Final Report

< 2120-0011 > < AI Based neighborhood application- Change Detection using Satellite Images for Retail Planning >

Submitted by

<Cui Xinbo>, < A0232372M >
< Cui Jing >, < A0232390M >
< Liu Xiaoshi >, < A0232365J >
< Zhu Ying >, < A0232352R >

Supervised by

<Asst Prof Feng Ling>
<Department of Physics> <Faculty of Science>

Project Sponsor

< Procter & Gamble International Operations SA Singapore Branch >

Submitted on

<10th June, 2022>

Contents

1. Introduction 1
1.1 Project Scope 1
1.2 Company Overview 1
2. Project Formulation 2
2.1 Analysis 2
2.1.1 Preliminary Formulation of Project 2
2.1.2 Technical Feasibility 3
2.1.3 Market Research 5
2.2 Literature Review 5
2.3 Industry and Company Review 9
2.3.1 Industry Review 9
2.3.2 Company Review 10
3. Project Execution and Outcome 10
3.1 Project Management 10
3.1.1 Project Process 10
3.1.2 Data Gathering 12
3.1.3 Data Pre-processing 16
3.1.4. Classification System Development 17
3.1.5 Methodology 19
3.2 Project Analysis 27
3.2.1 Image Enhancement 27
3.2.2 Image Labelling 29
3.2.3 Image Cropping 33
3.2.4 Unsupervised Method 34
3.2.5 Unet++ 38
3.3 Recommendation 43
3.3.1 Technical Recommendations 43
3.3.2 Business Recommendations 45
4. Reference 52

1. Introduction

1.1 Project Scope

Urban growth estimation is a critical component of retail activity planning. In rapidly growing cities, there are rapid changes in land use due to urbanization. And this trend brings many opportunities for physical retail activity, i.e., setting up of supermarkets to better serve the changing needs of the consumers. However, the development of a city may not be equally distributed. Hence, change detection using remote sensing (satellite photos) allows for timely tracking of urbanization and affluence of population with varying growth rates within the city. This information can then be used to predict future growth rate to plan retail activity such as the opening of new stores or introduction of new products.

1.2 Company Overview

Procter & gamble (P&G) was founded in 1837, which is one of the world's largest consumer goods companies. P&G is headquartered in Cincinnati, Ohio, USA, and employs nearly 100,000 people worldwide [1]. With factories and branches in more than 80 countries, products are exported to more than 180 countries and regions, including fabric and home care, hairdressing, beauty, baby and home care, health care, food, and beverage, etc. [2]. Their purpose is to make every day more than ordinary.

P&G was one of the first American corporations to invest in Vietnam following the restoration of diplomatic ties between Vietnam and the United States in 1995, and it has consistently experienced double-digit growth, expanding 12-fold in the previous decade.

P&G has served Vietnamese customers for the past 25 years through a variety of top brands in a wide range of consumer goods categories. In addition to a headquarters in Ho Chi Minh

City, the corporation operates two significant production sites in Binh Duong Province. Vietnam is without a doubt one of P&G's fastest-growing markets in the globe.

P&G's activities in Vietnam have only just begun, yet several excellent outcomes have already been achieved. P&G's investment in Vietnam has tripled during the last two decades, output has surged 40 times, and operations have expanded 12 times. The average growth rate hit two figures 15 years ago. With 14 well-known brands such as Tide, Downy, Ariel, and Pampers, P&G has become one of the major FMCG firms in the Vietnamese industry. With substantial growth, P&G's goods are trusted by over 19 million Vietnamese families. It's distribution network is also expanding countrywide as a result of strategic collaborations with consumers and distributors [3].

2. Project Formulation

Remote sensing image change detection is often used in urban planning, disaster assessment and other fields. In this project, we judge the potential location of a region by detecting the changes of building areas in remote sensing satellite images in different periods., which will be beneficial to the development of the region, or the enterprises interested in the region to make correct business decisions.

2.1 Analysis

2.1.1 Preliminary Formulation of Project

Based on the Sentinel-2 satellite image data collected in Da Nang with a time span of one year, the remote sensing satellite images were cropped and labelled by using the object-oriented scripting language Python, cross-platform computer vision library OpenCV, remote sensing image processing platform ENVI and other tools, and then the changes of images in Da Nang were detected by models such as deep learning model.

The first stage: remote sensing satellite image pre-processing.

- According to the project objectives, the satellite images of Da Nang with low resolution are obtained free of charge from remote sensing satellite related websites, and the satellite images of Da Nang with high resolution are obtained free of charge by using Google Earth system.
- According to the specific situation of the acquired remote sensing satellite images and the research purpose of the project, image enhancement operations such as sharpening and changing RGB brands are carried out.
- The image of the whole area of Da Nang in target area is cropped for the first time.
- According to the purpose of the project and the format of the acquired images, semi-automatic annotation of low-resolution satellite images and manual annotation of high-resolution satellite images are carried out.
- The original high-resolution satellite image and the manually labeled high-resolution satellite image are further cut into a square image with a size of 650×650, and the image format is converted into PNG format.

The second stage: use models to detect changes.

- Using models and aiming at the changes of buildings in industrial buildings and residential buildings, detect the changes of remote sensing satellite images in Da Nang.
- Do classification on the changed area.

2.1.2 Technical Feasibility

We will study and analyze the feasibility of this project from the following aspects.

1) technical aspects

Although the analysis and research of satellite images is a new technology, the technologies of image cropping, marking and change detection required by this project have been applied by many large enterprises, and the selected technical framework is reliable. In the development process, agreement precedes configuration, which is the most important thing

to improve the development efficiency. Lightweight sub-services, rich support for class library components, rapid deployment optimization, ready-to-use out of the box, flexible selection and low requirements for deployment environment are all its advantages.

Moreover, during the development of the project, we can study and practice independently by consulting books, papers and other research and academic materials, consulting corporate and school tutors, and watching teaching videos. In addition, today's network knowledge is very easy to query. In the system development, online query and learning can be realized for technologies that are in doubt, which effectively improves the speed of technology learning, and reduces the interference of useless knowledge, to make active use of it. At the same time, you can also improve your self-study ability during technical discussion and study.

To sum up, the technology and programming language needed for project development are the mainstream at present, and the applied development tools are relatively common, so this project is completely feasible in terms of technology.

2) Environmental and safety issues

This project mainly needs to use a PC with Windows system, so the working environment only needs a small space and has good mobility. And in the development process, large-scale electrical appliances with high risk coefficient will not be used, and they will not go to dangerous areas, so the environment and their own safety will be guaranteed in the development process.

3) Economic cost

Other equipment needed in the development process, such as computers, are already available, and most software environments can support free and open resources from the Internet during the development process, so it doesn't need to spend too much money to ensure the completion of this design.

4) Legal factors

Because the code was written by myself, and the original idea and topic selection of this project were put forward by the development department of Chengdu Guangda Lanbo Trading Co., Ltd., which does not involve the third party and infringement, the project is legal and very safe.

2.1.3 Market Research

Space technology can help non-space companies' grow. Earth Observation imaging data is a particularly useful instrument in a wide range of industrial industries. There has been a tremendous increase in the availability of imaging data from satellites in recent years, which will lead to a significant expansion of the services accessible to various businesses.

Historically, only governments and heavyweight aerospace firms (like Boeing) could handle the space industry. AI applications in space technology may be thought to be much more expensive, but the last decade of innovation has made space more accessible – and data from space is becoming much more relevant for businesses and governments owing to AI.

Nowadays remote sensing satellites are widely used for resource investigation, agricultural yield estimation, weather and sea state forecast, disaster prevention and mitigation, etc. With the continuous improvement of management level in the fields of smart city, ecological environment protection, ocean and land monitoring lights, the demand for high-level satellite data application services for colleges and universities are also increasing. Remote sensing image change detection technology has high Business value and development potential.

2.2 Literature Review

Applications of AI and Satellite Data can be divided into two groups: “one-level” applications and “multi-level” applications. “One-level” application is a method that is applied directly to satellite imagery, while a "multi-level" application is an application that receives data from a

"non-satellite" source when information received from a satellite is a single set of features. Some of the most common one-step satellite data applications are object detection and change detection [4].

Change detection (CD) identifies the difference by processing the same object or phenomenon based on its observation at different times to find useful change information and filter out irrelevant change information as interference factors. Remote sensing image change detection is to utilize remote sensing images and related geospatial data covering the same surface area at different times, combine the corresponding feature characteristics and use image and graphic processing methods to determine and analyze the changes in the location, range, and state of the feature. CD is widely used in urban planning, forest and vegetation change, disaster monitoring, geographic information update, target surveillance and tracking, and state environment monitoring. However, typical methods for CD are visual interpretation and manual outlining, which require a lot of labor and time and are inefficient to handle. Therefore, automated change detection techniques are important to unlock the potential of images and data [5]. Compared to other remote sensing data interpretation techniques, the main feature of change detection is the processing and analysis of multiple remote sensing images covering the same area acquired at different times, resulting in a larger volume of data, greater data heterogeneity and more complex feature conditions.

There are many change detection methods proposed, which can be broadly classified as traditional and AI-based.

Fig.1 [6] shows the general process and classification of change detection. With the development of remote sensing big data and artificial intelligence, deep learning methods are rapidly introduced into the field of remote sensing image change detection. As an effective method for feature mining of high-resolution remote sensing data, deep learning methods provide an effective way for classification, detection, and extraction of the high-

resolution image. Besides, the features extracted by the deep network are robust to noise and can handle homogenous or heterogenous multi-temporal remote sensing image data. The accuracy of traditional change detection methods depends heavily on the disparity map, but the process of generating the disparity map loses a lot of information, resulting in unstable accuracy of the detection results; the end-to-end structure of deep learning networks enables us to obtain change detection results directly from multi-temporal remote sensing images.

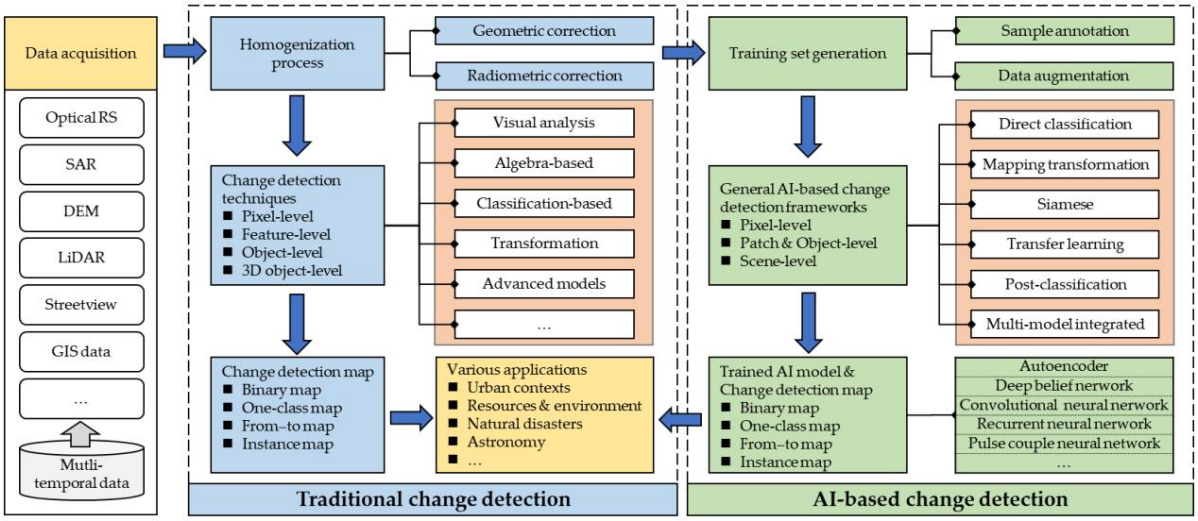


Fig.1 [6] *General process of change detection*

AI-based general change detection frameworks mainly include Autoencoders (AES), Deep Belief Networks (DBNS), CNN, RNN, Pulse Coupled Neural Networks (PCNNS), Siamese, and Generative Adversarial Networks (GANS). The basic process refers to inputting a set of photos (usually two photos, which are called co-registered images) that are of the same size (length x width) and contain the same geographical area taken at different times. The output is an image of the same size, which consists of only two types of pixels: 1 and 0. If the pixel at a position is 1, it means that the pixel at the corresponding position in the co-registered images has changed, and if there is no change, it is 0.

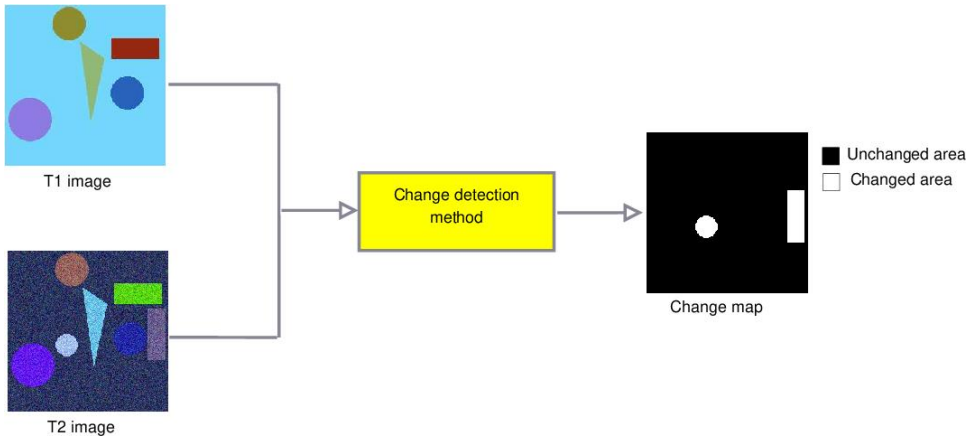


Fig. 2 [7] Change detection process

The key of AI-based change detection is to obtain a high-performance trained AI model based on the satellite image. Implementation process of AI-based change detection can be segmented into 4 steps: homogenization, training set generation, model training, and model serving. Due to differences in lighting and atmospheric conditions, seasons, and sensor attitudes at the time of acquisition, multi-period data usually needs to be homogenized before change detection. This step is very important because when given two periodic data, the comparison between the corresponding positions is meaningful only if they overlap. To develop an AI model, a large, high-quality training set is needed so that it can help the model to understand a specific pattern or set of outcomes that accompany a given problem. There are some existing multispectral, hyperspectral, 3D dataset available for remote sensing change detection that derived from Google Earth, Sentinel-1, Sentinel-2, IKONOS sensors, AVIRIS sensor for various use like land use: land cover, suburban dilation, and disaster detection, etc. To address the issue of insufficient training data, change detection dataset can be used and some data augmentation techniques, such as horizontal or vertical flipping, rotation, scaling, cropping, translation, or adding noise, can also significantly increase the diversity of data available for training a model without having to collect new data. Model training is the same to normal DL process: optimizing the model according to a learning criterion, which can be a loss function in deep learning. By monitoring the training process and testing accuracy, the convergence state of the AI model can be obtained. Change maps

for real-world applications may be created more intelligently and automatically by deploying trained AI models. This also aids in validating the model's generalization capacity and resilience, both of which are critical factors in determining the feasibility of AI-based change detection strategies [6].

2.3 Industry and Company Review

2.3.1 Industry Review

Procter & gamble company is in the fast-moving consumer goods (FMCG) industry. The so called FMCG refers to the high consumption frequency, fast consumption, low unit price, wide demand goods, including shampoo, toothpaste, washing powder, razor, etc. Based on the characteristics of FMCG, there are three important features in terms of sales: convenience, visuality, low loyalty. Because of the low unit price of FMCG, the purchase is usually for convenience, and most people will need it, so it is very important to establish a broad sales network. Therefore, these three sale features lead to the two important competition modes in the FMCG industry: brand marketing and sales channels.

In terms of sales channels, urban growth estimation is a key component of FMCG industry planning sales activities. Timely tracking of urbanization and population affluence within cities at different rates can be used to predict future growth rates to plan sales activities to better understand and meet the growing needs of local consumers.

In recent years, from first-tier cities to second tier and third-tier cities etc., supermarkets, department stores and even street stores are all the important cooperation partner of FMCG companies. Especially small and medium-sized cities, which have been developing rapidly in recent years, are very promising markets. Because of the urbanization, land use changed rapidly. Divide the geography of a fast-growing city into different areas of activity, such as agricultural housing and industry, corresponding to low-growth, medium-growth, and high-growth areas respectively. Based on this information, the FMCG companies can plan sale

activities, such as opening new stores or launch new products, etc., to better serve the customers' changing needs and make it a major engine of company business growth.

2.3.2 Company Review

Procter & Gamble is an American multinational consumer goods company. It specialises in a wide range of personal health, care and hygiene products; it now has over 65 different brands in seven areas such as dishwashing, health care and skin care. According to the research [8], P&G is indeed the leading company in the laundry and care industry, with a high share in almost every sector of the laundry and care industry and is the rightful dominant player in the laundry and care industry. However, compared to 2008, P&G's global market share has declined or remained at the same level for almost all their products over the last decade, meaning that P&G have not made much progress in terms of their own market share, so they may need new technology to make changes.

3. Project Execution and Outcome

3.1 Project Management

3.1.1 Project Process

Based on the actual needs of the project, the entire project process can be divided into eight steps as follows.

Step 1: Data Gathering

At the request of this P&G company, we needed to perform change detection on satellite remote sensing images of Da Nang, Vietnam. The first data we collected was remote sensing images from the Sentinel-2 satellite of Da Nang, Vietnam, which could be collected through python code automated download. However, Sentinel-2 remote sensing images

have a maximum resolution of up to 10m, which is not sufficient for building detection due to the resolution, so they are only used for pre-detection by unsupervised learning methods to identify areas with large changes before more detailed change detection.

Step 2: Data Pre-processing

In the process of data pre-processing, we mainly converted the collected Sentinel-2 satellite remote sensing images of Da Nang into TIF format, and then used ENVI software to sharpen and label the images. As the TIF format contains geographical information, ENVI software can use this information for semi-automatic tagging using algorithms such as SVM, saving a lot of time and effort in manual labelling.

Step 3: Unsupervised Learning Methods Pre-detection

In this step, we use an unsupervised learning method to pre-detect the Da Nang Sentinel 2 remote sensing images completed by the ENVI software processing and can discern areas of Da Nang that are highly variable, after which we will perform a more detailed detection of these highly variable areas.

Step 4: Data Gathering

After detecting areas of high variability in Da Nang using unsupervised learning methods, we collected high-resolution satellite remote sensing images for these areas of high variability. And as high-resolution images in TIF format are expensive, we collected Google Earth high-resolution remote sensing images considering the balance of cost and benefit. These images are well suited for the Unet++ method to detect changes, but as the format is not TIF, more manual labelling may be required in the labelling step for them.

Step 5: Data Pre-processing

As the high-resolution remote sensing images collected by Google Earth are not in TIF format and do not contain geographical information, we need to manually tag them using

ENVI software for building type change detection. Finally the images are cropped to a size of 650*650 to facilitate Unet++ change detection.

Step 6: Unet++ Method Change Detection

After we have cropped the pre-processed high-resolution images, we group them for change detection using the Unet++ method. The results are then brightened to make them more visible.

Step 7: Image Stitching and Multiply

We stitch the detected images back to their original size and then multiply the labelled images with them to determine the type of building change based on the different coloured parts of the overlay.

Step 8: Recommendations

For the final detection, stitching and multiplying of the results, we can clearly distinguish between changes in industrial areas and residential areas. Considering P&G's need to open a shop, a more residential area represents an increase in footfall and is more suitable for opening a shop to bring in more profit. Therefore we will use the business analysis method in conjunction with the test results to make a recommendation for P&G to open a shop.

3.1.2 Data Gathering

- Research Area

The research area is Da Nang, which is in central Vietnam with an area of about 1,285.4 square kilometres. The geographical coordinates are 15°15' N to 16°40' N and 107°17' E to 108°20' E. It has a tropical monsoon climate with an average annual temperature of 25.6 ℃ and an average annual precipitation of 2,044.5 mm. As an important transportation hub in Vietnam, Da Nang focuses on the development of tourism service, high-tech, information

technology, logistics and marine economy industry, and plans to build itself into a high-tech industrial centre for entrepreneurship and innovation in Vietnam and even southeast Asia.

- **Research Data—— Sentinel-2**

The Sentinel satellites are an important part of the Global Environment and Safety Monitoring System (Copernicus project), carried out by the European Union and the European Space Agency. Sentinel 2 is made up of two polar-orbiting satellites, Sentinel-2A and Sentinel-2B. One satellite's revisiting period is 10 days, and the two complementary satellites will be 5 days.

The Satellite carries a multispectral Imager (MSI) that covers 13 spectral bands, ranging from visible and near-infrared to short-wave infrared, with different spatial resolutions of 10m 20m and 60m, respectively, see *Fig. 3*. Sentinel 2 covers all continental land surfaces, including inland waters, from 56° S to 84° N, and is used to monitor changes in land surface conditions, providing information on land vegetation, soil cover and the environment in inland rivers and coastal areas.

Sentinel-2 Bands	Central Wavelength(μm)	Resolution(m)
Band 1 – Coastal aerosol	0.443	60
Band 2 – Blue	0.490	10
Band 3 – Green	0.560	10
Band 4 – Red	0.665	10
Band 5 – Vegetation Red Edge	0.705	20
Band 6 – Vegetation Red Edge	0.740	20
Band 7 – Vegetation Red Edge	0.783	20
Band 8 – NIR	0.842	10
Band 8A – Vegetation Red Edge	0.865	20
Band 9 – Water vapour	0.945	60
Band 10 – SWIR - Cirrus	1.375	60
Band 11 – SWIR	1.610	20
Band 12 – SWIR	2.190	20

Fig. 3 Sentinel-2 spatial information

Image acquisition dates are selected from May to October each year, to reduce the effect of phenology on image spectrum identification. In the selection of cloud cover, as it is difficult to obtain completely cloud-free images, better quality data with less cloud cover are selected.

Data can be downloaded from *https://scihub.copernicus.eu/dhus/#/home*. In this experiment, L1C images on April 3,2018, and July 11,2020, are selected for the study, as shown in *Fig. 4*.

Fig. 4 Sentinel-2 images in Danang on April 3, 2018, and July 11, 2020

- **Research Data—— Google Earth**

Since this study mainly focuses on changes in residential areas and industrial areas, sentinel-2 images are still medium-resolution remote sensing images, although their resolution is improved compared with other satellites. Therefore, the study considers adding high-resolution images for experiments. The data set used in this study was obtained from Google Earth for base period (2018) and terminal period (2021) images of Da Nang coastal area with annual variation. It has 462 image sets with image size of 650×650 pixels and spatial resolution of 50 to 100 cm/pixel. Compared with sentinel satellite images, it can provide more ground object details. Part of the data set is shown in *Fig. 5*.

Fig. 5 Google Earth images in Danang (Top left geographical location: 16°02‘30.12’’N 108°14‘51.32’’E)

- **Research Data—— LEVIR-CD Dataset**

At present, the sample data that can be used for change detection training is relatively scarce, which also brings great difficulties to the training of change detection model. The quality of sample data and the basis of change judgment have great influence on the final output result of the model. LEVIR-CD is a large new scale remote sensing building change detection data set. In the model construction phase of this project, the LEVIR-CD dataset is used as the basic dataset to train the model. This data set will become a new benchmark for evaluating change detection algorithms, especially those based on deep learning.

The LEVIR-CD dataset covers various types of buildings such as villas, residences, high-rise apartments, small garages and large warehouses. These dual-time images, ranging from 5 to 14 years, show significant changes in land use, especially the growth of construction land. The data set focuses on changes related to building, including the growth of building (change from soil/grass/hardened ground or buildings under construction to new construction areas) and decline of building. Remote sensing image interpreters label these bi-temporal images with binary labels (1 for change,0 for constant). Each example in the dataset is annotated by one annotator, and then reviewed repeatedly by another to produce high-quality annotations. The fully annotated LEVIR-CD contains a total of 31,333 individual change-build instances.

3.1.3 Data Pre-processing

The European Space Agency (ESA) has released the Sentinel 2 L1C, L2A product to use. The LIC product are ortho-projective images that have been geometrically corrected without radiometric calibration and atmospheric correction. The L2A product are bottom-to-atmosphere corrected reflectance data with radiometric calibration and atmospheric correction. But the L2A data needs to be produced by users according to their own requirements through Sen2cor, a plug-in released by ESA to produce L2A data.

- **Radiometric Calibration**

In the sensor receiving system of remote sensing satellite, the electromagnetic wave signal collected by the sensor needs to be converted into electrical signal by photoelectric conversion system and recorded, which will cause radiation error. Therefore, radiometric calibration is firstly carried out to eliminate errors. The process of converting the original digital quantization value (DN) of the recorded image into radiation brightness value or reflectivity or surface temperature and other physical quantities is radiometric calibration. Different sensors have different radiometric calibration parameters.

- **Atmospheric Correction**

The main purpose of atmospheric correction is to eliminate the radiation distortion caused by atmospheric factors in the process of ground object information transmission. With the development of computer technology and radiation propagation theory, atmospheric correction using radiative transfer equation has become more and more popular. It is not only high precision, but also fast processing speed.

Sen2cor software are used to calibrate the radiation and the atmospheric correction of image. Then, we converted the data to the Geotif format for easy subsequent processing. Later, cut the image to obtain the data of the study area. The L2A image after pre-processing is shown in *Fig. 6*.

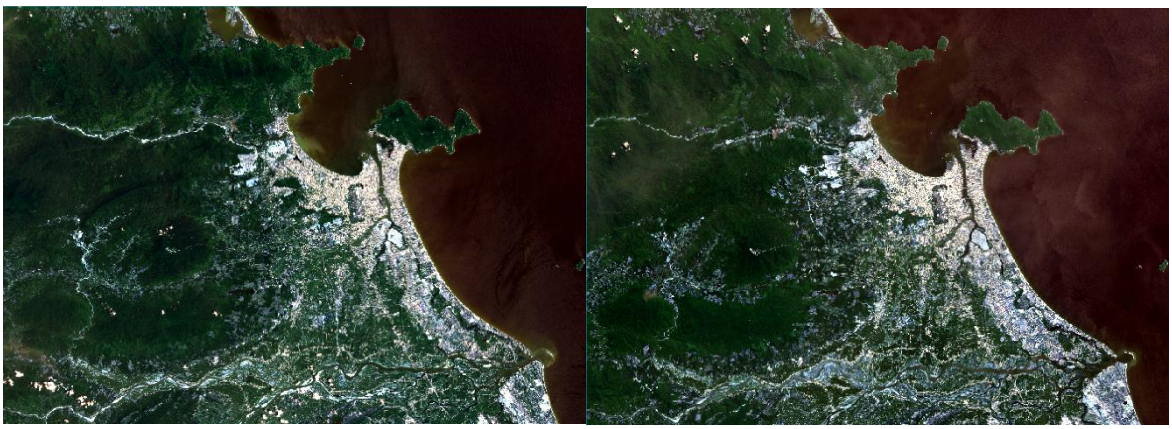


Fig. 6 Sentinel-2 images after pre-processing in Danang

3.1.4. Classification System Development

As the goal of this project is to detect which areas in Da Nang become industrial buildings and residential buildings with the change of time, this project divides the study area into industrial buildings, residential buildings, and other area, which are three categories. As shown in *Table 1.*

Table 1. Classification system developed

Serial Number	Classification Name	Sample Image
1	Industrial building	
2	Residential building	
3	Other area: Forest	
4	Other area: Water	
5	Other area: Bare land	
6	Other area: Road	

3.1.5 Methodology

Support Vector Machine (SVM)

As shown in *Fig.7, t*he full name of SVM is Support Vector Machine, that is mainly used to solve the problem of data classification in the field of pattern recognition and belongs to a kind of supervised learning algorithm. SVM is a kind of generalized linear classifier that classifies data by supervised learning. Its decision boundary is the maximum-margin hyperplane for learning samples. SVM uses hinge loss function to calculate empirical risk and adds regularization term to the solution system to optimize structural risk. SVM is a sparse and robust classifier. SVM can perform nonlinear classification by kernel method, which is one of the common kernel learning methods.

Inputs:Determine the various training and test data.
Outputs:Determine the calculated accuracy.
Select the optimal value of cost and gamma for SVM.
while (stopping condition is not met) **do**
    Implement SVM train step for each data point.
    Implement SVM classify for testing data points.
end while
Return *accuracy*

Fig. 7 SVM algorithm

Principal Component Analysis (PCA)

As shown in *Fig.8,* Principal Component Analysis (PCA) is a statistical dimensionality reduction method that transforms an original random vector with correlated components into a new random vector with uncorrelated components using an orthogonal transformation, which is expressed algebraically by transforming the original random vector's covariance array into a diagonal array and geometrically by transforming the original coordinate system into a new orthogonal coordinate system.

1: Find the dot product matrix $X^T X = \sum_{i=1}^{N} (X_i - \mu)^T (X_i - \mu)$

2: Find the eigenvalues of $X^T X = XV\Lambda^T$

3: Find the eigenvectors $U = XV\Lambda^{-1/2}$

4: Find d number of principal components $U_d = [u_1, u_2, .. u_d]$

5: Compute $Y = U_d^T X$

6: Find the covariance matrix of Y as $YY^T = U^T XX^T U = \Lambda$

7: Find $W = U\Lambda^{-1/2}$

Fig. 8 PCA algorithm

K-means

K-Means clustering is a technique for categorizing or grouping objects into K groups based on their attributes/features, where K is a positive integer. As seen in *Fig. 9*, grouping is accomplished by minimizing the sum of squares of the distances between the data and the respective cluster centroids.

Since the K-Means algorithm values operate on a given complete data set without any special training data, K-Means is an unsupervised machine learning method. the most common implementation of the K-Means algorithm is the Lloyd's algorithm using an iterative refinement heuristic.

Given several divisions k, an initial division is created by randomly selecting k objects from the dataset, each of which initially represents a Cluster Centroid. For the other objects, their distance from each Cluster Centroid is calculated and they are assigned to the cluster with the closest distance.

An iterative relocation technique is used to try to improve the division by moving objects between divisions. By relocation technique, the cluster average is recalculated when a new object joins a cluster or when an existing object leaves a cluster, and the objects are then reallocated. This process is repeated until the objects in each cluster no longer change.

1: Randomly select the number of clusters k and their centers c_i

2: **for** $i \le i_{final}$ **do**

3: Calculate the distance between the data point and the clusters centers c_i.

4: Assign every data sample to its closest cluster.

5: Calculate the clusters centers c_i again.

6: **end for**

Fig. 9 K-means algorithm

Unsupervised Method

We will provide an unsupervised method for detecting changes [9]. It entails the automated analysis of a difference picture created from several temporal photographs. A difference picture is created by subtracting the two images pixel by pixel. Principal Component Analysis will then be used to extract Eigen vectors of pixel blocks from the difference picture. PCA is used to extract the feature vector of a block of pixels from the disparity image. In the detection of unlabelled images, the detection of PCA-treated images is more visible. By projecting the neighbourhood of a pixel onto a feature vector, which can be clustered by the K-means algorithm, we can obtain two clusters - one representing pixels belonging to the change class and another representing pixels belonging to the invariant class, resulting in a change map. The main steps can be divided into three steps.

- **Difference Image Generation and Eigen Vector Space (EVS)**

A non-overlapping 5 × 5 block is extracted from the difference picture and flattened into a row vector. Both sizes of the picture may be changed such that they are multiples of 5. A vector set is formed by the set of these row vectors.

- **Building the Feature Vector Space (FVS)**

It involves pulling 5 × 5 blocks from the other image, flattening them, and then projecting them onto the EVS, with the exception that the blocks will overlap this time. Note that, according to this logic, pixels with four boundary rows and four boundary columns will not get feature vectors because they lack a 5 × 5 neighborhood.

- **Clustering of the Feature Vector Space and Change Map**

The feature vectors for the pixels provide information on whether the pixels have altered or unchanged properties. We now need to cluster the feature vector space such that the pixels may be divided into two distinct classes. The K-means method is used to do this. As a result, each pixel will be allocated to a cluster with the shortest distance between the cluster's mean vector and the pixel's feature vector. Each pixel is assigned a label ranging from 1 to K, indicating the cluster number to which it belongs. Because the backdrop in satellite photos stays relatively constant and the changes that occur are very little, it may be hypothesized that the cluster with the fewest pixels is the cluster representing the altered class. This cluster's mean will also be the highest. Since the values of difference image pixels in an area where some changes have occurred are larger than the values of pixels in regions where no changes have occurred, the largest mean value for that cluster is. As a consequence, the cluster with the fewest pixels and the highest mean belongs to the modified class. Using this information, we will now generate a change map - a binary image depicting the result of change detection.

Unet++

- **Unet Architecture**

The main contribution of Unet is in the U-shaped structure (*Fig.10* [10]), which allows it to use fewer training images while the ensure the accuracy of segmentation through a series of nested, dense jump paths. It builds on FCN architecture that allows a smaller training dataset and its training time is shorter with higher accuracy [11]. Besides, the output of Unet is in the same resolution as the input, which indicates that the masks are as precise as our Very High Resolution (VHR) satellite images.

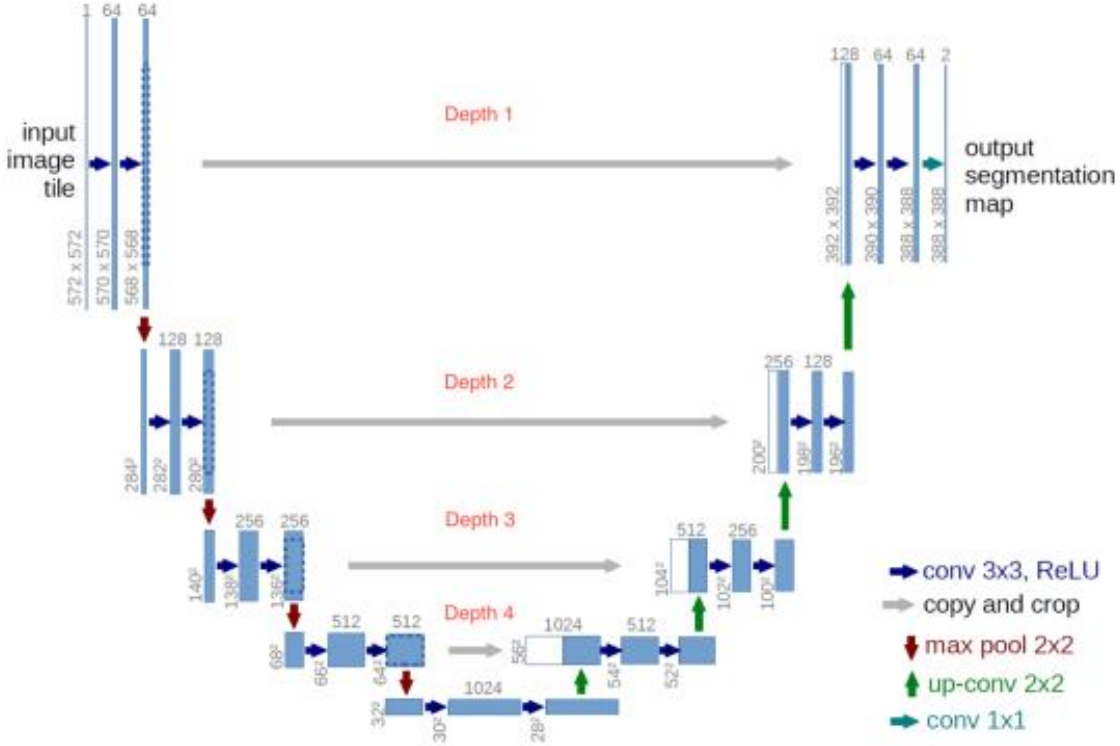


Fig.10 [11] Unet structure

- **Unet++ Architecture**

We use Unet++ (Nested Unet) structure to process CD[12]. Unet++ is an improved structure based on Unet, which was developed initially for medical image segmentation and was capable of semantic segmentation on a small dataset [11].

As shown in *Fig.11*, in Unet++, the redesigned jump paths make it easier to optimize semantically similar feature mappings. The dense jump connections increase segmentation accuracy and improve gradient flow. Deep supervision allows model complexity tuning to balance speed and performance optimization.

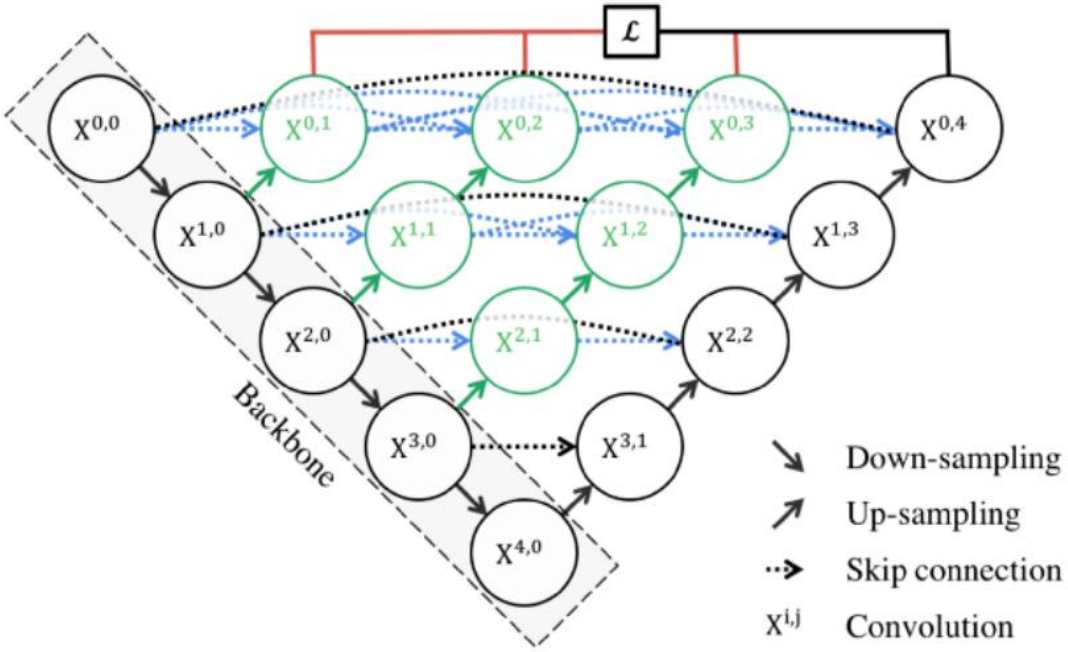


Fig. 11 [11] Unet++ structure

(1) **Redesigned Jump Paths**

In Unet++, a redesigned jump path (shown in green) has been added to compensate for the semantic differences between the encoder and decoder sub-paths. The purpose of these convolutional layers is to reduce the semantic gap between the feature mappings of the encoder and decoder sub-networks. However, U-Net uses jump connections to directly connect feature mappings between encoders and decoders, leading to the fusion of semantically dissimilar feature mappings. In Unet++, the output of the previous convolutional layer of the same dense block is fused with the up sampled output corresponding to the dense block of the lower layer. This makes the semantic level of the encoded features closer to the semantic level of the feature mappings waiting in the decoder, and thus makes optimization easier when semantically similar feature mappings are received. The stack of feature maps represented by $x^{i,j}$ is computed as [11]

$$x^{i,j} = \begin{cases} \mathcal{H}\left(x^{i-1,j}\right), & j = 0 \\ \mathcal{H}\left(\left[\left[x^{i,k}\right]_{k=0}^{j-1}, \mathcal{U}\left(x^{i+1,j-1}\right)\right]\right), & j > 0 \end{cases}$$

(2) **Dense jump connection**

In Unet++, dense jump connections (shown in blue) implement the jump path between the encoder and decoder. These Dense blocks are inspired by DenseNet and aim to increase segmentation accuracy and improve gradient flow.

The dense jump connection ensures that all a priori feature maps are accumulated and pass through the dense convolution blocks on each jump path to reach the current node. This generates a full resolution feature map at multiple semantic levels.

(3) **Deep Supervision**

Deep supervision (shown in red) has been added to Unet++ to adjust the complexity of the model by pruning it to achieve a balance between speed (inference time) and performance. To be specific, Unet++ allows $x^{0,1}$, $x^{0,2}$ and $x^{0,3}$ directly connected to the final output as well.

Training and evaluation of Unet++

In Unet++ architecture, each pair of two periods of images are concatenated as the network's input. Then, to learn multiscale and diverse semantic levels of visual feature representations, the Unet++ model with dense skip connections is used as the backbone. The proposed model is implemented on Google Colab, with “NVIDIA Tesla K80” GPU with a battery life of up to 12 hours. Based on the GPU and battery, we ran the model for 100 epochs.

The following 3 graphs show the evolution of different metrics during the training of Unet++. For the loss function, we use the CrossEntropyLoss from torch.nn, which is commonly used in segmentation tasks in deep learning. CrossEntropyLoss measures the difference between the discovered probability distribution and the predicted distribution. In *Fig 12*, train loss decreases steadily as the training process and it gradually converges, while test loss fluctuates dramatically in the first 50 epochs and then starts to converge.

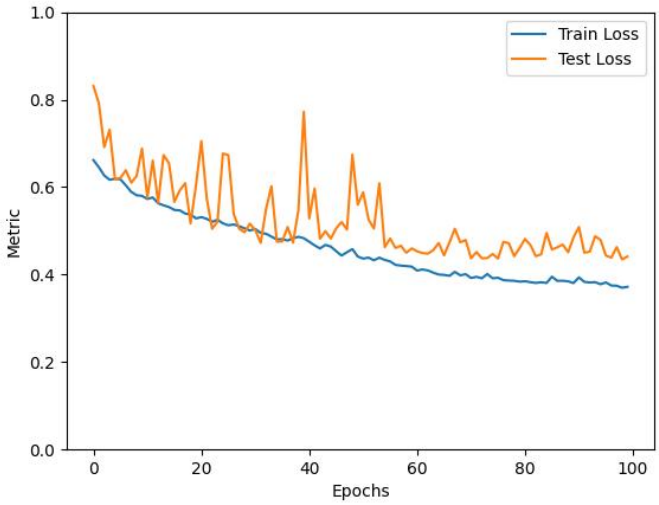


Fig 12. Train Loss and Test Loss

Fig.13 presents AUC of each epoch. AUC refers to Area Under Curve of the Receiver Operating Characteristic. The ROC curve has the advantage of not varying with sample proportion and therefore provides an indication of the model's performance in the presence of unbalanced sample proportions, and the AUC inherits this advantage as the area under the ROC curve. However, we can't plot AUC curve of every epoch, and the ROC AUC refers to the Precision of the model, but not its Recall. It is also not very representative of a "good" model, as it always stays between 0.85 and 0.9 as training process. Thus, we consider both AUC and F1 values of each epoch. AUC The F1 score is a metric that considers both precision and recall.

$$Precision = \frac{TP}{TP+FP}$$

$$Recall = \frac{TP}{TP+FN}$$

$$F1 = 2 \cdot \frac{\text{Precision} \cdot \text{Rcall}}{Precision+Rcall}$$

Both the AUC and F1-Score have values between 0 and 1, and the closer to 1 the better. For readability reasons and let them converge, we chose to plot 1-AUC and 1-F1, so that both the values decrease when training, which is shown in *Fig. 14*.

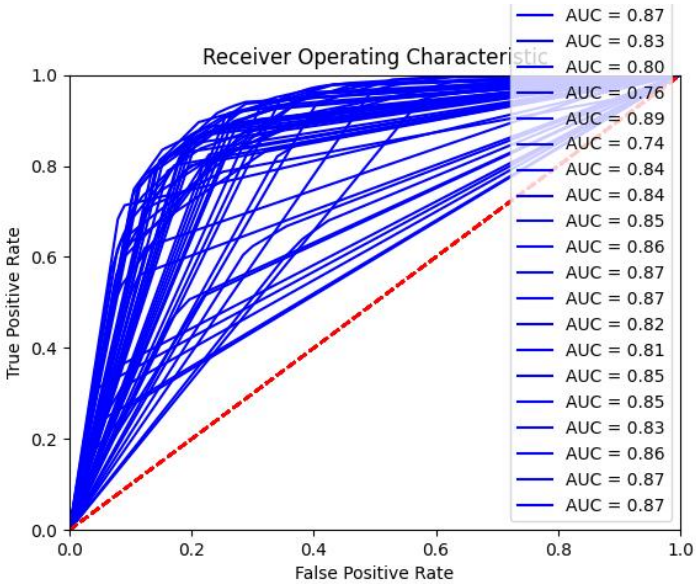


Fig. 13 AUC Curve

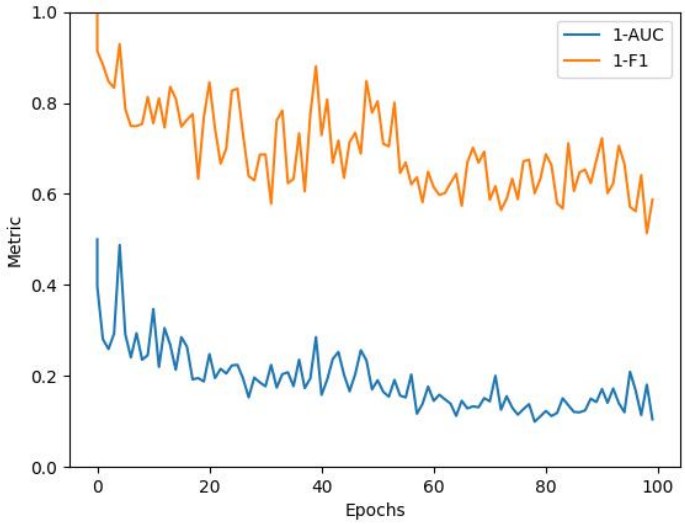


Fig. 14 1-AUC and 1-F1

3.2 Project Analysis

3.2.1 Image Enhancement

Due to the influence of many factors such as light source, imaging system, channel bandwidth and noise during the process of image generation, transmission or transformation, some degradation phenomena such as low contrast, insufficient dynamic range, reduced

definition, and obvious noise may occur. Therefore, it is necessary to enhance the image before analyzing it.

Most scenes using image enhancement are designed to improve the quality of images. There are all kinds of information in the original image, but enhancement can only improve the recognition ability of some information, but it can't increase this information. What's more, it's important to choose an appropriate image enhancement method to avoid partial loss of other information in the image. Image enhancement methods can be divided into smoothing and sharpening according to the purpose and effect of processing.

Smoothing blurs the image, making the image transition natural and soft, and suppressing noise; Based on the frequency characteristics of the image, from the angle of frequency, smoothing is to maintain or strengthen the low-frequency components in the image and weaken or eliminate the frequency components in the image.

Sharpening can be regarded as the reverse operation of smoothing, and the effect is to highlight details and make the image outline clear and clear; From the degree of frequency domain processing, sharpening is to enhance the frequency components in the image.

Because the effect of image enhancement is closely related to the psychology of the observer and the purpose of processing, there is a strong pertinence and selectivity in the application of image enhancement, and there is no general enhancement algorithm. Moreover, the evaluation of image quality is a subjective process for observers in many cases, and there is no general standard and general quantitative judgment to measure image enhancement quality. Therefore, based on the satellite images obtained by us and our research purpose of change detection, we choose to sharpen the images to enhance the high-frequency components in the images. The result of sharpening is shown in *Fig. 15*.

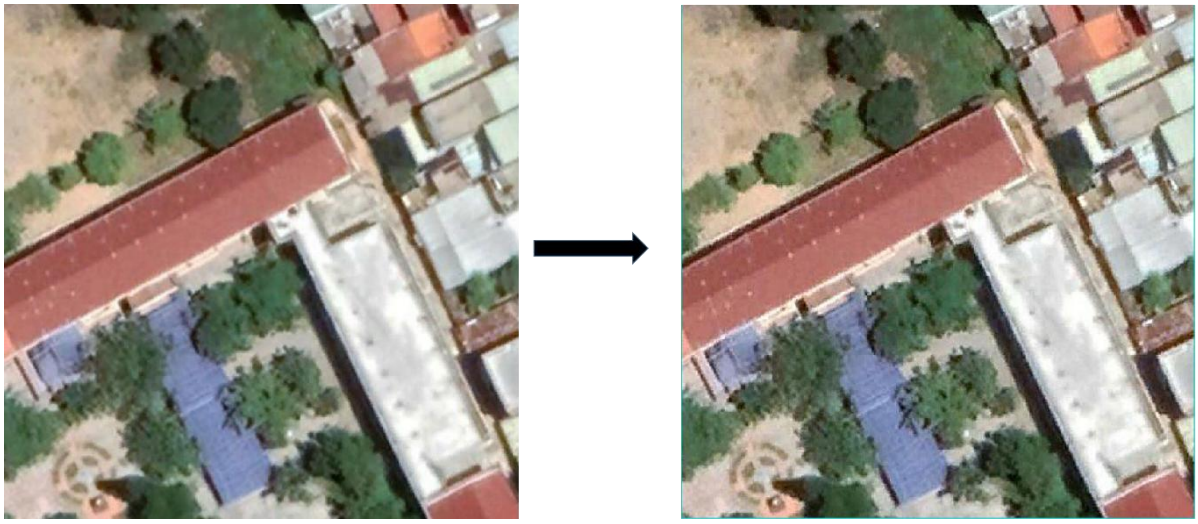


Fig. 15 The result of sharpening

As our goal is not only to obtain urban development by analyzing satellite images, but also to distinguish residential buildings from industrial buildings in changing areas, it is very important to distinguish residential buildings from industrial buildings more clearly when marking satellite images. This can be achieved by the operation of changing RGB brands. The result of changing RGB brands is shown in *Fig. 16*.

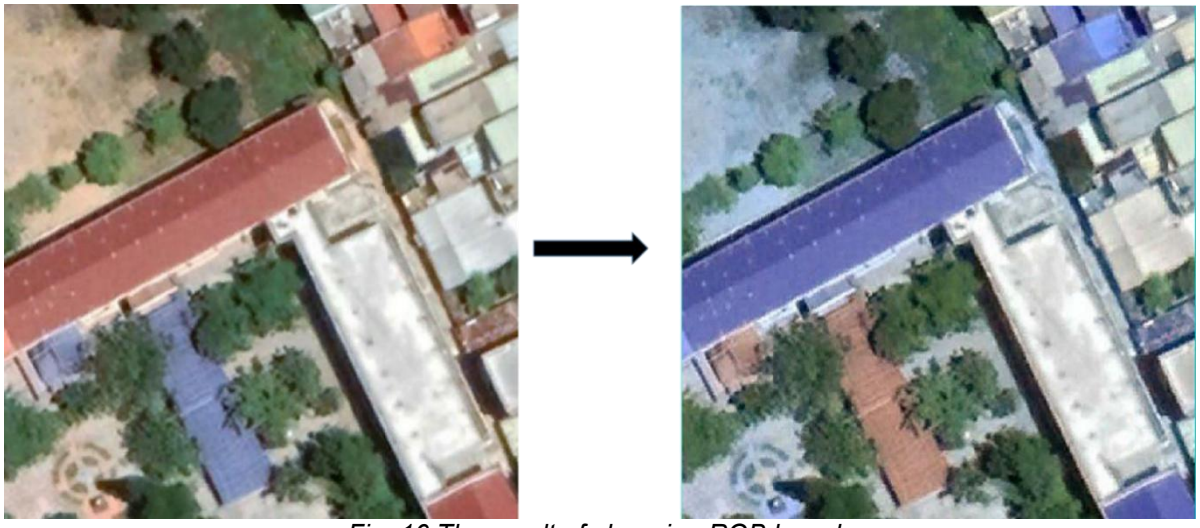


Fig. 16 The result of changing RGB brands

3.2.2 Image Labelling

To get accurate change detection results, and if the samples are labelled completely manually, there is a great demand for time and energy., in this project, the image labelling technology adopted is a semi-automatic labelling technology based on the combination of manual interpretation and computer automatic classification based on spectrum. Using this

technology, we need to find and use a convenient sample labelling tool to ensure the label quality. There are three requirements for tagging tools: brief introduction of software interface, simple operation and allowing users to carry out some secondary development. According to our own needs, we finally choose ENVI to label samples. Labeling software is shown in *Fig. 17.*

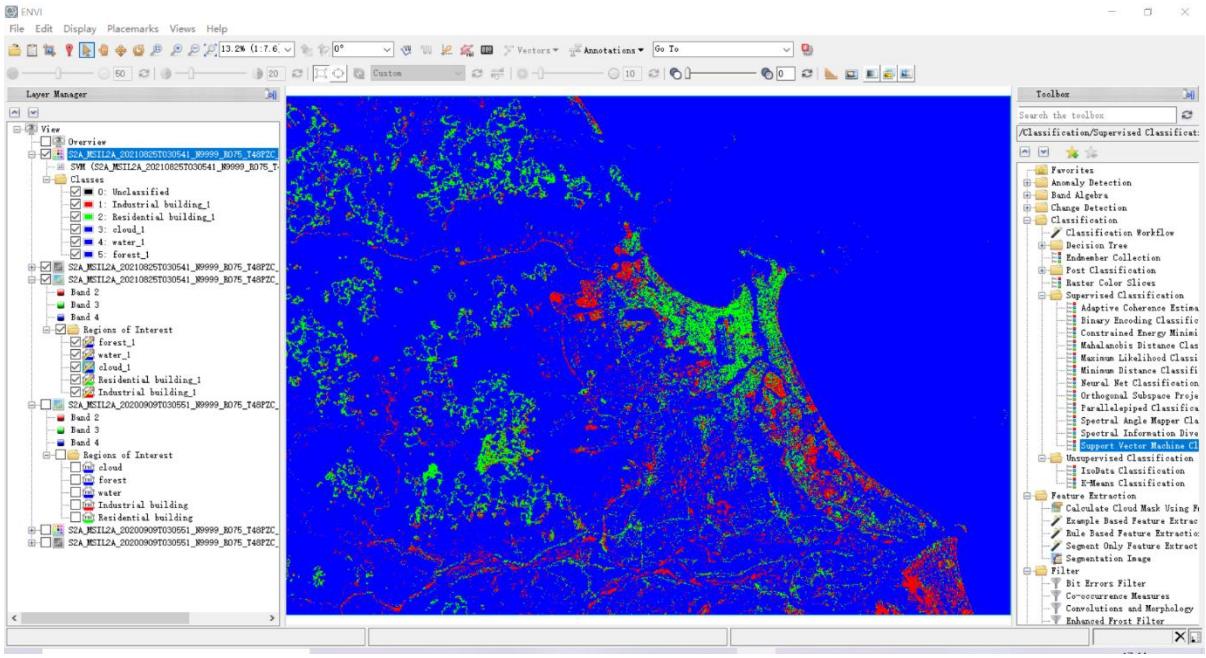


Fig. 17 Labelling software

Because we have acquired the low-resolution satellite images in TIF file format and the high-resolution images in non-TIF file format, we need to deal with the marking part according to the situation.

For low-resolution satellite images in TIF file format, there are three main steps in the image annotation preprocessing process:

Step 1: manually label sample.

Step 2: Calculate the separability of the sample.

Step 3: Select a classifier to carry out automatic computer classification based on spectrum.

After the step of calculating the separability of samples, the separability among various sample types can be observed, which is represented by the parameter Jeffries-Mastusita, Transformed Divergence", and the value of this parameter is between 0 and 2.0. The larger

the parameter value, the better the separability between samples. When the value of the parameter is less than 1, it is necessary to consider combining two kinds of samples into one kind of samples. *Fig.18* shows the separability calculation results of industrial building sample types and residential building sample types. We can find that the numerical value is about equal to 1.7, which is greater than 1.5, indicating that the selected samples of industrial buildings and residential buildings have a good separation effect.

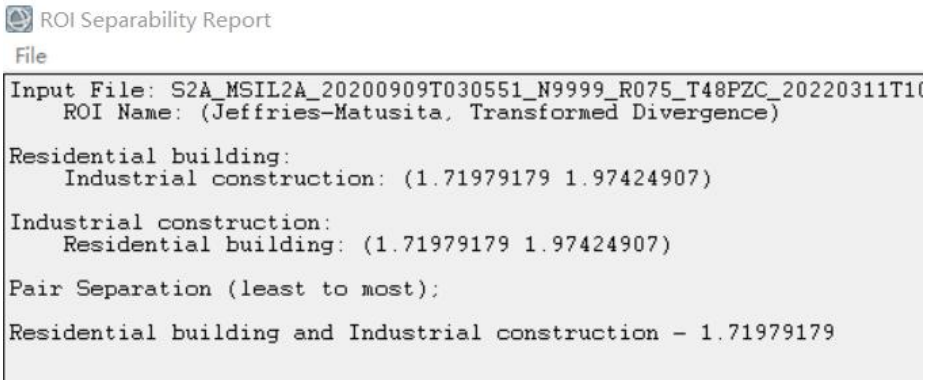


Fig.18 ROI separability report for low-resolution satellite images in TIF file format

To better detect the change, the classifier chose Support Vector Machine. SVM belongs to a method of combining statistical theory and machine learning theory knowledge. It can maximize the distance between classes, and can automatically generate support vectors, which are based on the ability to make a great difference in classification.

The main change process of remote sensing satellite images when using semi-automatic labelling technology for image labelling is shown in *Fig. 19*. Mark industrial buildings with red (255,0,0), residential buildings with green (0,255,0) and other areas with blue (0,0,255).

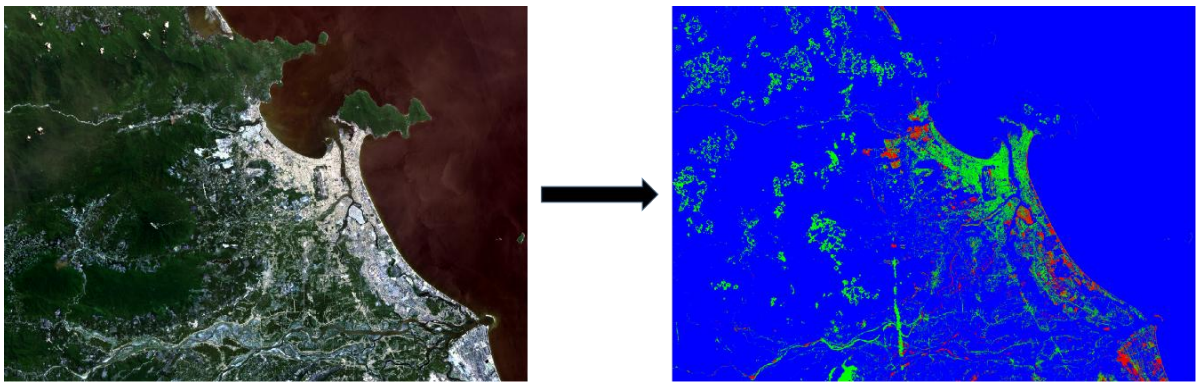


Fig. 19 The main change process of low-resolution satellite images in TIF file format

For high-resolution images in non-TIF file format, there are two main steps in the image annotation preprocessing process:

Step 1: manually label sample.

Step 2: Calculate the separability of the sample.

Fig.20 shows the separability calculation results of industrial building sample types and residential building sample types. We can find that the numerical value is about equal to 2.0, which is much greater than 1.5, indicating that the selected samples of industrial buildings and residential buildings have a perfect separation effect. It can be observed that the numerical value of Jeffries-Mastusita of high-resolution satellite images is larger than that of low-resolution satellite images, indicating that the higher the resolution, the better the marking effect.

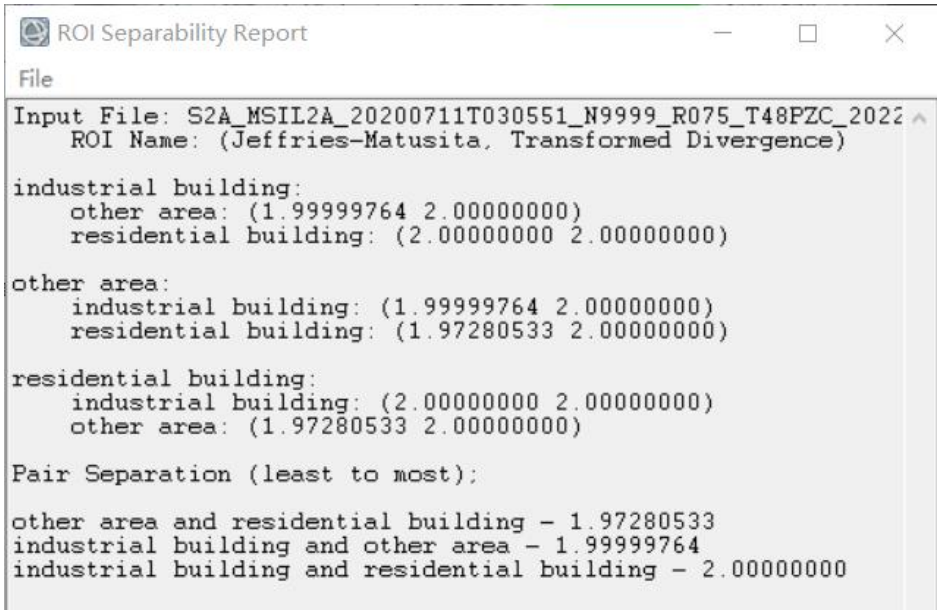


Fig.20 ROI separability report for high-resolution images in non-TIF file format

The main change process of remote sensing satellite images is shown in *Fig. 21* when manually marking images. Industrial buildings are marked with red (255,0,0), residential buildings with green (0,255,0) and other areas with black (0,0,0).

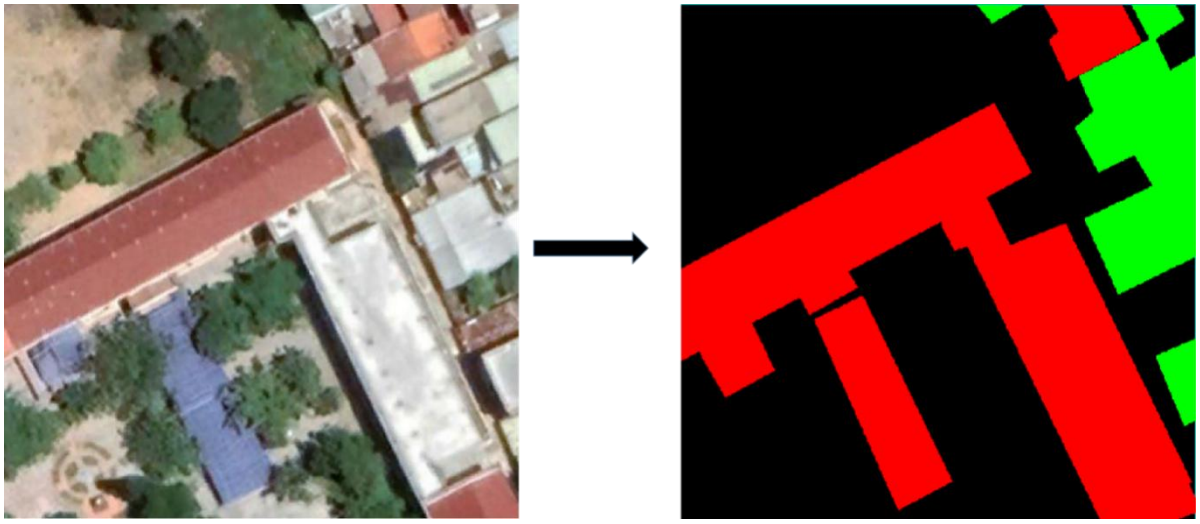
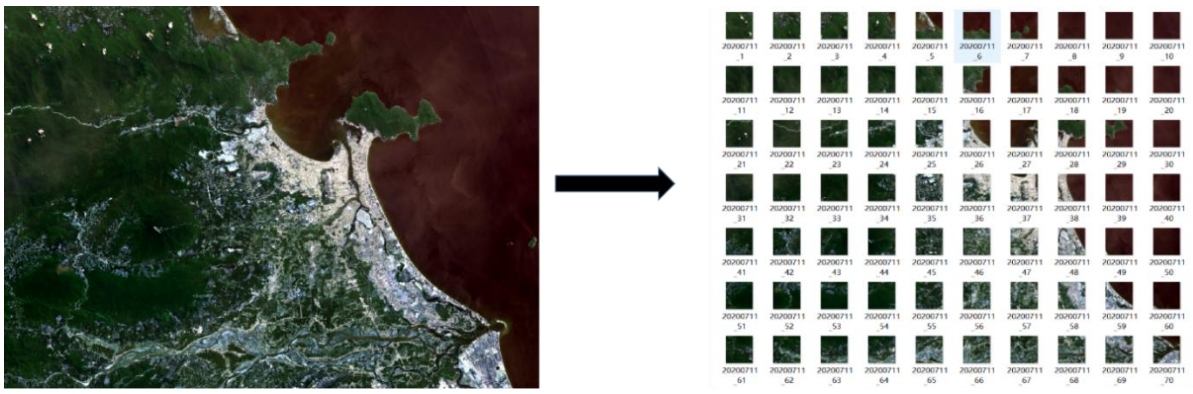


Fig. 21 The main change process of high-resolution images in non-TIF file format

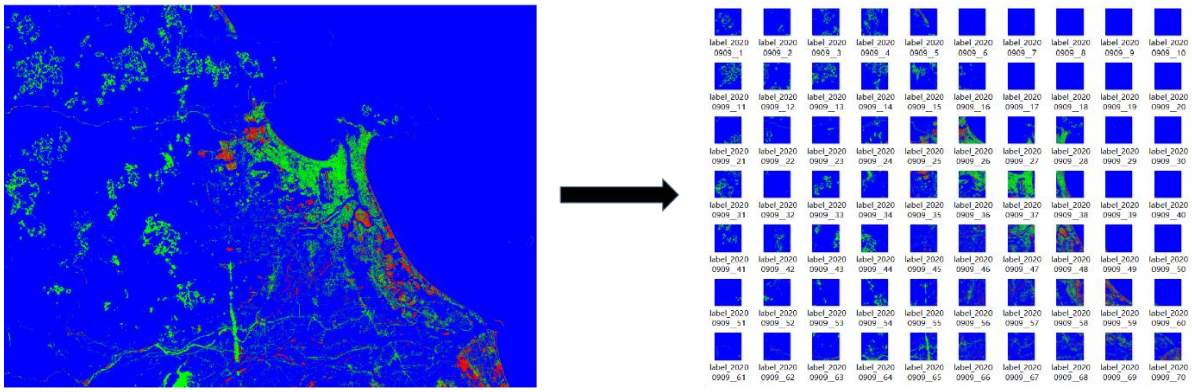
3.2.3 Image Cropping

In the target area, the complete remote sensing satellite image not only has high memory requirement, but also has large image size, so that the change detection model can process the remote sensing satellite image more efficiently and quickly. Using Python code combined with OpenCV, TIF picture files are first converted into PNG format, then the images in TIF picture file format and PNG format are cropped according to the size of 650×650, and the cropped small images are read to the corresponding folder path.

Taking high-resolution images in non-TIF file format as an example, a comparison chart of cropping images before and after labelling is shown in *Fig. 22.*



(a) A comparison chart of cropping images before labelling



(b) A comparison chart of cropping images after labelling

Fig. 22 A comparison chart of cropping images before (a) and after (b) labelling

3.2.4 Unsupervised Method

Automation

To meet P&G's need for automation, we implemented an unsupervised learning method based on the continuity of cropping and stitching operations. Firstly, during the cropping of the images, we returned the names of the two images, the number of small images after cropping and the number of rows. *Code1, Code2* and *Code3* show the implementation of automation.

Then, in the detection of the unsupervised learning method, we detect the two images according to their different names by means of a loop and put the obtained results into diff, change map and clean change map respectively. where diff stores the image obtained by subtracting the pixel values of the two images to take the absolute values, change map is the image obtained by subtracting the pixel values of the two images from diff The clean change map is a corrupted version of the image from the change map, where the smaller areas of change are ignored, and the larger ones are kept.

Finally, in the stitching process, we sorted reasonably according to the number of rows returned by the crop according to the number in the image name, and finally successfully stitched into a large image, achieving partial automation of unsupervised learning change detection.

Code 1. Crop return value

```
if __name__ == '__main__':
_path = "/content/drive/MyDrive/capstone/P/"  # Remote sensing TIF image location path
# Crop image map
after, before, number, row, column = Convert_To_Png_AndCut(_path)
```

Code 2. Unsupervised learning methods change detection automation

```
path = "/content/drive/MyDrive/capstone/P cut/"
for i in range(1, number + 1):
    a= path + before + '_' + str(i) + '.png'
    b= path + after + '_' + str(i) + '.png'
    find_PCAKmeans(a, b, after, i)
```

Code 3. Sorting of the stitching of images

```
x=image_names
a='.'
b='_'
image_names.sort(key = lambda x:int(x.split(a)[0].split(b)[-2])) # Image sorting
```

Analysis of pre-detection

In the pre-test section, we used data from Sentinel-2 images in Danang on April 3, 2018, and July 11, 2020. In the *Fig. 23*, we can see that the lighter areas are the more variable areas and we have selected some of them for more accurate variation detection.

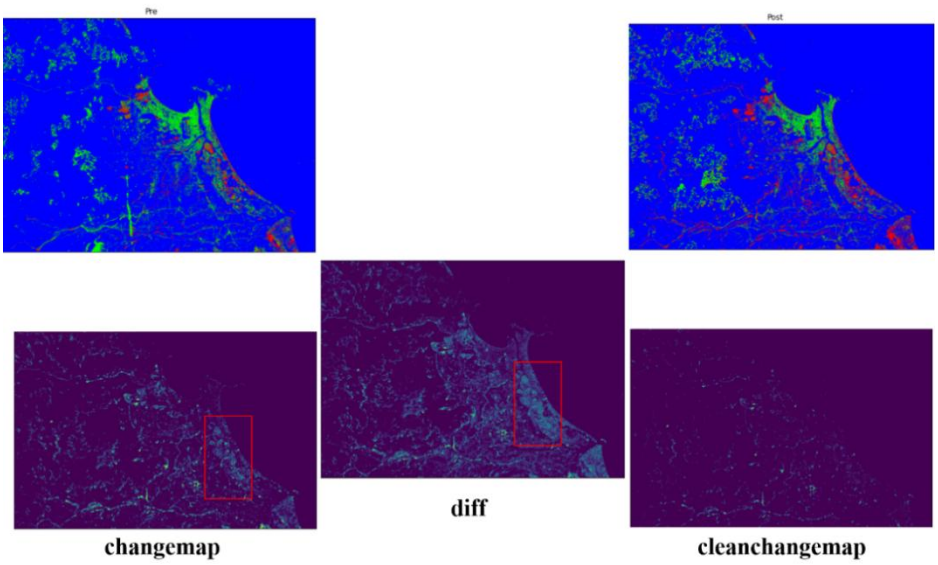


Fig. 23 Unsupervised learning methods to pre-detect low-resolution image results

We then performed a change detection on the high-resolution images collected by Google Earth and multiplied the image consists of 21*22 images of size 650*650 stitched together, located at 16°02'30.12"N 108°14'51.32" E，the results show in *Fig. 24.*

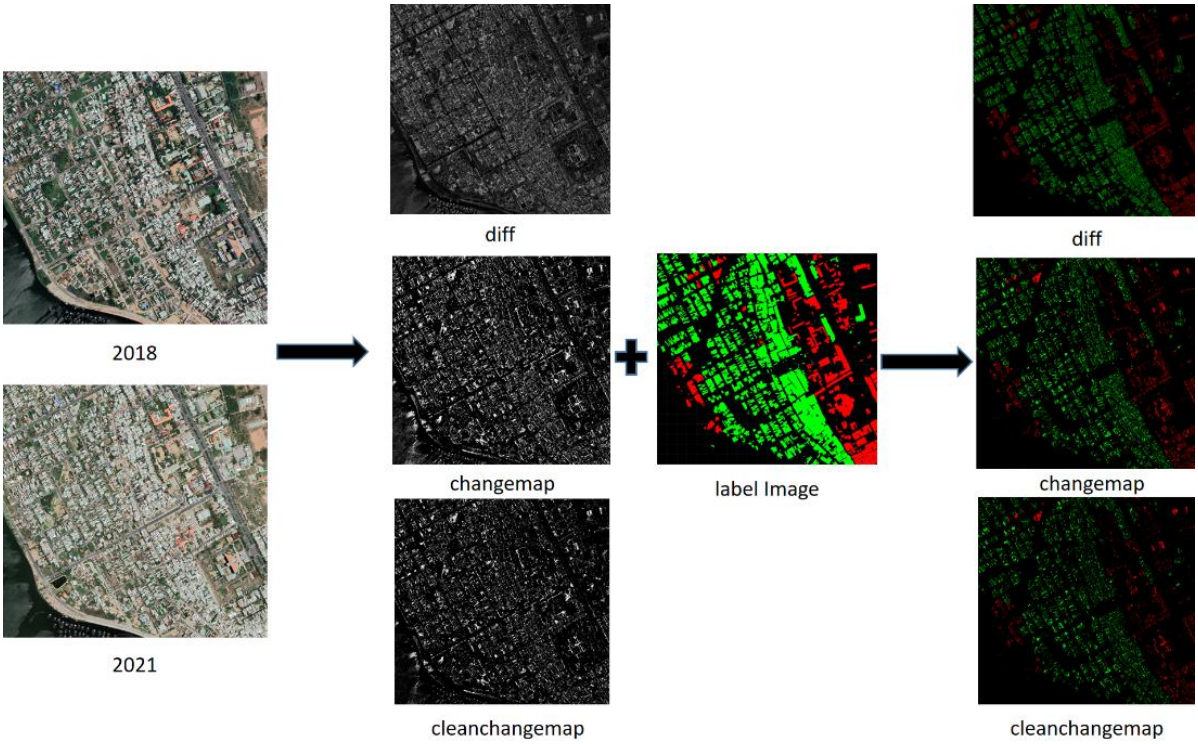


Fig. 24 Unsupervised learning methods to pre-detect high-resolution image results

Next as shown in *Fig. 25*and *Fig. 26*, the area on the left side of the test chart with a large variation was selected for observation. The size of the area consisted of 5*7 images of size 650*650. As we can see after multiplying the label image, the industrial area on the left is more varied, while on the right it is predominantly residential, which would also go some way towards meeting P&G's need for variation in building types.

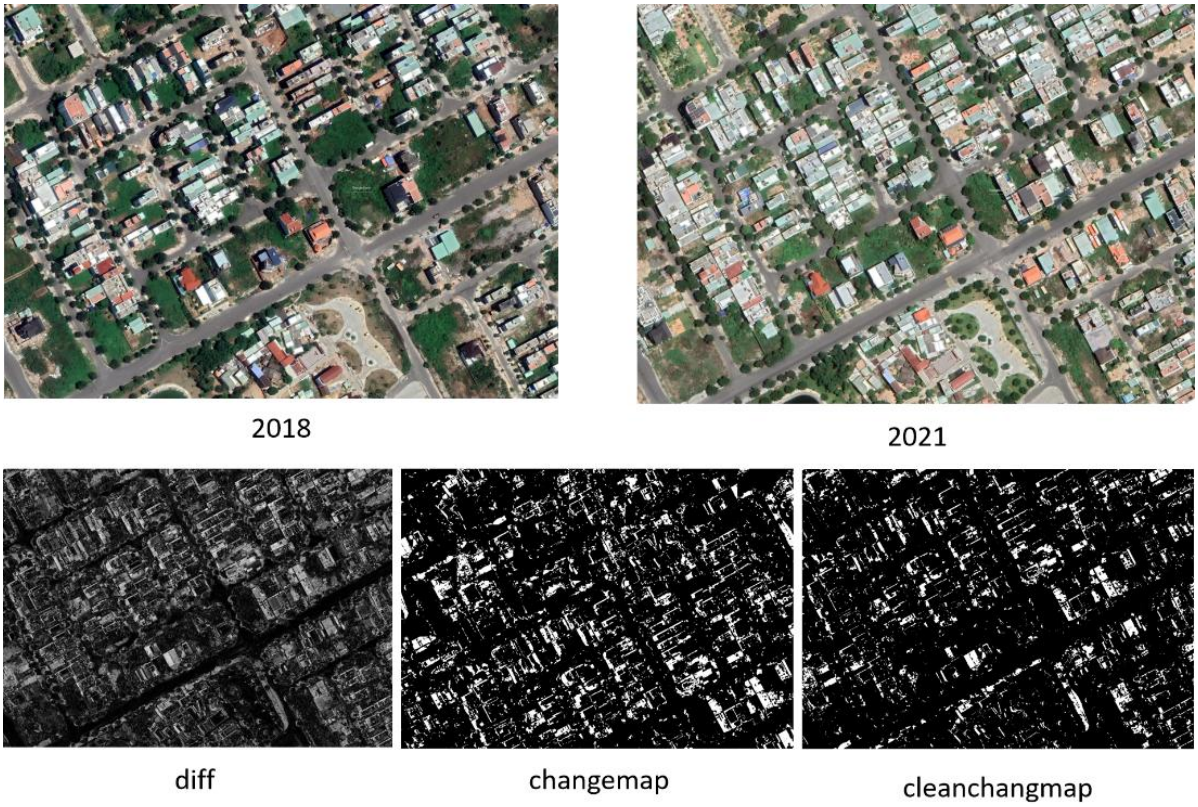


Fig. 25 Change detection in selected areas

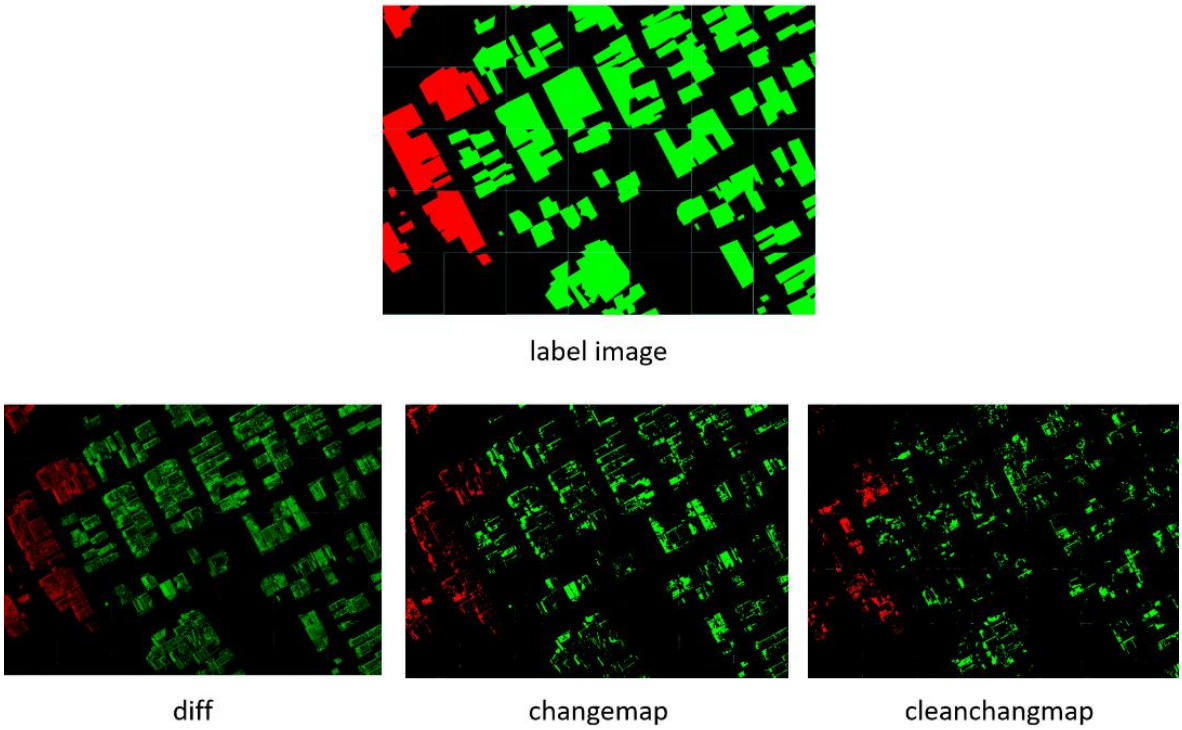


Fig. 26 Multiply results for selected areas

3.2.5 Unet++

To meet the requirements of P&G, the result of change detection should not only present the new buildings but also show the type of new buildings: residential buildings and industrial buildings.

We use a dataset that includes 32 images with labels from the LEVIR-CD dataset (*Fig. 27*) That is especially for architecture change detection to train the model and use the model to predict three sets of images of Da Nang. In the field of remote sensing image CD, there is a lack of publicly available, large remote sensing image change detection datasets. The LEVIR-CD dataset fills this gap and provides a better benchmark for evaluating CD algorithms. Through the Google Earth API, LEVIR-CD collects 637 very high resolution (VHR, 0.5 m/pixel) Google Earth (GE) image patch pairs of 1024 x 1024 pixels in size. These diachronic images were from 20 different areas in several cities in Texas, USA. Collection dates from 2002 to 2018.

Fig.28 shows the result of architecture change detection utilizing Unet++. We can see from the result that the zones of the changing architecture can be detected, which refers to the white zone, and the black zones are the areas that keep intact.

Fig. 27 LEVIR-CD dataset

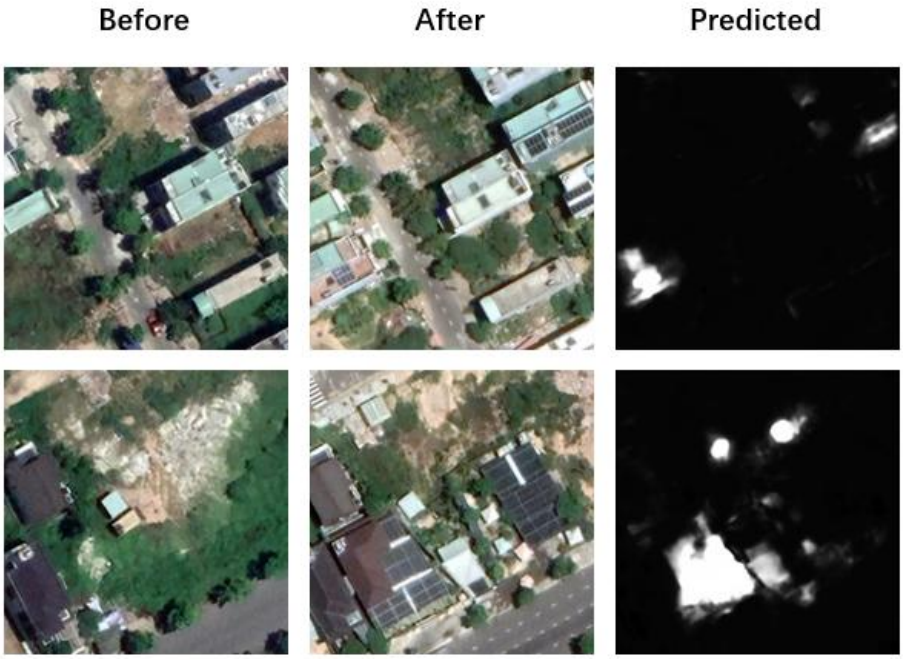


Fig. 28 Unet++ Change detection result

However, there are several issues that need to be addressed: firstly, the edge of the blocks is somehow blurred, and the colour is shallow. Secondly, the results of the change detection only show "zones that have changed", so the white areas not only indicate new buildings that have been built in two years, but also buildings that have been demolished, which does not meet the company's requirements. A further problem is that the change detection alone can't do the classification of new buildings. For the first problem, we propose a solution: the changing areas can be made more distinguishable to the human eye by increasing brightness and enhancing the contrast. This solution is feasible because such blurred areas are white though the colour is shallow, so, they correctly indicate the changes.

Most of the previous studies on architecture classification are based on photographs rather than satellite images and there was no readily available labelled dataset that would fit this requirement. However, we were inspired by a paper issued in 2021, where Mohammad Dimassia proposed a deep learning method based on detecting building roofs to classify them [13]. In this paper, the author divided the whole problem into two steps: semantic segmentation and image classification. In our study, Unet++ works well for change detection

and the second step can be done with the ENVI software and can be better automated once the TIF format images are obtained. Based on the above assumptions, we propose a single image processing pipeline as shown in *Fig. 29*, which not only solves the problem of building classification but also filters out our unwanted change detection results through image multiply. The function of the multiply is to inspect the colour information in each channel and to overlay the base colour with a mixture of colours, and the resultant colour is always a darker tolerant colour. The result is always a darker, more tolerant colour. Any colour that is multiplied with black will produce black, and any colour with a white positive multiplied remains unchanged.

When using Unet++ to process change detection, it is necessary to input two fixed-size (650*650) images of different time periods, detect them in pairs, and create a uniform folder path to store them. Therefore, to simplify the process when detecting a large area, the image processing steps, which include brightening and contrast enhancement, need to be adjusted after stitching the predicted images.

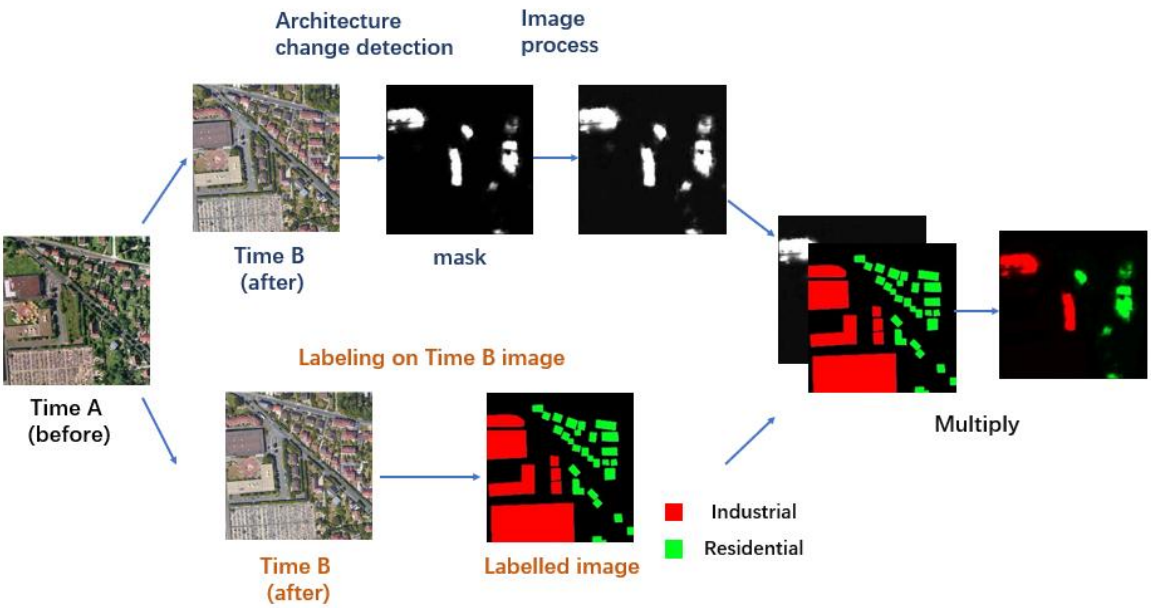


Fig. 29 Unet++ single pipeline process

We detected 5*7=35 pairs of 650*650 images of Da Nang, stitched the predicted images, enhanced brightness, and contrast, and do the multiply on the labelled image (*Fig. 302 Fig. 31* and *Fig. 32* show the result of Unet++ change detection.

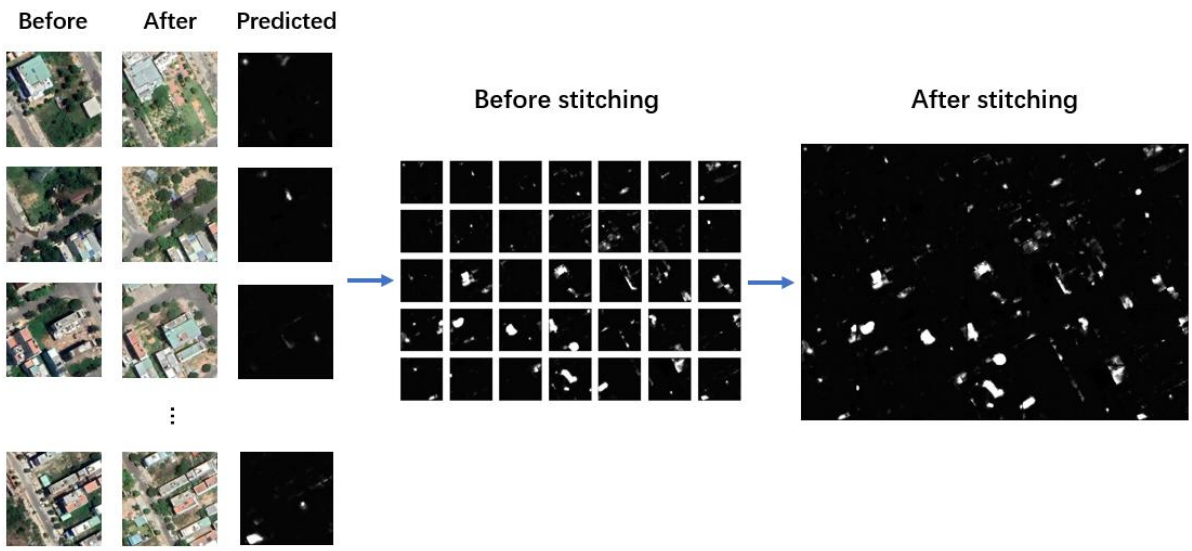
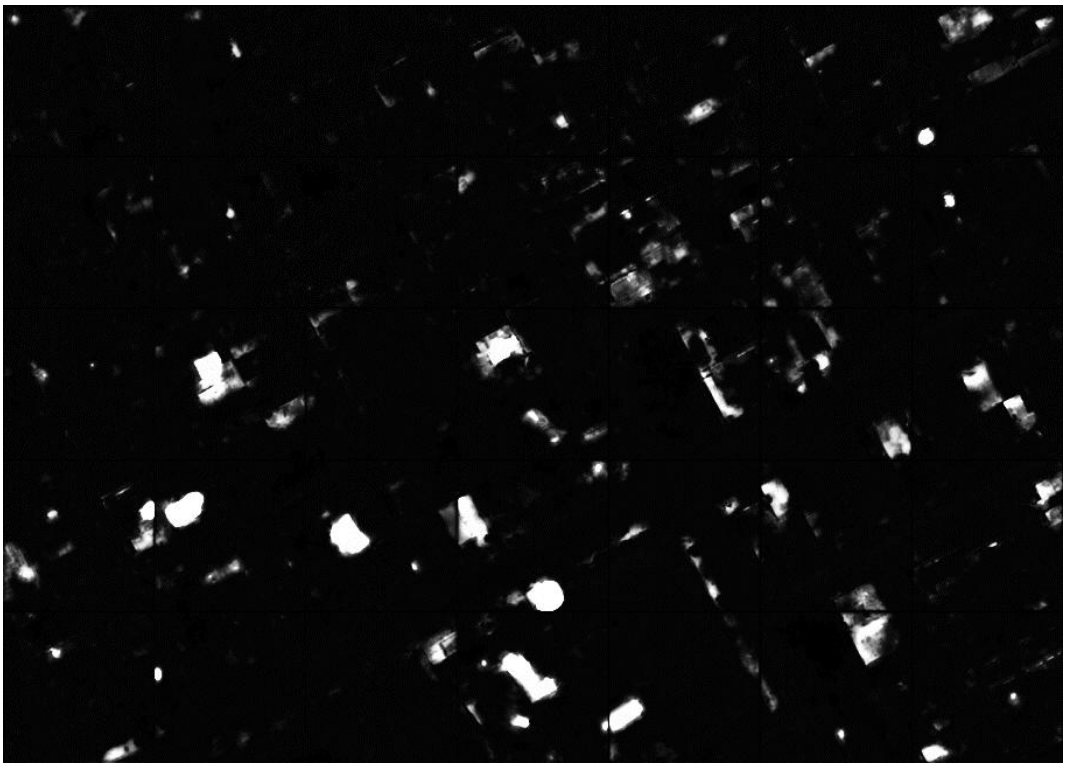
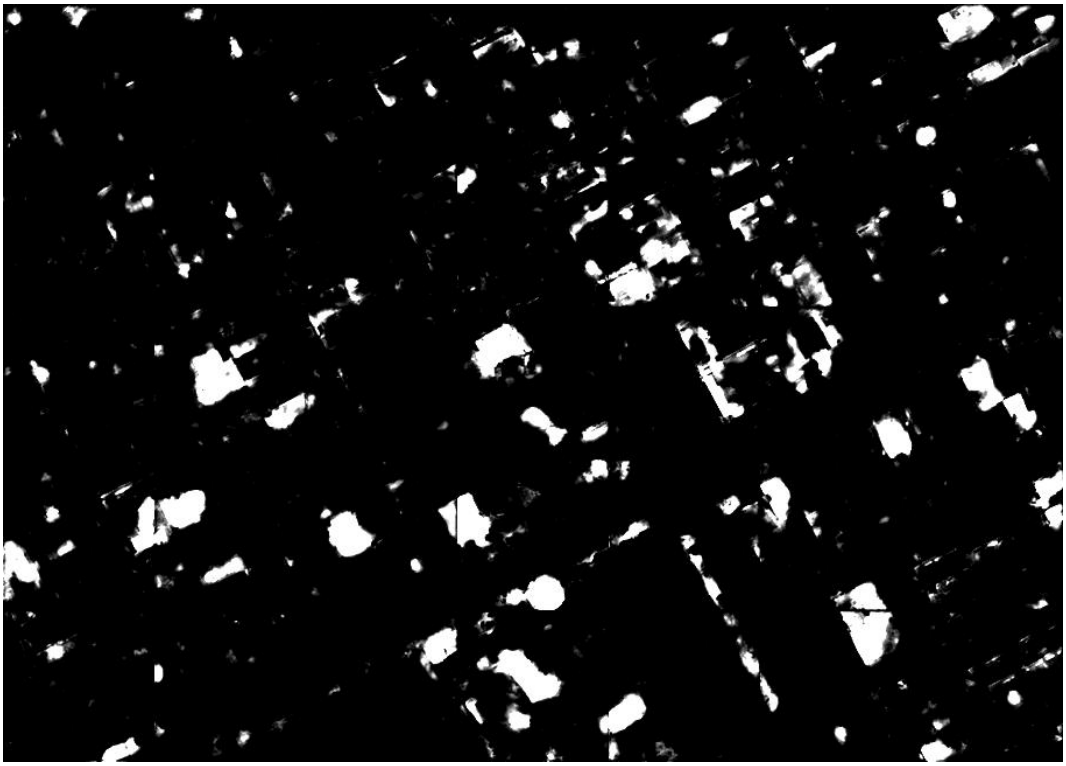


Fig. 30 Unet++ change detection on 35 images



(a)Stitched image before process



(b)Stitched image after processing

Fig. 31 Results before(a) and after(b) processing

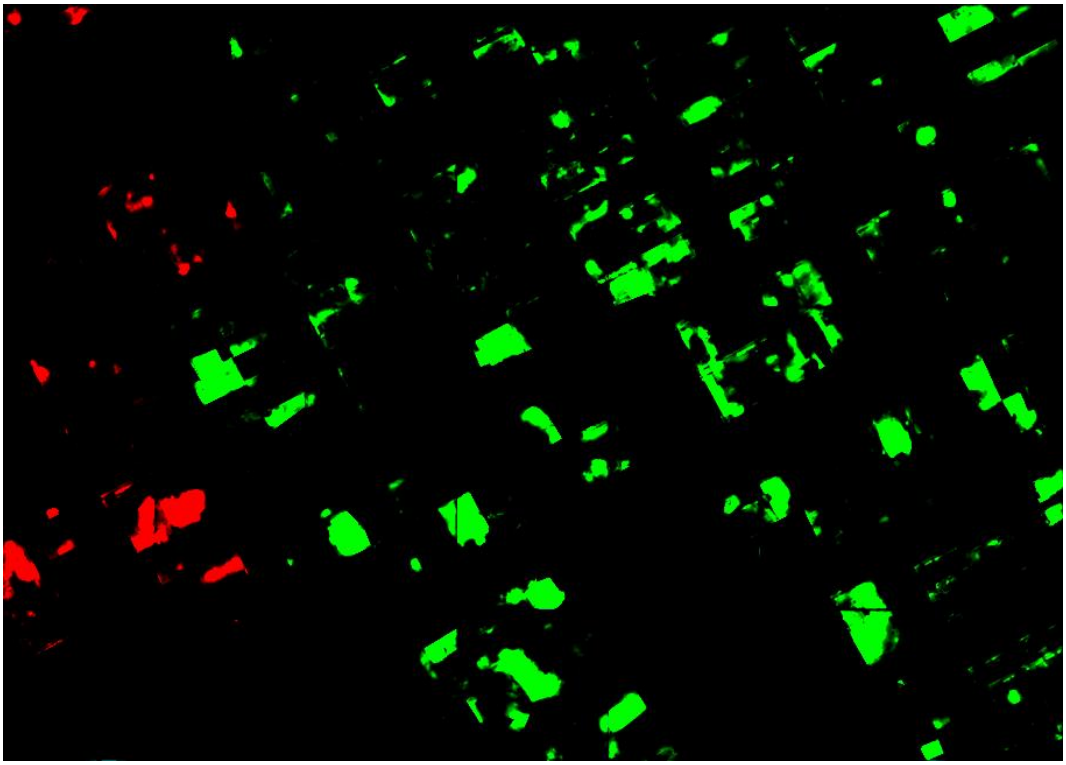


Fig. 32 The result of Unet++ Change Detection

3.3 Recommendation

3.3.1 Technical Recommendations

- **Advantages and Disadvantages of Unsupervised Learning Detection Methods**

As the unsupervised learning method is centred on clustering using the magnitude of pixel differences to show more variable regions, it also has advantages and disadvantages more like the k-means clustering algorithm. Its advantages include ease of understanding, good clustering results, although local optima are often sufficient; low algorithm complexity, no advance training required, and simpler operation, thus facilitating automated batch detection.

There are, however, some disadvantages that need to be noted. The first is that unsupervised learning methods are more likely to detect changes based on pixel differences, rather than being able to detect only building changes, and therefore may not be able to detect building changes and disappearances as well. For example, it may detect changes in the road or just changes in the building colour.

Secondly unsupervised learning methods tend to achieve local optima and often detect well in two separate images, whereas once the detection is cropped for larger images, each image may be able to achieve a local optimum for pixel interpolation clustering, while the whole is often difficult to achieve, so we also see more outliers in the detection results, which are not clean enough. Our current treatment is to corrode the change map to eliminate some outliers. In addition, we can also modify the size of the cropped image for detection, the less the original image is cropped the better the unsupervised learning method works. However, as the process involves multi-step matrix operations, there will be high requirements for memory size when detecting larger images, so the number of crops and memory size will be considered together to achieve better detection results.

The third is that as it is mainly implemented by unsupervised learning algorithms, it may not be as accurate as supervised and deep learning methods in terms of detection and can therefore be used as a pre-detection of large images with their more variable ranges.

- **Advantages and disadvantages of the Unet++ method**

From the results, Unet++ focuses on detecting changes in buildings with a clear outline of the results compared to unsupervised learning change detection methods. Besides, due to its Unet architecture, the model doesn't require a large training dataset. However, Unet++ also has some limitations. The detection of changes and the precision of the borders are greatly impacted by the image quality and resolution. Besides, arranging the images and files properly is also demanding (*Fig. 33*) if we zoom in the detected area to the whole city since Unet++ detects changes in a pair of 2 images. It is inevitable that we will get thousands of pairs of images of Da Nang or even more. However, for the unsupervised method, it can ignore the resolution requirement and detect the whole Da Nang once.

Even still, we think that Unet++ model performs well, and it can be optimized if a larger and more diverse dataset can be obtained.

Fig. 33 File path of Unet++

3.3.2 Business Recommendations

- **Analysis of Satellite Image Industry**

Remote sensing is one of the main application scenarios of satellite, which refers to the observation of the earth by satellite to obtain information beyond the scope of human vision. It is mostly used in military reconnaissance, mapping, environmental resources monitoring and other scenarios.

In the satellite remote sensing image analysis industry, the applications that can be seen at present mostly appear in agricultural and ecological monitoring scenes. As for whether it is possible for satellite image data analysts who are deeply involved in agriculture, ecology, and other scenes to cut into the Business field, the satellite image data analysis industry is still in its early stage, and talents are scarce, so everyone is still in the stage of making the market bigger together[14].

Climate change, environmental protection, disaster monitoring-these are just the "tip of the iceberg" in many application fields of remote sensing satellites. After decades of development and application, especially the rapid development in recent years, it has laid a strong and solid foundation for Commercialisation, including a reliable technical foundation and a broad application foundation.

The application of remote sensing technology is extensive, and remote sensing technology can provide information for all disciplines and technical types involved in earth science. This extensiveness will inevitably widen the range of users who need remote sensing data, so there are some Business users besides social welfare users. The combination of high-resolution image data and geographic information system will have a broad market in future urban planning, cadastral management, factory evaluation, etc[15]. It is expected that there will be a certain percentage of growth rate every year. In recent years, due to the increase of satellite data and the development of small and cheap workstations, image processing systems and software, the number of related spatial information service companies will increase greatly, and the resulting value-added revenue is several times that of satellite

image sales. Therefore, the Commercialization of satellite remote sensing is one of the driving forces for the industrialization of satellite remote sensing applications. As satellite remote sensing has the characteristics of large coverage area, large amount of information, fast acquisition speed and multi-time and space resolution, it has unique advantages in building resources inventory, building change monitoring, optimal location selection, etc[16]. It plays a significant role and has a broad prospect in the design of roads and building projects, selecting appropriate locations to carry out related activities, etc.

- **Remote Sensing Data Applied to Procter & Gamble**

With the improvement of satellite coverage frequency and accuracy, satellite remote sensing has gradually been implemented in the Business field. Compared with the traditional mode, the method of obtaining results through remote sensing image analysis is more accurate and can help the demander to understand the required information in a shorter time. In this project, Procter & Gamble company can use remote sensing satellite images to detect changes and timely track urbanization and affluence of population with different growth rates in cities, to make corresponding business decisions.

From the perspective of operation flow, the process of this project is to obtain the required original image from the upstream (remote sensing satellite manufacturer), and then carry out data extraction, cleaning, analysis, and interpretation according to the image, to provide the required data information and decision-making suggestions for the downstream (Procter & Gamble company). The key is getting enough high-quality raw satellite data and using algorithms to get accurate results.

“Enough”

Image processing in the satellite field is different from other industries. To obtain a specific result based on image analysis, data analysis often needs to cooperate with several satellite manufacturers with different specifications to obtain data from different angles. In addition, due to the small quantity and high price of satellite images, data analysis needs to

get enough data through various means to train its own algorithm. To solve these two problems, Procter & Gamble company needs to ensure that it can get more original images. Since there are not many suppliers available in the industry, if Procter & Gamble has little experience in using satellite remote sensing, it is suggested to choose suppliers through word of mouth. If the company has previous experience in using such services, it can select qualified suppliers according to its own purposes and may also test and compare the data accuracy of the new analyst based on the previous analysis results.

“High-quality”

Satellite images of different quality the price will be different due to factors such as resolution and shooting time. High quality satellite images have obvious advantages in image resolution, signal-to-noise ratio, texture sharpness and so on. According to the report, the demand for Business sold satellite data varies from application to application, and many Business satellite data sold is high-resolution optical data. Because of high resolution level image can provide more clearly and more abundant data information, help to support to improve decision-making, improve operational efficiency, enhance the Business company earth observation application ability[17]. On the one hand, high quality remote sensing images are comparable to aerial remote sensing images in resolution, which will attract more users to choose satellite images. On the other hand, high-quality remote sensing images have more advantages in data price, global coverage and data update cycle compared with aerial images.

Market research shows that the average price of 0.5m resolution satellite images taken in the past five years is \$30/km^2, and the average price of 0.3m resolution image is \$39/km^2, with a minimum order of 25km^2. If Procter & Gamble needs higher resolution and newer images, it is recommended to contact the supplier (Business remote sensing satellite operators) directly, but if the analysis requirements are more relaxed on image clarity and shooting time, the images can be obtained through distributors. However, no matter which

method of acquisition, the final requirement is to produce analysis results that meet the required criteria under existing conditions.

- **Cost and Benefit of Satellite Images**

Observing the satellite images of our project, we can find that the low-resolution satellite images and high-resolution satellite images we use are completely different in satellite image formats and acquisition methods. This is because we choose the most suitable channel based on the trade-off between cost and benefit.

For low-resolution satellite images, because the society hopes that more students and individuals can learn and study remote sensing technology in the future, they can get free remote sensing satellite images from many websites, but these websites only provide low-resolution satellite images for free. Many people think that low-resolution satellite images are of little use, but low-resolution satellite images can be used to learn and deepen our proficiency and skills in image processing. There are also some industrial applications that don't require high resolution. For example, in our project, we can obtain the area of Da Nang that has changed the most in two years by using low-resolution satellite images, so that we can study the regional scope of the target under the condition that the resolution of the received satellite images is limited, thus successfully verifying the correctness and accuracy of using methods, algorithms and technologies. And the satellite images provided by these websites are in TIF image file format, TIF image format is the abbreviation of Tag Image File Format, and the Chinese translation is called Tag Image File Format. This is a flexible bitmap format primarily used to store images including photographs and artwork. The TIF format is flexible in storing image information, can support many colour systems, and is independent of the operating system, so it has been widely used, but its image format is relatively complex. In this project, the use of semi-automatic tagging technology needs to use the geographic information and spectral information contained in TIF image files, etc., so obtaining free low-resolution satellite images through relevant websites can

not only make the cost zero, but also the labour cost can be greatly reduced in the one step of labelling the image.

For high-resolution satellite images, because high-resolution satellite images are restricted by the corresponding policies of various countries, there is no channel that can provide high-resolution satellite images in free TIF image file format, but we have already learned about TIF images. High-resolution satellite images in file format are expensive to purchase, but through Google Earth, we can obtain free high-resolution satellite images in non-TIF image file formats, but due to satellite images in non-TIF image file formats, For example: JPG, PNG, etc., are often images compressed by compression algorithms, so they do not contain geographic information or spectral information, etc., so semi-automatic labelling technology cannot be used in the step of labelling images, and only manual labelling can be used. technology, which will increase the labour cost, but after weighing the purchase cost and labour cost, we believe that the increased labour cost is insignificant compared to the high cost of the purchase.

- **Business Decisions Obtained for Procter & Gamble to Analyse the Change Detection Results of High-resolution Satellite Remote Sensing Images**

As Procter & Gamble is a consumer goods company with factories and branches in more than 80 countries all over the world, its products of more than 300 brands sell well in more than 160 countries and regions, including fabric and home care, hairdressing and beauty care, baby and family care, health care, food and beverage, etc. The brands sold in China are Olay, Head & Shoulders, Sassoon, clairol, Rejoice, Pan Ting, Shufujia, Carmel, Jishuang, Gillette, Crest, Hushubao, Pampers, Duracell, Bilang and Tide. Therefore, for Procter & Gamble, we mainly think and analyse to get the best location to open supermarkets and processing factories.

Observing the change detection results of high-resolution satellite images in 2018 and 2020, the green covered area indicates that this location was not a residential building in 2018, but it has become a residential building in 2020; The area covered in red indicates that this

location was not an industrial building in 2018, but it has become an industrial building in 2020. We can find that: in just two years, the coverage of residential buildings and industrial buildings in selected areas has changed significantly, among which residential buildings are the main ones. A place with high green density indicates that the area is liveable, with many people migrating to the area, a large demand for daily consumer goods, strong population circulation and high population density. The red area with high density shows that it may be an industrial area planned by the government, with concentrated factories, large land area and lower rental cost compared with residential building areas. As supermarkets are suitable to be set up in densely populated areas with huge traffic, while processing plants are suitable to be set up in areas with vast land area and low rental costs, it is suggested that supermarkets should be set up in green areas with high density, while processing plants should be set up in red areas with high density. Considering the cost of freight, after considering the best possible location, we can make further business decisions by keeping the distance between supermarkets and processing plants as small as possible. As shown in *Fig. 34*, an example of business decision, you can choose the area with blue dots to open a supermarket, and the area with yellow dots to open a processing factory.

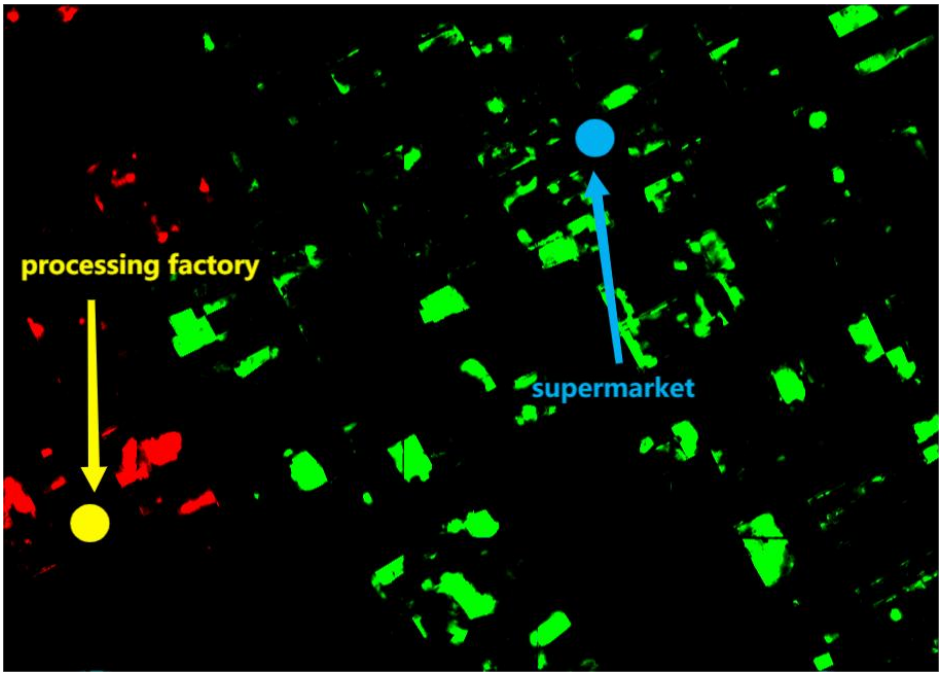


Fig. 34 Example diagram of business decision

For large enterprises of consumer goods, it is very important to choose the right site. In the long run, it can bring huge profits to Procter & Gamble by using the change detection of satellite remote sensing images for correct business analysis.

4. Reference

[1] Procter & Gamble. (n.d.). Retrieved June 10, 2022, from https://us.pg.com/

[2] Wikimedia Foundation. (2022, June 6). Procter & Gamble. Wikipedia. Retrieved June 10, 2022, from https://en.wikipedia.org/wiki/Procter_%26_Gamble

[3] Procter & Gamble Co (P&G). DMSpro Jsc | Sales and Distribution Management Solution. (2018, February 26). Retrieved June 10, 2022, from https://www.dmspro.vn/en/?customer=procter-gamble-co-pg

[4] Komissarov, V. (2017). AI Applications for Satellite Imagery and Satellite Data. Tech Emergence.

[5] SUI, H., FENG, W., LI, W., SUN, K., & XU, C. (2018). Review of change detection methods for multi-temporal remote sensing imagery. 武汉大学学报● 信息科学版, 43(12), 1885-1898.

[6] Shi, W., Zhang, M., Zhang, R., Chen, S., & Zhan, Z. (2020). Change detection based on artificial intelligence: State-of-the-art and challenges. Remote Sensing, 12(10), 1688.

[7] Khelifi, L., & Mignotte, M. (2020). Deep learning for change detection in remote sensing images: Comprehensive review and meta-analysis. IEEE Access, 8, 126385-126400.

[8] Chris Hudgins, A. B. (2017, September 27). Small brands, Digital Strategy an issue for P&G, rivals. S&P Global. Retrieved June 10, 2022, from https://www.spglobal.com/marketintelligence/en/news-insights/trending/lhvnpfpw0opeel15fbdkbg2

[9] Author: Published by View all posts by, by, P., by, V. all posts, says:, F., says:, andy_hui, says:, raga2207, says:, A. K., Says:, F., says:, V. S., says:, P. S., says:, L. H., says:, S. P., says:, A., says:, O., says:, S., says:, H. M., says:, J. W., says:, C. W., … says:, X. J. (2021, May 31). Unsupervised changed detection in multi-temporal satellite images using PCA & K-means : Python code. Machine Learning in Action. Retrieved June 10, 2022, from

https://appliedmachinelearning.blog/2017/11/25/unsupervised-changed-detection-in-multi-temporal-satellite-images-using-pca-k-means-python-code/

[10] Zhou, Z., Rahman Siddiquee, M. M., Tajbakhsh, N., & Liang, J. (2018). Unet++: A nested u-net architecture for medical image segmentation. In Deep learning in medical image analysis and multimodal learning for clinical decision support (pp. 3-11). Springer, Cham.

[11] Alexakis, E. B., & Armenakis, C. (2020). Evaluation of unet and unet++ architectures in high resolution image change detection applications. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, *43*, 1507-1514

[12] Héloïse Baudhuin – Antoine Lamborghini. (2020, June 3). Change Detection in Satellite Imagery Using Deep Learning: Python Code. Retrieved from https://github.com/hbaudhuin/LamboiseNet#lamboisenet

[13] Dimassi, M., Samhat, A. E., Zaraket, M., Haidar, J., Shukor, M., & Ghandour, A. J. (2021). Buildings Classification using Very High Resolution Satellite Imagery. *arXiv preprint arXiv:2111.14650*.

[14] Jocumsen, G. (2004). How do small business managers make strategic marketing decisions? A model of process. European journal of marketing.

[15] Popkova, E. G., Chesnokova, A. V., Gyiazov, A. T., Morozova, I. A., & Fetisova, O. V. (2019). The Concept of Business System. In Specifics of Decision Making in Modern Business Systems. Emerald Publishing Limited.

[16] Johnson, P. (2006). Business Development. In Astute Competition. Emerald Group Publishing Limited.

[17] Tretyakova, O. G., Osadchaya, O. P., Kostyukova, E. I., Sirotenko, M. V., & Gimelshtein, I. V. (2019). The Essence of the Process of Decision Making as a Choice of the Existing Alternatives. In Specifics of Decision Making in Modern Business Systems. Emerald Publishing Limited.