procedures, guides and accuracy requirements of agriculture land adjudication.

Technical Regulations of Digital Cadastre of Zhejiang Province
Technical Regulations of Digital Cadastre of Zhejiang Province was enacted in 2008 according to the cadastral survey requirement of Ministry of Land and Resources based on the real situation of Zhejiang Province. This regulations was formulated based on Land Administration Law of the People's Republic of China, Measures of Land Survey, which is contribute to the rapid development and requirement of cadastral management of Zhejiang Province. It stipulates the digital cadastral survey in cities, towns and villages in Zhejiang Province.

The No. 1 Document from the National Central Government of 2013
The No. 1 Document from the National Central Government of 2013 was implemented in 2013, which focus is on solving rural problems. One of policies is to start rural land adjudication and registration and to improve institution of right to rural land contractual management. To finish general adjudication and registration of right to rural land contractual management within 5 years. Accelerate the cadastral survey, adjudication and registration of rural curtilage. Rural adjudication are ongoing in recent years in different places in China.

Specifications for surveying and mapping 1:500, 1:1000, 1:2000 digital topographic maps
Specifications for surveying and mapping 1:500, 1:1000, 1:2000 digital topographic maps was enacted in 2014, which is a regulation for digital topographic survey. It stipulates the content, methods and results requirement of surveying and mapping 1:500, 1:1000, 1:2000 digital topographic maps. This is the latest regulations in Zhejiang province.

4.1.2. SWOT analysis of the current adjudication procedure

The current adjudication procedure was analyzed by SWOT. SWOT, or Strengths Weaknesses Opportunities and Threats, is a framework to analyze the different dynamics of the different systems or procedures, and reveal their associated advantages, challenges, and problems.

Strengths

The main strengths of the current adjudication procedure are:

1) The regulations and rules of the current adjudication procedure are completely operational. Traditional surveying method has been implemented in China for many years. The land staff is very much acquainted and familiar with the regulations and procedures for traditional method.
2) Total Station and GPS-RTK are the instruments commonly used in surveying in China, which were also the instruments they were considering when proposing the accuracy requirements for surveys.
3) The time and cost are less in training new staff to use Total Station because it requires less skill to learn and master in using Total Station.
4) The traditional adjudication procedure has greater acceptance by the people in rural areas. They are more willing to cooperate and feel secure during the survey and investigation section.

Weaknesses

The conventional method is time consuming and labor intensive. The ground work needed in surveying requires laborious work. Building a control network of the surveying area takes time, including horizontal control and vertical control. For larger areas, the efficiency of parcel boundary measurements degrades dramatically, especially for certain conditions. Land investigation is conducted on the parcel level, which requires longer time to finish especially for more complex areas.

Opportunities

Better instruments in land surveying are being developed which can help minimize the time and labor costs of the conventional method, and thus improve its efficiency.

Threats

During the survey, the topography greatly influences efficiency. For instance, rugged or hilly areas will be difficult to survey using a Total Station. Irregularly fractal parcels complicates boundary measurements. During the land investigation process, illegal construction works not consistent with the 'old document' are revealed which can cause disputes. It would be difficult to perform validation surveys because the land owners in these areas are not willing to sign their names on documents to verify legal land information. This makes the process longer and more difficult to finish.

4.2. Results of orthophoto production and digitizing

4.2.1. Quality Report:

Images	Median of 58041 keypoints per image
Dataset	1026 out of 1062 images calibrated (96%), all images enabled, 7blocks
Camera Optimization	5.36% relative difference between initial and optimized internal camera parameters
Matching	Median of 11723 matches per calibrated image
Georeferencing	No, no 3D GCP

Figure 14 Report of quality check

A quality report was produced by the Pix4D Mapper software during the orthophoto generation process. Figure 14 shows the first part of the quality report obtained from Pix4D Mapper after initial processing using UAV imagery and POS Data. The median key points were 58041 per image for this project, which is far above the required minimum of 10000 key points per images (www.pix4d.com, 2016). Concerning the geolocation, there were 1026 out of 1062 images that were calibrated. Some images were not oriented because part of the study area was mountainous and were covered by thick vegetation. The camera optimization was 5.36%. The matching was 11723 matches per calibrated image, which was over the required minimum number (1000 per image) (www.pix4d.com, 2016).

One major issue in the testing was the large size of the final exported file (5.44GB) which was problematic when opening. To solve this problem, the number of the UAV image was reduced to 149. The area covered by the UAV image was still much larger than the study area. On Figure 15 the quality report were shown.

Images	Median of 57024 keypoints per image
Dataset	149out of 149 images calibrated (100%), all images enabled
Camera Optimization	5.46% relative difference between initial and optimized internal camera parameters
Matching	Median of 30125.6 matches per calibrated image
Georeferencing	No, no 3D GCP

Figure 15 Report of quality check

The median key points were 57024 per image for this project, which was also far above the required minimum of 10000 key points per image (www.pix4d.com, 2016). All the images were calibrated because no forested mountains covered the region. The camera optimization and the number of median matches per calibrated image also satisfied the requirement.

Another element of this report showed the result of image overlaps. Number of overlapping images was computed for each pixel of the orhtomosaic. Red and yellow areas indicate low overlap. Green areas indicate an overlap of over 5 images for every pixel. Good quality of results can be generated with more overlapping images (Source: quality report of Pix4Dmapper). The study area is located in the middle of orthophoto, with the number of overlapping images being greater than five. Figure 16 shows the number of overlapping images of this project.

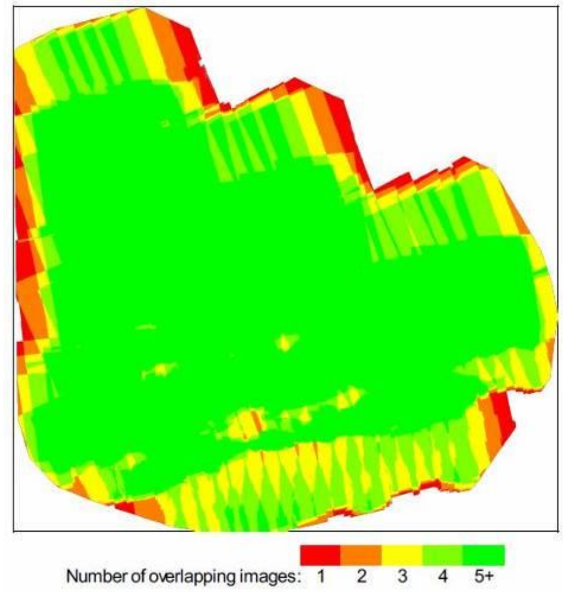

Figure 16 Number of overlap images

The orthophoto was then generated as shown in Figure 17. In general, the quality of the orthophoto is determined by many factors, which include quality of UAV image, POS data, image orientation, camera calibration and DSM (Maurice, 2015)

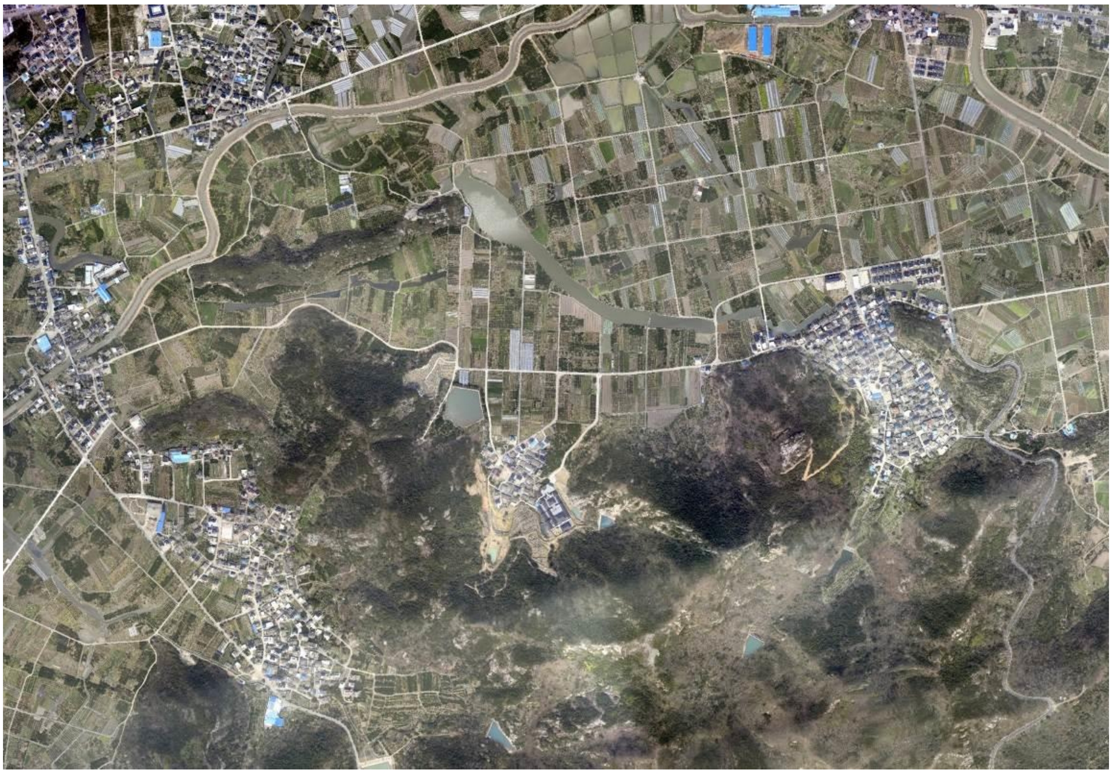

Figure 17 Orthophoto production

Most of the features in the orthophoto show clear discernibility of major ground features. However, some houses have visible distortions caused by height and the instability of the UAV. The distortion may have been caused by lack of overlap in this area resulting in unsatisfied reconstruction results. In Figure 18, agricultural lands are shown to be well visible while some houses have minor distortion.

Figure 18 Agricultural Lands are more clearly well-defined while houses are shown to have distortions

4.2.2. Orthophoto geo-referencing and digitizing

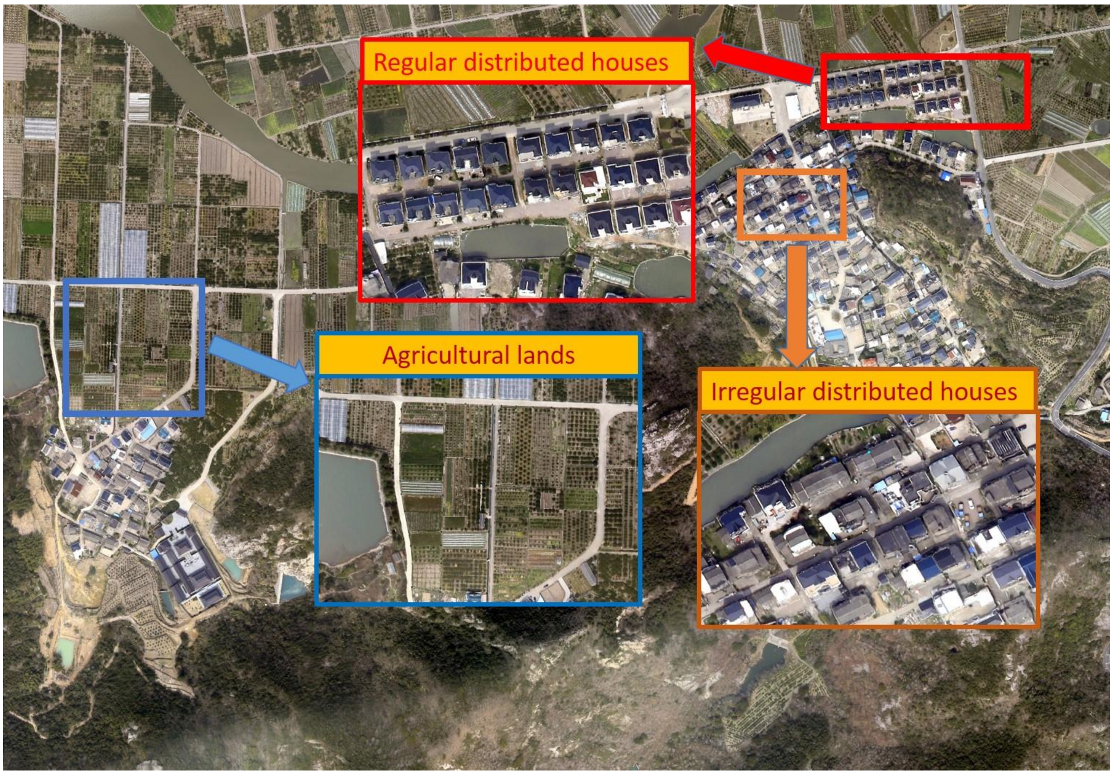

Figure 19 Three different kinds of rural land of Study Area

On Figure 19, the three different kinds of rural land of study area are shown. In order to geo-reference the orthophoto, the digital cadastral map and orthophoto were imported into ArcGIS. The georeferencing tool was used to perform the geo-referencing process. Well visible and distributed points were chosen, which included 30 road corner points, corner of parking lots, corner points of lakes. The value of residual should not be greater than half pixel (8cm) according to Stepanov & Aniskoff (2011). Figure 20 shows RMSE result of georeferencing.

Link

Total RMS Error: Forward:0.0427123

<Link>	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
1	633296.148743	31640.635554	633296.115000	31640.615000	0.0273119	0.0402596	0.0486495
2	633035.916569	32140.212043	633035.911000	32140.155000	0	-0.00473687	0.00473687
3	633396.975382	31638.893708	633396.919000	31638.799000	0.0143966	-0.0257356	0.0294887
4	634236.733779	31836.306924	634236.546900	31836.187700	-0.046807	0.0230748	0.0521856
5	634292.685312	31798.963998	634292.525600	31798.847400	-0.0122367	0.0293064	0.0317585
6	634084.769637	31904.110724	634084.649600	31903.951300	0	-0.0277697	0.0277697
7	633203.737688	31465.554962	633203.688792	31465.449603	0.0129961	-0.0565032	0.0579785
8	633115.808068	31647.657040	633115.749000	31647.601000	-0.0156206	-0.00972081	0.0183983
9	633286.567653	31878.968018	633286.490000	31878.875000	-0.0306637	-0.0269418	0.0408182
10	633374.101314	31857.815727	633374.073000	31857.792000	0.0282011	0.0489343	0.0564789
11	633211.060034	31958.025080	633210.949000	31957.959000	-0.0756164	-0.00414361	0.0757299
12	633173.088663	32082.518809	633173.106000	32082.481000	0.0422591	0.024195	0.0486953
13	633176.966770	32071.159194	633176.981000	32071.126000	0.0401491	0.0288377	0.0494324
14	633186.152611	32064.702886	633186.143000	32064.648000	0.0175412	0.00772873	0.0191683
15	633262.797240	31967.566928	633262.788000	31967.531000	0.0305907	0.0304602	0.0431696
16	634261.142123	31448.537314	634260.930600	31448.405600	-0.0477233	0.00274056	0.0478019
17	634234.630264	31438.053606	634234.509800	31437.919500	0.0413824	-0.0020742	0.0414343
18	634196.644996	31435.288933	634196.554600	31435.158600	0.0679763	-0.00146205	0.0679921
19	633156.114056	31366.352120	633156.044000	31366.340000	-0.0072378	0.0303464	0.0311976
20	634284.363230	31841.373394	634284.218500	31841.177500	0	-0.0495914	0.0495914
21	633412.201480	31638.740714	633412.140314	31638.645841	0.0110752	-0.0246658	0.0270382
22	634061.208122	31900.210838	634061.084200	31900.041200	0	-0.04	0.04
23	633114.096586	31650.006428	633114.018000	31649.943000	-0.0354312	-0.0171892	0.0393807
24	634199.422479	31871.165867	634199.309200	31871.045100	0.0213076	0.0193804	0.028803
25	634090.265748	31871.784155	634090.140600	31871.677100	0	0.0242271	0.0242271
26	633521.818051	31643.711805	633521.753000	31643.668000	0.0173832	0.0354467	0.0394797
27	633109.122605	32005.912976	633109.052000	32005.827000	-0.0475634	-0.0311188	0.0568389
28	633090.145440	32040.696550	633090.119000	32040.605000	-0.00712984	-0.0373543	0.0380287
29	633296.200299	31373.706488	633296.119000	31373.672000	0	0.0195628	0.0195628
30	634172.912403	31392.592251	634172.713600	31392.460900	-0.0403411	-0.0054934	0.0407134

Auto Adjust — Transformation: 1st Order Polynomial (Affine)

Degrees Minutes Seconds — Forward Residual Unit : Unknown

Figure 20 RMSE Results of Georeferencing

The total RMSE of the 30 points are 4.27 cm, which is less than 8 cm. The results demonstrate that after geo-referencing, the orthophoto had high matching rate with the digital cadastral map. On Figure 21 the quality of georeferencing result are shown.

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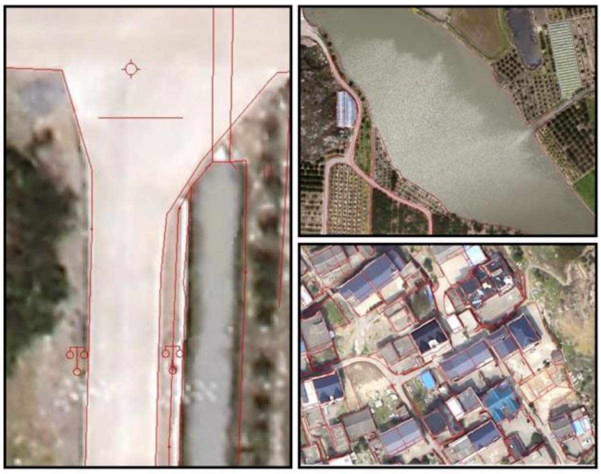


Figure 21 Quality of georeferencing result

The digitizing of three different part in the study area were performed after geo-referencing. The number of digitizing parcels were 23, 18 and 13 for agricultural lands, regularly distributed houses and irregularly distributed houses respectively.

4.3. Evaluation of the UAV Procedure

Three main types of assessment that will be used to evaluate and differentiate the UAV method with the traditional adjudication processes are: (1) Accuracy assessment; (2) Time Evaluation; and (3) Cost Assessment.

4.3.1. Accuracy assessment

The accuracy assessment was conducted after digitizing features. The assessment for accuracy was divided into three parts because the accuracy requirements of residential and agricultural areas are different. Also, parcel boundaries of regularly distributed houses are easier to be distinguished than the irregularly distributed houses.

The digitized parcel point coordinates of these three categories were compared with those obtained from field surveys using RMSE calculation. The reference data are the vector data from cadastral map. On Figure 22 the vector data exported from cadastral map are shown.

Figure 22 Vector data exported from cadastral map

Agricultural lands

The number of agricultural lands used in the analysis was 23, including 66 boundary points. The coordinates resulting from digitizing the orthophoto were exported into Excel. The coordinates of field measured points were also exported into Excel. RMSE was then calculated to assess the accuracy. On Figure 23 the digitizing agricultural lands are shown.

Figure 23 Agricultural lands of study area

RMSE shows what the difference is in distance between the points of test data and the points of digital cadastral data. It also reveals the standard deviation of the unexplained variance.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}}$$

The RMSE of agricultural lands is acceptable according to the accuracy assessment (Table 4). The RMSE (X) was computed to be 0.287m, and the RMSE (Y) was 0.393m. The calculated RMSE was 0.552m. According to the requirement of 1:2000 scale map, 0.552m satisfies the standards for agricultural lands (RMSE<1.0m).

Table 4 **RMSE (m) of agricultural land**

Unit: meter

Point	X(true)	Y(true)	X' (measured)	Y' (measured)	dX	dY	dX^2	dY^2
1	633121. 2090	31642. 8940	633121. 1421	31642. 8978	0. 0669	−0. 0038	0. 0045	0. 0000
2	633160. 4120	31641. 6440	633160. 2741	31641. 8262	0. 1379	−0. 1822	0. 0190	0. 0332
3	633159. 9410	31629. 5460	633159. 6258	31629. 5628	0. 3152	−0. 0168	0. 0994	0. 0003
4	633159. 6240	31622. 1530	633159. 4406	31622. 2999	0. 1834	−0. 1469	0. 0336	0. 0216
5	633159. 1480	31605. 8300	633158. 8419	31605. 6955	0. 3061	0. 1345	0. 0937	0. 0181
6	633159. 2630	31601. 4490	633159. 0182	31601. 1729	0. 2448	0. 2761	0. 0599	0. 0762
7	633158. 4480	31594. 8640	633158. 5807	31594. 7038	−0. 1327	0. 1602	0. 0176	0. 0257
8	633158. 0140	31579. 8530	633157. 6546	31579. 6754	0. 3594	0. 1776	0. 1292	0. 0315
9	633157. 6890	31568. 3820	633157. 5356	31568. 1264	0. 1534	0. 2556	0. 0235	0. 0653
		RMSE (X)	RMSE(Y)	RMSE				
		0. 287	0. 393	0. 552				

Regularly distributed house area

The second part to be assessed was the regularly distributed house areas. There were 18 parcels used in this analysis, including 172 boundary points. These houses were different from the old houses since they have been recently built. The houses are well structured and distributed. Figure 24 shows the digitizing result of regularly distributed houses.

Figure 24 **Regularly distributed houses area**

Table 5 **RMSE (m) of regularly distributed house area**

Unit: meter

Point	X(true)	Y(true)	X' (measured)	Y' (measured)	dX	dY	dX²	dY²
1	634095.1786	31908.2096	634095.4928	31908.2078	-0.3142	0.0018	0.0987	0
2	634099.3849	31908.8883	634099.4219	31909.1206	-0.037	-0.2323	0.0014	0.054
3	634099.6507	31907.3222	634099.7394	31907.4141	-0.0887	-0.0919	0.0079	0.0084
4	634107.3947	31908.6364	634107.3197	31908.7635	0.075	-0.1271	0.0056	0.0162
5	634109.1885	31898.0666	634109.3041	31897.8097	-0.1156	0.2569	0.0134	0.066
6	634104.972	31897.3397	634105.1369	31897.135	-0.1649	0.2047	0.0272	0.0419
7	634104.7655	31898.5457	634104.8591	31898.9209	-0.0936	-0.3752	0.0088	0.1408
8	634097.0596	31897.226	634097.5566	31897.135	-0.497	0.091	0.247	0.0083
		RMSE (X)	RMSE(Y)	RMSE				
		0.619	0.453	0.767				

On Table 5 the RMSE result of regularly distributed house area was shown. The RMSE (X) was 0.619m and the RMSE (Y) was 0.453m. The RMSE was 0.767m which failed to satisfy the accuracy requirement of 0.05m for residential areas.

Irregularly distributed house area

The third part was the irregularly distributed house area. Most of these areas are old houses which are commonly adjoining. Hence, it is difficult to distinguish parcel boundary of close houses in the orthophoto. There are 13 parcels, including 75 boundary points. On Figure 25 the digitizing result of irregular house area is shown.

On Table 6 the RMSE result of irregularly distributed house area is shown. The RMSE (X) was 0.488m and the RMSE (Y) was 0.624m. The RMSE was 0.792m in this process, which failed to satisfy the accuracy requirement of 0.05 for residential areas.

Figure 25 Irregularly distributed house area

Table 6 RMSE (m) of irregularly distributed house area

Unit: meter

Point	X(true)	Y(true)	X' (measured)	Y' (measured)	dX	dY	dX^2	dY^2
1	633965.3036	31777.4497	633965.5739	31777.593	-0.2703	-0.1433	0.0731	0.0205
2	633982.5909	31786.0814	633982.3221	31785.8083	0.2688	0.2731	0.0723	0.0746
3	633987.0953	31777.4725	633986.8861	31777.7121	0.2092	-0.2396	0.0438	0.0574
4	633969.6564	31769.0031	633969.7411	31769.2189	-0.0847	-0.2158	0.0072	0.0466
5	633965.3036	31777.4497	633965.5739	31777.593	-0.2703	-0.1433	0.0731	0.0205
6	633983.6259	31786.5419	633983.6582	31786.6753	-0.0323	-0.1334	0.001	0.0178
7	633994.0313	31791.7735	633993.5801	31791.4378	0.4512	0.3357	0.2036	0.1127
8	633998.2214	31783.4384	633998.0251	31783.7119	0.1963	-0.2735	0.0385	0.0748
.								
		RMSE (X)	RMSE(Y)	RMSE				
		0.488	0.624	0.792				

4.3.2. Time

The traditional way of cadastral surveying is carried out in the field, parcel by parcel. There are two persons in one team, measuring the parcel boundary points. The preparation needed for the traditional method is about one day, which will be used in planning and building the control network. Another 21days are needed to build the control network. Two persons make up the team. It takes 100 days to measure parcel boundary points of 1 km^2 for residential areas takes, while it takes 20 days to measure parcel boundary points of 1 km^2 for agricultural lands. After measuring the boundaries, it takes two days to process the data for 1 km^2.

The preparation of UAV method takes two days, including the investigation of the study area and the design the flight specification. It takes one day to set the GCPs; the average speed of setting GCP is 60 points per day. After capturing the imagery, the technical staff organizes the imagery and checks their relationship with the POS data. They will then delete some imagery that cannot be used before processing the data. The data processing takes about two days.

It takes 124 days to finish the whole parcel survey of 1 km^2 for residential areas. The mean parcel number of 1 km^2 in residential area is 3189, which means the time needed for one parcel is 56 minutes. For agricultural areas, it takes 44 days to finish parcel survey of 1 km^2, the mean parcel number of 1 km^2 in agricultural area is 1062, which means the time needed for one parcel is 60 minutes. The UAV method takes 6 1/12 days to accomplish 60km^2, which means it takes approximately 0.1 day for 1km^2.
For residential areas, the speed is 0.05 minutes per parcel, while it is 0.14 minutes per parcel for agricultural areas. UAV method shows obvious advantages in saving time for the area of 1 km^2 and requires much less time for one parcel than the traditional method

The data were collected by interviewing Director, surveyors, cartographers, UAV pilot in Zhejiang Surveying and Mapping Institution. The UAV method are much more efficient than traditional method. Table 7 mean parcel number of 1 km^2 in residential area Table 8 shows the comparison between traditional method and UAV method for residential area. Table 9 Mean parcel number of 1 km^2 in agricultural area. Table 10 shows the comparison between traditional method and UAV method for agricultural area.

Table 7 Mean parcel number of 1 km² in residential area

Residential Areas		
Area (km^2)	Number of parcel	Number of parcel in $1km^2$
0.0066	20	3030
0.0094	37	3936
0.0069	25	3623
0.0044	18	4091
0.0150	19	1267
		3189

Table 8 Time comparison between Traditional and UAV method of residential areas

Method	Preparation before survey	Build control network	Measure boundary points		Data processing	Total time ($1km^2$)	Number of parcel (1 km^2)	Time per parcel (min)
Field Survey	1 day	6days(outside)+15days(inside)=21days	100 days per km^2 (2 persons in a team)		2 days	1+21+100+2=124 days	3189	55.99
	Preparation before Flight	Set GCPs	Flight time	Orgnize imagery and POS data		Total time ($60km^2$)		
UAV method	2 days	1 day	2 hours	1 day	2 days	2+1+1/12+1+2=6 1/12 days	3189	0.05

Table 9 Mean parcel number of 1 km² in agricultural area

Agricultural Areas		
Area(km²)	Number of parcel	Number of parcel in 1km²
0.0760	51	671
0.0090	14	1556
0.0110	14	1273
0.0120	9	750
		1062

Table 10 Time comparison between Traditional and UAV method of agricultural areas

Method	Preparation before survey	Build control network	Measure boundary points		Data processing	Total time(1km²)	Number of parcel (1 km²)	Time per parcel(min)
Field Survey	1 day	6days(outside)+15days(inside)=21days	20 days per km² (2 persons in a team)		2 days	1+21+20+2=44 days	1062	59.66
UAV method	Preparation before Flight	Set GCPs	Flight time	Orgnize imagery and POS data		Total time(60km²)		
	2 days	1 day	2 hours	1 day	2 days	2+1+1/12+1+2=6 1/12 days	1062	0.14

4.3.3. Cost

Cost is another indicator to assess the feasibility of integrating UAV in rural adjudication procedure. The traditional method is quite different from the UAV method. It takes a long time to do the field survey. It is labor-intensive and it has much more additional cost during the field surveying process.

The cost of traditional method includes daily salary for two persons in a team, house rent, salary, transportation cost, food subsidies and instrument rent. The cost per day was computed to be ¥680. The time needed for one parcel in residential area is 56 minutes. The working hours in a day is 8 hours, which means the measurements of 8 parcels can be done in one day. The cost for one parcel was ¥85. For agricultural area the cost for one parcel was ¥85. These calculated results were based on the area of 1 km^2.

UAV method reduces the cost for daily salary of staff. There are four persons in a team, including team leader, security guard, software operator and UAV operator. The salary was placed at ¥200 per person per day. The gas fee was ¥40 for 1 km^2. Cost of rent UAV was ¥2000 for 1 km^2. The cost per day was ¥3040 for 1 km^2. For residential area, the time needed for one parcel was 0.05 minutes. The flight time was 2 hours, which means 2400 parcels can be done in one day. The cost for one parcel was ¥1.3. For agricultural areas, the cost for one parcel was ¥3.5. Table 11 shows the cost comparison between traditional method and UAV method. Table 12 shows the cost comparison between Traditional method and UAV method of different areas.

The major cost of UAV method is the rent fee of UAV, which is ¥2000 for 1 km^2. The area cannot be smaller than 20 km^2, which means the cost of rent fee is ¥40000 when the area is smaller than 20 km^2. Table 10 shows the cost comparison between traditional method and UAV method based on different areas. Figure 26 shows the cost comparison based on different area.

The data were collected by interviewing Director, surveyors, cartographers, UAV pilot in Zhejiang Surveying and Mapping Institution. The UAV method takes significant advantage over the traditional method.

Table 11 Cost comparison between Traditional method and UAV method

Unit: ¥

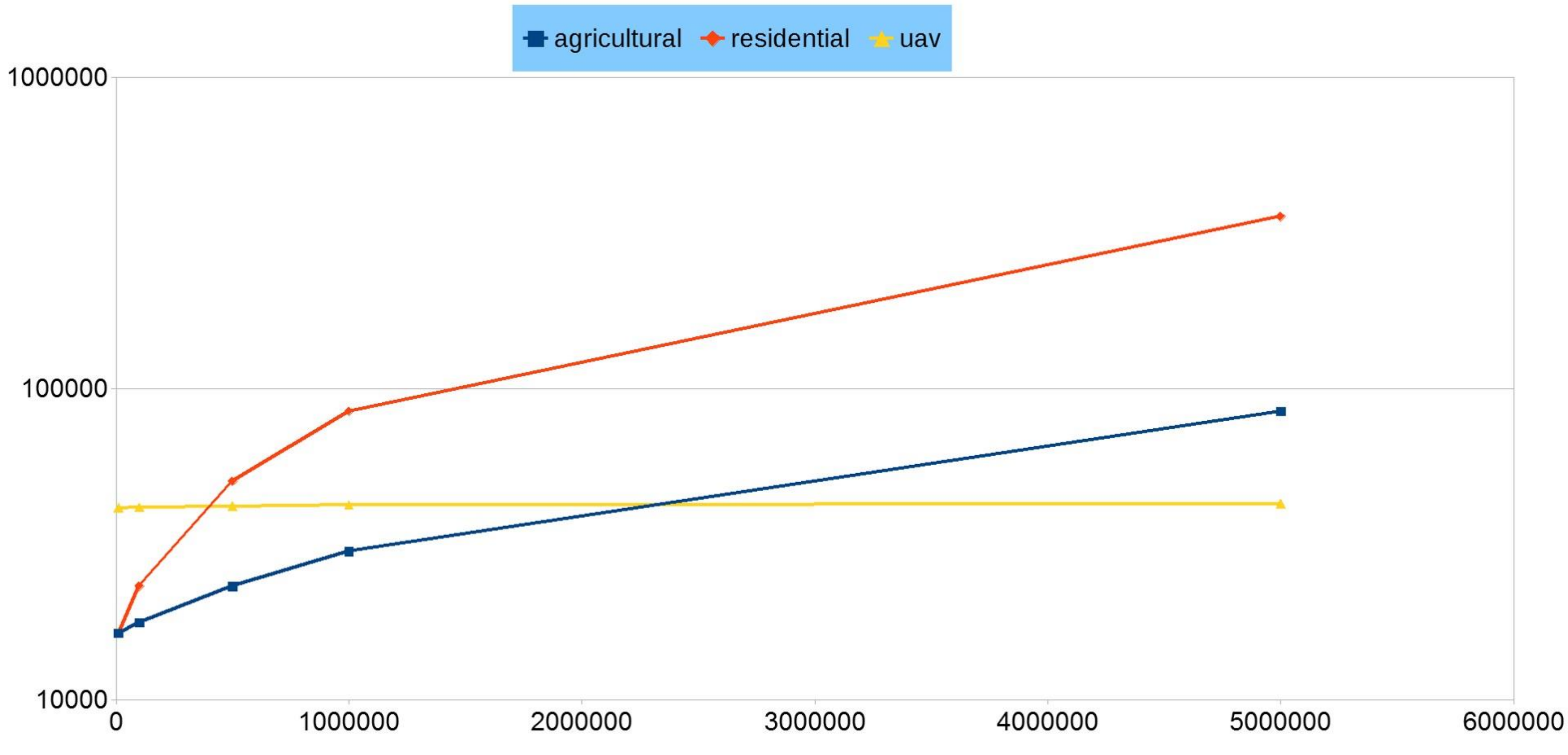
Method	No. of Staff (N)	Cost per Individual per day (S+L+T+F)					Personnel (P=N*C)	Local Hire (H)	Instrument (I)	GAS fee (G)	Cost per day (P+H+I+G)
		Salary (S)	Lodging (L)	Food (F)	Transportation (T)	Total Cost (C)					
Field Survey	2	150	40	40	10	240	480	100	100		680
UAV method	4	200		40	10	250	1000		2000 (1 km²)	40 (1 km²)	3040

Notice: "¥" is unit of RMB, currency is Yuan. The exchange rate is: One euro=7.32 Yuan

Table 8 Cost comparison between Traditional method and UAV method of different areas

	Field survey of agricultural lands		Field survey of residential lands		UAV Method	
Area	Days	Total Cost	Days	Total Cost	Days	Total Cost
10000	24	16320	24	16320	1	41300
100000	26	17680	34	23120	1	41500
500000	34	23120	74	50320	1	41800
1000000	44	29920	124	84320	1	42200
5000000	124	84320	524	356320	1	42600

Unit: ¥



Unit: m²

Figure 26 Cost comparison of different area of different methods

4.4. Chapter Summary

According to the results of this chapter, the feasibility of integrating UAV technology in rural adjudication is assessed by three criteria- accuracy, time and cost.

Accuracy:

The results of testing three different types of area in the study area indicate that only the agricultural area can satisfy the accuracy requirement. The accuracy is accumulated results from different elements, which include imagery quality, the quality of POS data, quality of geo-referencing, quality of digitizing and the structure of features in the orthophoto.

There are some minor feature distortions of houses in the orthophoto, resulting from shadows of the house or the side overlap being not high enough. During geo-referencing, most of the points chosen were (1) well-visible road corner point, (2) corner points of lakes, and (3) corner points of park. The quality of geo-referencing result can be influenced by this manual process of choosing tie-points. The accuracy of digitizing would be affected by the feature distortion of some houses because some parcel corners are not viable. The parcel boundary points of regularly structured houses are easier to be distinguished than the irregular distributed houses, because the irregularly distributed houses had some overlaps between adjacent houses. The parcel boundary points of agricultural lands are clear and visible, which is why the accuracy of agricultural lands are higher than the accuracy of residential areas.

The result (0.552m) of agricultural lands can satisfy the accuracy requirement (1 m) for the 1:2000 scale map. The results of regularly distributed houses (0.767m) and irregularly distributed houses (0.792) do satisfy the accuracy requirement of 0.05m. The procedure was found to be feasible for land use right adjudication for agricultural lands. The result can also be improved by changing the flight specifications: increasing side overlap and lowering the flight height. The accuracy results could have been improved with the use of GCPs. Table 13 shows the accuracy comparison between test data and requirement.

Table 13 Accuracy comparison between test data and requirement

Type	Test accuracy	Accuracy requirement
Agricultural land	0.552m	1.00m
Regularly distributed houses	0.767m	0.05m
Irregularly distribute houses	0.792m	0.05m

Time:

For residential areas, the field survey of traditional method takes 124 days for 1 km², the time needed for one parcel is 56 minutes. For agricultural areas, the field survey of traditional method takes 44 days, the time needed for one parcel is 60 minutes. The UAV method takes 0.1 day for 1 km². The time needed for one parcel is 0.05 minute in residential area and is 0.14 minute in agricultural area. Table 14 shows the time compassion between traditional method and UAV method. The UAV method enhances the efficiency greatly in this process.

Table 14 Time compassion between traditional method and UAV method

	Traditional method			UAV method	
Land Type	Parcel number(per km²)	Time(per km²)	Time(per parcel)	Time(per km²)	Time(per parcel)
Residential	3189	124 days	56 mins	0.1 day	0.05 min
Agricultural	1062	44 days	60 mins	0.1 day	0.14 min

Cost:
For residential areas, the cost of traditional method is approximated at ¥84320 for 1 km², and the cost for one parcel is calculated to average ¥85. The cost of UAV method is ¥42200 for 1km² and ¥1.3 parcel. The overall cost of UAV method is higher than traditional method when the area is smaller than 0.38 km². When the area is larger than 0.38 km², the cost of UAV method is less than the traditional method.

For agricultural areas, the cost of traditional method is ¥29920 for 1 km² and the cost for one parcel is ¥85. The cost of UAV method is ¥42200 for 1 km² and the cost for one parcel is ¥3.5. The overall cost of UAV method is higher than traditional method when the area is smaller than 1.9 km², otherwise, the cost is less.

Therefore. For residential areas, the traditional method takes advantage when the survey area is smaller than 0.38 km². For agricultural area, the area is 1.9 km². This means surveying areas larger than 1.9 km², UAV is more cost-efficient than traditional method. The UAV method is more beneficial for surveying large areas in rural areas, as long as the accuracy requirement can be achieved. Table 15 shows the cost comparison between traditional method and UAV method.

Table 15 Cost comparison between traditional method and UAV method.

	Traditional method			UAV method	
Land Type	Parcel number(per km²)	Cost(per km²)	Cost(per parcel)	Cost(per km²)	Cost(per parcel)
Residential	3189	¥84320	¥85	¥42200	¥1.3
Agricultural	1062	¥29920	¥85	¥42200	¥3.5

5. CONCLUSION AND RECOMMENDATIONS

This research aims to assess the feasibility of integrating UAV technology in cadastral surveying and mapping process to improve the rural adjudication procedure in China. This chapter will come to the conclusion and recommendations for the further research.

There are 7 research questions in this thesis.

Research question 1: What are the procedures, regulations, and policies of current adjudication procedure in rural area of China?

As introduced in chapter four, the conventional adjudication procedure is: Preparation, cadastral surveying and mapping, land right investigation, data compilation and verification. The relevant regulations and policies are as follow:

- Land Administration Law of the People's Republic of China (2004 Amendment)
- Measures for Land Registration
- Cadastral Survey Regulations for Cities and Towns
- Investigation Code of Practice for the Right to Rural Land Contractual Management
- Regulations for Land Right Adjudication
- Specifications for surveying and mapping 1:500, 1:1000, 1:2000 digital topographic maps
- Technical Regulations of Digital Cadastre of Zhejiang Province
- The No. 1 Document from the National Central Government of 2013

Research question 2: What are the advantages and disadvantages of the current procedure in China?

The advantage of the current procedure is that the method has been used by the surveying department for a long time. The regulations and rules are completely operational. The traditional adjudication procedure has greater acceptance in rural area and the instruments used are considering when proposing the accuracy requirement for surveys. The disadvantage of the current procedure is time consuming, labor-intensive and costly. The results can be affected by several factors: topography and participations.

Research question 3: How suitable is the usage of UAV technology for adjudication procedure in rural areas of China?

The UAV technology has been applied to produce Digital Line Graphic (DLG) and has the potential to be applied in more fields of land administration. It is suitable to integrate UAV technology with the adjudication procedure in rural areas of China.

Research question 4: What would be the new adjudication procedure that would integrate UAV technology?

As explained in chapter four, the UAV technology would be integrated in surveying and mapping procedure to improve the efficiency, to reduce the costs, and to save labor. Images would be taken by the UAV which would then be calibrated and used to measure and map the area for adjudication.

Research question 5: What are the criteria to assess the adjudication procedure and what are the obtained results?

Accuracy, time, and cost are the criteria to assess the adjudication procedure. The obtained results are shown table and figures in chapter four. For agricultural lands in rural area, the accuracy result (0.552m) can satisfy the accuracy requirement (1m). The accuracy result of residential lands in rural area cannot satisfy the accuracy requirement. The UAV method takes obvious advantages than the traditional method in saving time and reduce cost for the both types of land in rural areas.

Research question 6: What are the advantages and disadvantages while applying the new procedure compared to the conventional adjudication procedure?

The new procedure shows great potential by reducing time and costs. The disadvantage, however, is that the accuracy is highly influenced by several factors. For example, topography, weather and structure of the houses affect the accuracy of measurements. The overall accuracy was lower compared to the current adjudication procedure for residential areas.

Research question 7: What are the recommendations for future development?

The purpose of this research was to assess the feasibility of integrating UAV technology in cadastral surveying and mapping procedure to improve the rural adjudication procedure in China. The results reveal good potentials for UAV usage in adjudication, specifically for the use right of agricultural lands (Right to Rural Land Contractual Management) of larger areas. The new procedure has been shown to save time, minimize require manpower and reduce costs, while still being able to achieve required accuracy for agricultural lands.

The research has some limitations that can influence the quality of the results. The flight specifications were not specifically designed for purpose of rural adjudication, which can affect the quality of orthophoto production. The non-availability of GCPs will influence the quality of orthophoto production and the result of geo-referencing. The accuracy of digitizing can be affected by the minor house distortion. These limitations can be solved with the specifically designed flight specification and complete data.

Given the current state of UAV usage in different fields, the technology is poised to become more stable thus improving accuracy, and even lower costs in the future as UAV becomes more common.

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Appendix A:

权属核(调)查表
(Land Ownership Investigation Form)

地籍子区外码 地籍子区名称: 表格编号:
(Code of cadastral sub district) (Name of cadastral sub district) (Number of form)
类型: 已登记□ 未登记□ 调查地图号: 土地证编号:
(Type: Registered Unregistered) (Number of base map) (Number of land certificate)

内容 (Content)		登记情况 (Status of Registration)	核查情况 (Status of Investigation)	备注 (Remarks)
土地权利人 (Land Obligee)				
法定代表人 (Legal Person)				
土地坐落 (Land Location)				
地籍号 (Cadastral Number)				
权属性质 (Land Right Type)				
使用权类型 (Land Use Right Type)				
土地用途 (Land Utility)	批准用途 (Approved Utility)			
	实际用途 (Actual Utility)			
使用期限 (Utility Period)				
土地面积 (Land Area)				
其中 (Include)	独自使用 (Exclusive Use)			
	共用分摊 (Shared Use)			
建筑占地面积 (Construction Area)				

建筑面积 (Building Area)				
登记日期 (Registration Date)				
他项权利 (Other Right)				
四至 (Boundary Neighbors)	东至 (East)			
	南至 (South)			
	西至 (West)			
	北至 (North)			
其他需要说明情况 (Other Introductions)				
调查员意见 (Opinion of Investigator)				
审核意见 (Audit Opinion)				
备注 (Remarks)				

Appendix B:

Questionnaires and Interviews

Topic: ASSESSING FEASIBILITY OF INTEGRATING UAV TECHNOLOGY IN RURAL ADJUDICATION IN CHINA

These interview questions are meant provide data to answer the research objective of assessing feasibility of integrating UAV technology in rural adjudication in China. Answers will be treated confidential and be used for academic purpose only.

Interview Director of Land administration

1. How are the land rights determined? What are the advantages and what are the disadvantages?

Land staff will bring the topographic map to the land owners to investigate their land attribute information. Then they will check the relevant information and fill in the cadastral form. If agreements achieved, then land owners will sign their names and put their fingerprints on the form. Land staff bring the data to the department and compile the data and validate the information.

The main advantage of the process is result is accurate, accuracy is high. Land owners are certain and feel secure about their land rights.

The main disadvantage is the process is complicated, time and labor consuming.

2. What are the main processes of surveying and mapping used nowadays in the traditional approach? What are the advantages and what are the disadvantages?

At first, surveyors will go to the study area to get an overview information before setting control network. After setting the control network, their will use Total Station and GPS_RTK to measure boundary points of land. Finally a topographic map will be produced.

The main advantages of the process are the accuracy is high and the technology is not complicated.
The main disadvantages of the process are time consuming and labor intensive.

3. How do you compile the data?

Land officer will build a data base to store the collected information. The name is digital cadastre. They put the attribute information in the relevant land using Auto CAD. After that, it will be very easy to check the land and the related land owners' information.

4. How do you validate the output?

After finishing all the surveying, investigation and compile process. There will be an output. The department will show the results to the land owners. If land owners have different opinions or they made some mistakes, they could claim with certain proofs. When everyone agree with the output, it is validated.

5. What are the relevant regulations, land polices and laws for rural adjudication?

- The relevant regulations, polices and laws of current adjudication procedure are as follow:

- Land Administration Law of the People's Republic of China (2004 Amendment)
- Measures for Land Registration
- Cadastral Survey Regulations for Cities and Towns
- Execute Solution of Second National Land Survey
- Investigation Code of Practice for the Right to Rural Land Contractual Management
- Measures for Land Registration of Zhejiang Province
- Overall Guide of Second National Land Survey
- Regulations for Land Right Adjudication
- Regulations on Land Survey
- Rural Land Contractual Law of the People's Republic of China
- Specifications for surveying and mapping 1:500, 1:1000, 1:2000 digital topographic maps
- Technical Regulations of Digital Cadastre of Zhejiang Province
- The No. 1 Document from the National Central Government of 2013

6. What are the technologies for rural adjudication?

Surveyors use Total Station and GPS_RTK to do the measurements. They use the AutoCAD to compile the data.

7. Are you aware of using UAV technology in land administration? If so, in which projects or applications have UAVs been employed?
[√] "Yes" [ ] "No

Their department used UAV to produce DLG (Digital Line Graphic). It is a vector dataset, which contain the spatial relationship information and related attribute information of different elements. It is one of the 4D product. It was the first our department tried to use UAV to this project this year.

8. Have UAV technology been used for adjudication purpose? If so, what kind of area? If not, have UAV technology been used in some other areas, which would be a good example to follow?
[ ] "Yes" [√] "No

As mentioned before, our department used UAV to produce DLG (Digital Line Graphic). It is a vector dataset, which contain the spatial relationship information and related attribute information of different elements. It is one of the 4D product. It was the first our department tried to use UAV to this project this year. During the process, we also produced orthophoto, but the accuracy is not high enough, but it might be an good example to follow.

9. What is the level of accuracy used in the cadastral survey?

The rural adjudication are divided into two types based on different purpose of use. One is adjudication for curtilage, in other words, the residential area. The other is adjudication for agricultural land. According to the regulations in China. The requirement of accuracy for this two parts are different even though they are all rural lands.

The accuracy requirement of residential area is 5cm (level one), 7.5cm (level two). The accuracy requirement is the same for all the acceptable scale, which includes 1:500, 1:1000, and 1:2000. But the accuracy requirement of agricultural land is different. The requirement is as follow.

Unit: meter

Scale	RMSE	
	Plain, Hill	Mountains
1:500	±0.25	±0.37
1:1000	±0.50	±0.75
1:2000	±1.00	±1.50
1:5000	±2.00	±3.00

The common use scale for agricultural land is 1:2000 according to the regulation established in 2014.

Interview Project Manager of Xiangshan County

1. What are the major problems and limitations of the current adjudication procedure in China?

    Firstly, time consuming and labor intensive are the two major problems and limitations. On one hand, the ground work of measurement takes a long time to finish. On the other hand, land investigation also takes a long time and there are some problems here. For instance, some parcel buildings are illegal construction, it is not consistent to the old document. Some parcel sketches are not standardized, the boundary line are not clear enough, which will cause some troubles for work. When we deal with the land owners, if the area of their parcel are smaller then we measured, it will be difficult to confirm the information.

2. In your own experience, how long will it take to complete adjudication procedure for $1km^2$?
   It needs calculation.

3. In your experience, how much pre-survey time (preparation) will be needed for $1km^2$?

   a. 1-2 days; **b. 3-4 days**; c. 5-6 days; d. 7-8days; e. > 8 days

4. In your own approximation, how much money will it take to complete adjudication procedure for $1km^2$?
   It needs calculation.

5. How much would you budget the cost of equipment (GPS_RTK, Total Station) for $1km^2$?

   a. <200 €; b. 200-400€; c. 401-600€; d.601-800€; **e. >800€**
   The average price of Total Station is between 700€ and 1400€

6. How many days would you think you would need to use (or rent) for $1km^2$?

   a. 1-10 days; b. 11-20 days; c. 21-30 days; d. 31-40 days**; e. >40 days**

7. On the average, how much is the rental cost of the instrument per day?

   a. <20 €; b. 21-40€; c. 41-60€; d.61-80€; e. >80€

The instrument belongs to the company, so they don't have to rent. They just use when needed.

8. How much would you budget the cost of labor for $1km^2$?

a. <200 €; b. 200-400€; c. 401-600€; d.601-800€; **e. >800€**

9. How many people would be needed to be employed for 1km²?

    a. **1-3**; b. 4-7; c. 8-11; d. 12-15; e.>15

10. On the average, how much is the salary for the people/staff per day?

    a. >10 €; **b.10--20€**; c. 21-30€; d. 31-40€; e. >40€

11. How much would you budget the miscellaneous for 1km²?

    a. >200 €; b. 200-400€; c. 401-600€; d.601-800€; e. >800€

They don't have budget for miscellaneous.

12. In your approximation, how much pre-survey time (preparation) will be needed for 1km²using the UAV technology?

    The staff will go to the study area to get an overview information and preparation for one day. The next day they will make a flight specification. It might takes 2-3 days for the preparation.

Interview Land Staff

1. Are you aware of UAV use in land administration or surveying applications?

   a. **Yes** b. No

This year they started to use UAV technology in producing DLG.

2. From your personal view, what do you think are the limitations of utilizing UAVs in land adjudication? List all you think apply.

   First, the accuracy requirement may not satisfy. Second, the weather dependency will also be a limitation. The topographic effect.

3. From your experience, how much fieldwork time (cadastral surveying and mapping) will be needed for 1km²?

   a. 1-10 days; b. 11-20 days; c. 21-30 days; d. 31-40 days; e. >40 days

4. From your experience, how much processing time (data compilation and verification) will be needed for 1km²?

   a. 1-3 days; b. 4-6 days; c. 7-9 days; d. 9-12 days; **e. >12days**

5. How long will be the preparation time (preparation)for 1km²?

   a. 1-2 days; **b. 3-4 days**; c. 5-6 days; d. 7-8days; e. > 8 days

6. In your approximation, how much time will you need to undertake UAV survey 1km²?
   a. 1-2 days; b. 3-4 days; c. 5-6 days; d. 7-8days; e. > 8 days

7. In your approximation, how much time will you need to finish the ground control point survey for 1km²?

   a. **1-2 days;** b. 3-4 days; c. 5-6 days; d. 7-8days; e. > 8 days

50-60 points per day.

8. The UAV method offers more flexibility than the traditional method. (Read the statement and select where you think you agree more)

   a. Strongly agree; **b. Agree**; c. Undecided; d. Disagree; e. Strongly disagree

9. The UAV method provides faster means of updating information that the

traditional method.

a. Strongly agree; **b. Agree**; c. Undecided; d. Disagree; e. Strongly disagree

10. Based from your experience with the UAV in adjudication process, what can you say in relation to updating new information to the system?

Actually, they haven't use UAV technology in adjudication process. But regarding updating new information, UAV technology obviously can provides faster means. It is easy to execute mission.

11. The weather dependency of the UAV makes it unappealing for surveying applications.

a. **Strongly agree;** b. Agree; c. Undecided; d. Disagree; e. Strongly disagree

12. Based from your experience with the UAV in adjudication process, what can you say about the effect of weather on the new process?

The weather is a big limitation of using UAV technology. The windy weather will influence the UAV flying attitude, which is an important factor for the accuracy of the product. The visibility will also influence the quality of the images a lot. The rainy day they can't use the UAV. But the traditional method will not be influenced so much by weather

13. Topographic limitations of UAV use makes it unappealing to be used in surveying applications.

a. Strongly agree; b. Agree; **c. Undecided**; d. Disagree; e. Strongly disagree

14. Based from your experience with the UAV in adjudication process, what can you say about the topographic effects on accuracy when using UAV?

It is difficult to perorate. For example. Let us assume the study area is a complicated topographic area, which includes plain, hill and mountains. The flight height will be higher because of mountains and this will influence the resolution. But when we do the measurement in the mountain area, it is very difficult to use Total Station.

15. Security and other ethical issues make the use of UAV unappealing to be used in surveying applications.

a. Strongly agree; **b. Agree**; c. Undecided; d. Disagree; e. Strongly disagree

16. Based from your experience with the UAV in adjudication process, what can you say in relation to security and other ethical issues?

At first, the flight route should be away from the military area, which is the most important thing. They don't consider the privacy because it will not be a problem based on the real situation. But the security should be taken into consideration. The UAV might lost control in some cases, people in study will also be curious or scared by it. People should be informed the purpose of using the UAV in their living area in case the drop of UAV may damage their property or their personal security.

17. The need for personnel training make the use of UAV unappealing to be used in surveying applications.

a. Strongly agree; **b. Agree**; c. Undecided; d. Disagree; e. Strongly disagree

18. Based on your experience with the UAV in adjudication process, what can you say regarding the needs for personal training for using the UAV technology?

The training of a UAV team will take around 1months. The UAV team includes four people, a team leader, a security guard, a software operator and a UAV maintainer. When they buy the UAV form the UAV Company. The company will provide the lessons for training the UAV group. To use UAV skillfully is not easy compare to use Total Station because it only takes two or three days to train a staff to use Total Station skillfully with the guide of another skillful staff.