CHRU

www.gsc.ce.ntu.edu.tw/

Integration of multiple geospatial information for engineering applications

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01
Evolution of Remote Sensing

01 Evolution of Sensing Technology

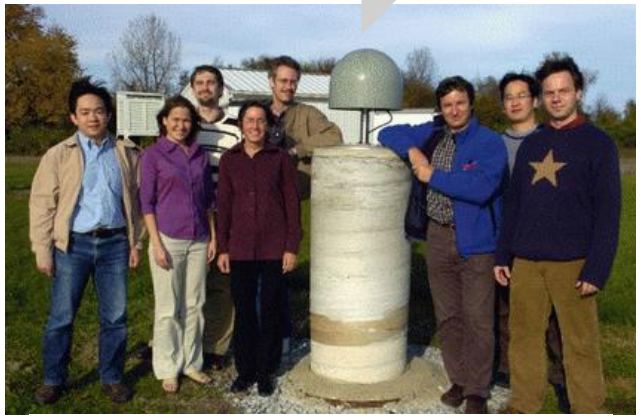
Master's Study

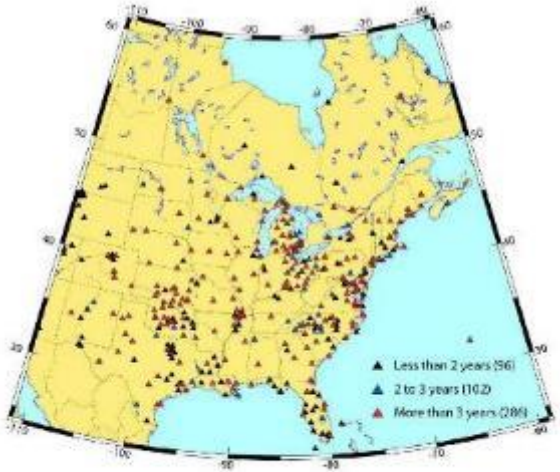
- Year: **1996 – 1998.**
- Topic: **Analysis of Nuclear Power Plant Subsidence**.
- Data Collection: Levels & Total Stations.
- Data Frequency: **150 points x per season**.
- Analysis Method: Fortran 77, free network adjustment, each calculation takes approximately 10 seconds.

01 Evolution of Sensing Technology

PhD Study

- Year: **2002 – 2006.**
- Topic: **Application of Continuous GPS Technique in Observing Surface Deformations**.
- Data Collection: Continuous GPS(CGPS) Stations.
- Data Frequency: **563 stations x per second (48 million entries/day).**
- Analysis Method: Linux Script, coordinate & velocity analysis, approximately 2-3 hours required to process one day's (24 hours) observation data.



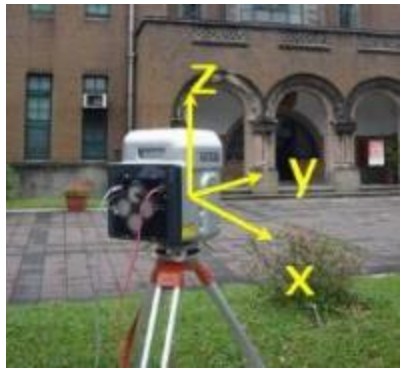


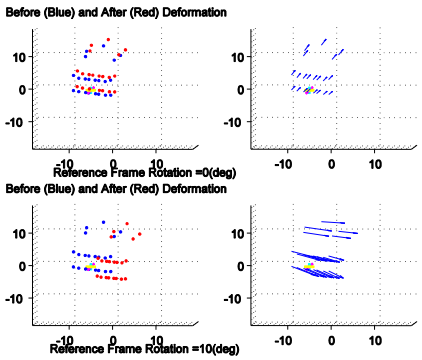
563 continuous GPS sites: most are "CORS" stations + IGS + NRCan + local networks (*e.g.*, GAMA)

01 Evolution of Sensing Technology

Early period after returning to Taiwan

- Year: **2007 ~**
- Topic: **Monitoring Building Displacement using LiDAR Point Cloud.**
- Data Collection: MENSI GS200 Laser Scanner.
- Data Frequency: **500 points per second (500Hz).**
- Analysis Method: MATLAB Script, tensor algorithm for feature extraction, approximately 2 - 3 hours processing time for 3 million points.

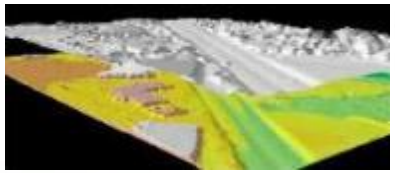




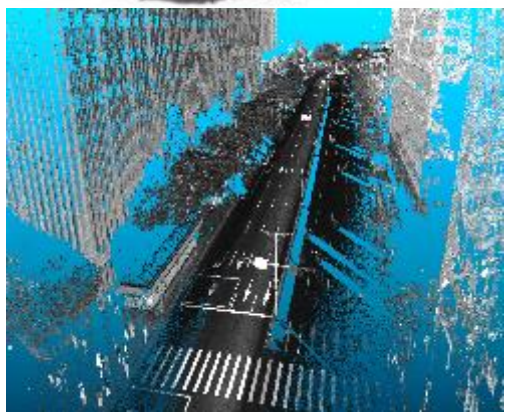
01 Evolution of Sensing Technology

NOW (2015 ~)

MMS: 1 million points per second (1MHz).

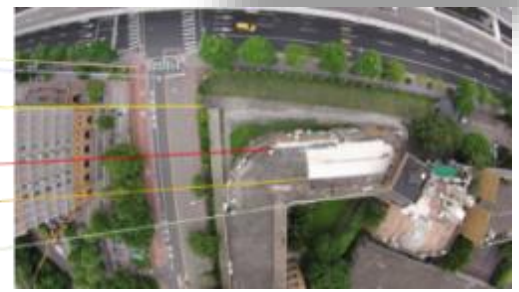





UAV: 30 images per second, each image contains 20 million pixels (600 MHz).








01 Evolution of Sensing Technology

Manual Measurement
(2pts/min)

LiDAR Scanning Measurement
(1M pts/sec)

Photogrammetric surveying
(600M pts/sec)

Fast

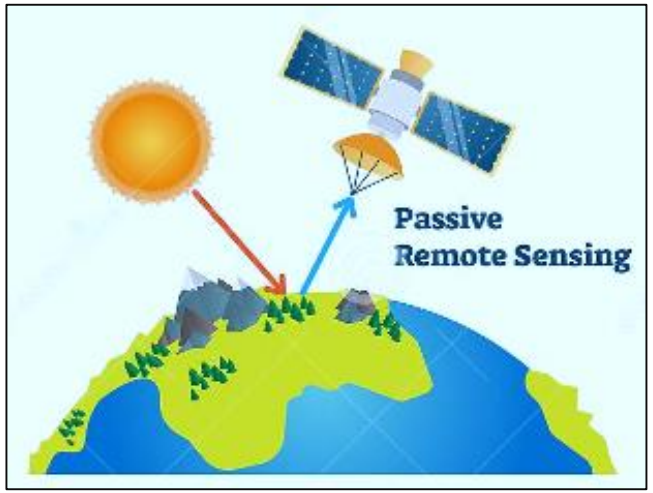
Automated

Abundant Information

Data frequency increased 18 billion times.

01 Evolution of Sensing Technology

- Remote sensing：
  - Acquiring data from a far distance without touching the target.



Passive

- Passive systems detect solar reflected radiation.
- EX：optical, multi-spectral, near-infrared, thermal

Active

- Active systems emit signals (laser, radar, etc.) and record the returned ones.
- EX： LIDAR, RADAR or SAR

Picture Reference: https://www.dreamstime.com/

01 Evolution of Sensing Technology

- Passive systems

optical, near-infrared

Principle

Most objects have different reflection in the visible light band (400-700 nm) and near-infrared (800 nm - 2500 nm).

Application

Combined with computer vision to identify target objects and the principle of spectral reflection to understand plant growth status

Infrared

Principle

Infrared ray (750 nm-100 μm), most of the thermal radiation emitted by objects at room temperature is in this band.

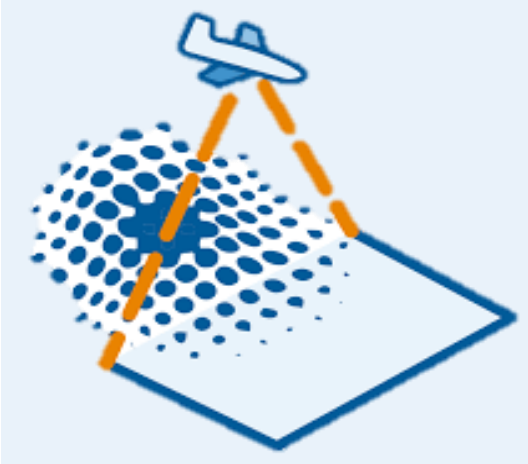
Application

Solar panel inspection, air pollution monitoring

01 Evolution of Sensing Technology

- Active systems

LIDAR



Principle

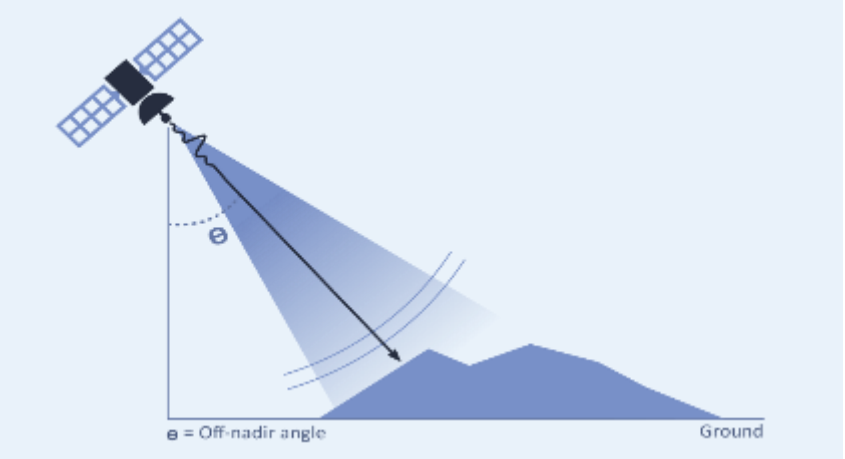
It uses light in the form of a pulsed laser to measure ranges.

Application

Producing DEM, iceberg monitoring, tree volume estimation.

InSAR

(Interferometric Synthetic Aperture Radar)



Principle

It is a technique for mapping ground deformation using radar images of the earth's surface that are collected from orbiting satellites.

Application

Surface deformation, infrastructure monitoring, biomass estimation.

01 Evolution of Sensing Technology

- Advantages and disadvantages

Passive: Optical

SPOT

Advantages

Easy to identify and apply

Disadvantages

Affected by light and weather condition

Active: Radar

Radarsat

Advantages

Not affected by weather and can even penetrate the surface of objects

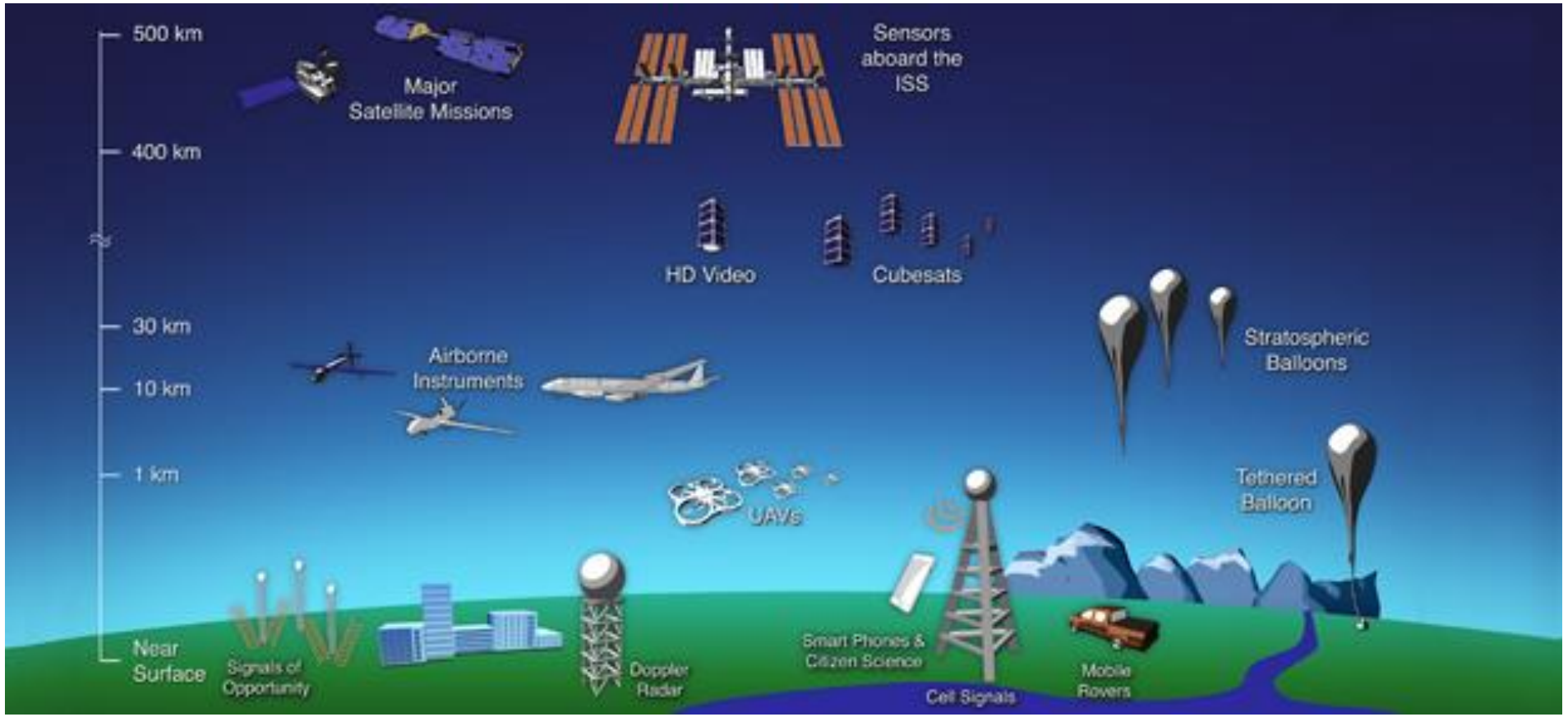
Disadvantages

The process of raw data is much complicated

Reference: Center for Space and Remote Sensing Research, CSRSR

01 Evolution of Sensing Technology

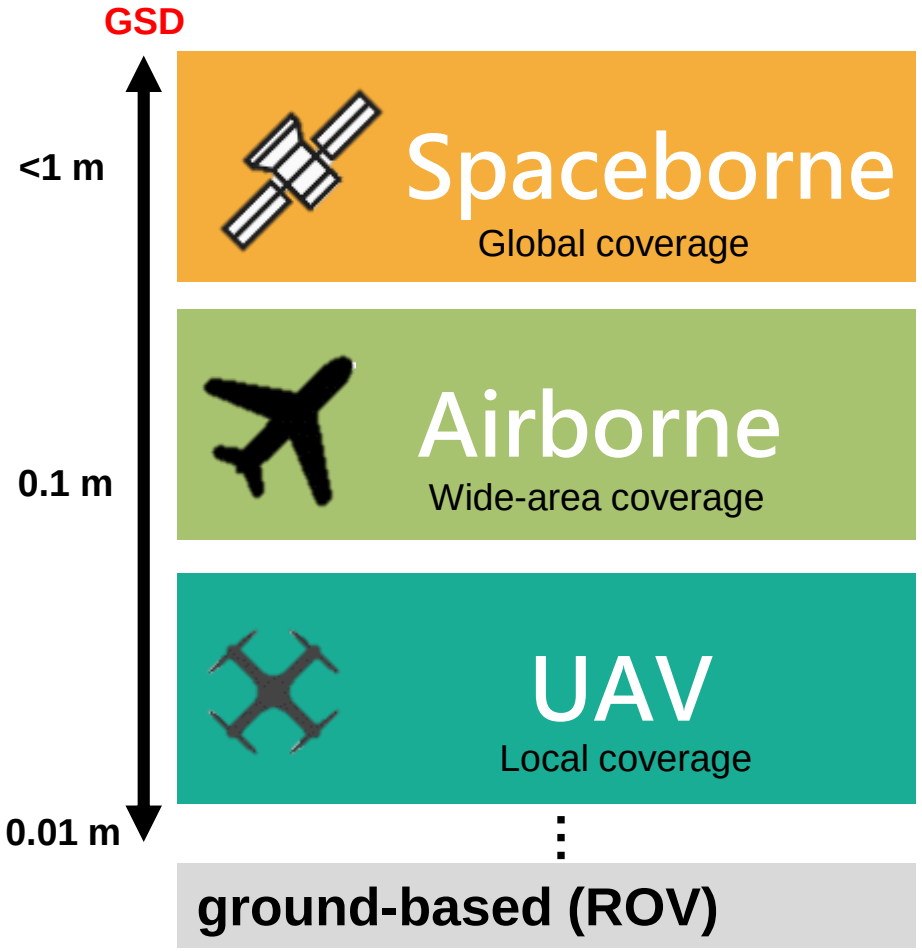
- Different platforms：
  - satellite-borne, airborne, UAV-Borne, vehicle-mounted



Reference: What is Geographic Information Systems (GIS)?

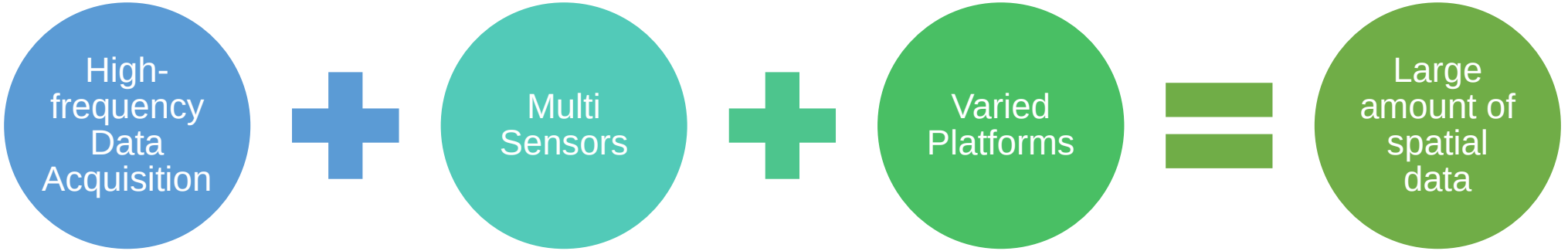
01 Evolution of Sensing Technology

- RS sensors can be equipped on different platforms, including ground-based, airborne, and spaceborne.



- **Advantages : Covering a large area, data collection is not affected by weather.**
- **Disadvantages : Limited by the orbit of the satellite.**
- **Advantages : High resolution, relatively high mobility, equipped with sensor as needed.**
- **Disadvantages : Covering a small area and covered by clouds.**
- **Advantages : Ultra-high resolution, high maneuverability (free flight path planning), and equipped with sensor as needed.**
- **Disadvantages : Covering a very limited area.**

01 Evolution of Sensing Technology

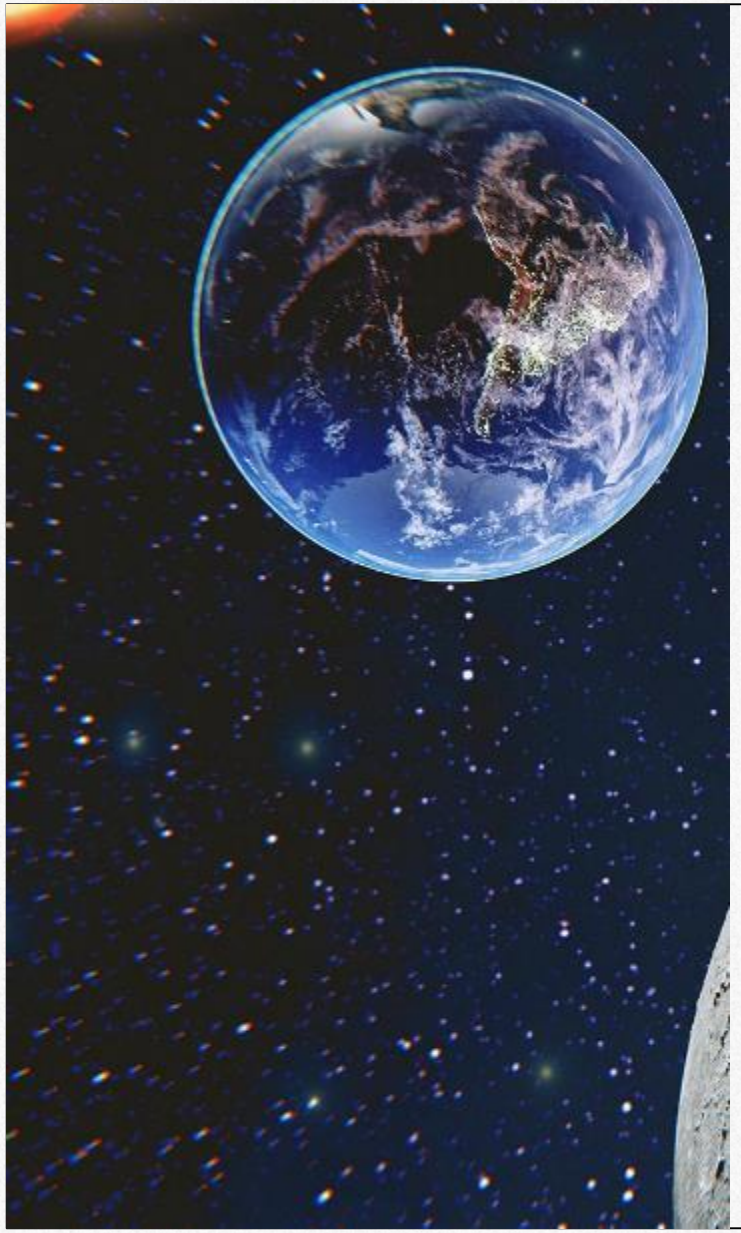


Up to several MHz

Image, Laser, Radar, Multi-spectral

Ground, aerial, and space

Huge information to be analyzed!



02
Artificial Intelligence

Task：Find Jen-Yu Han

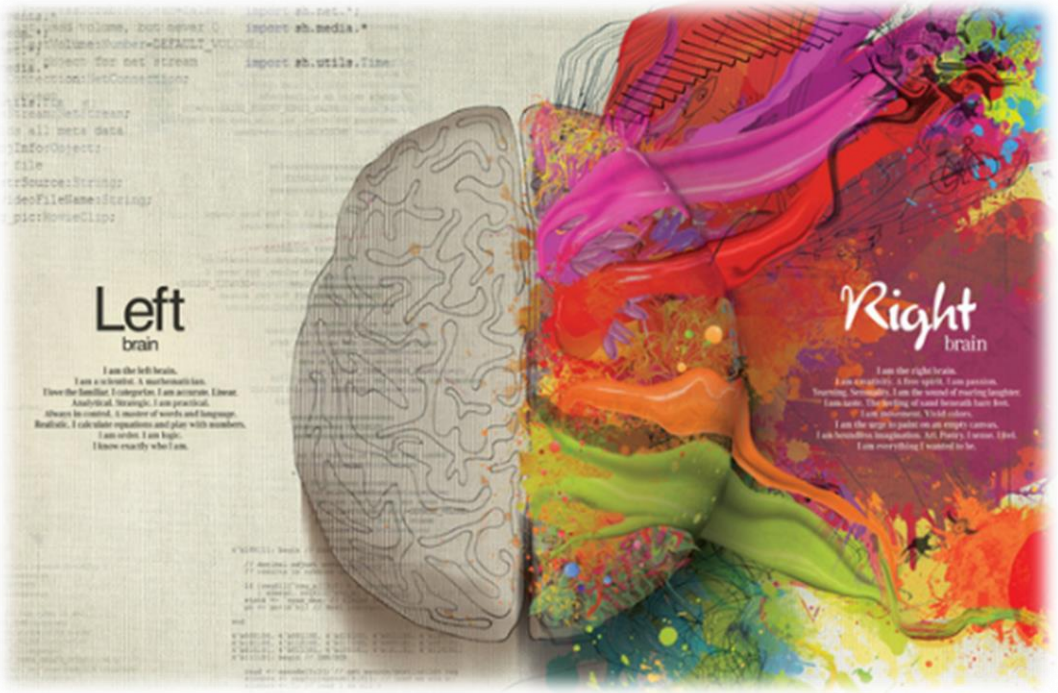
Task：Find Jen-Yu Han

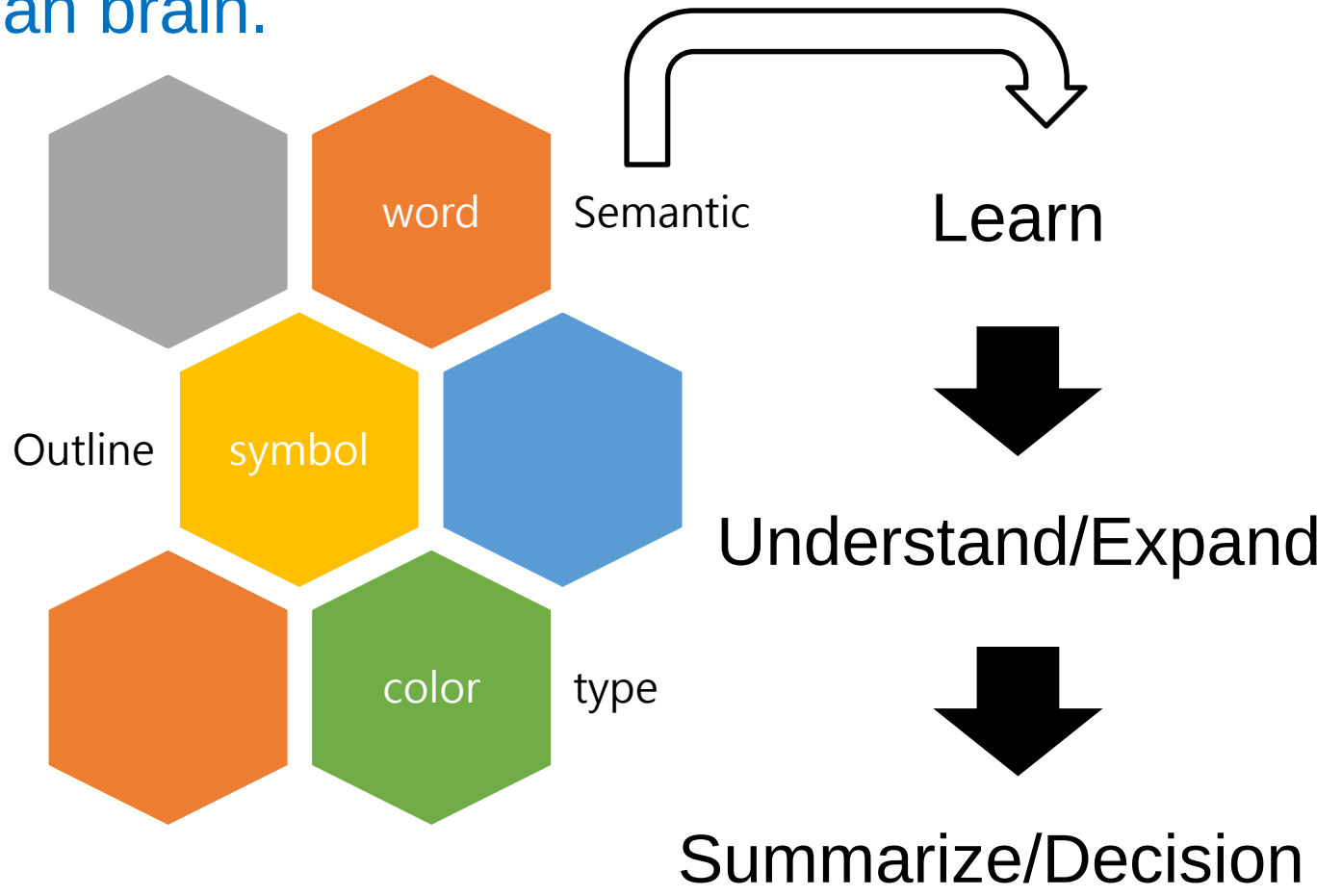
Task：Find Jen-Yu Han

02 Introduction to AI

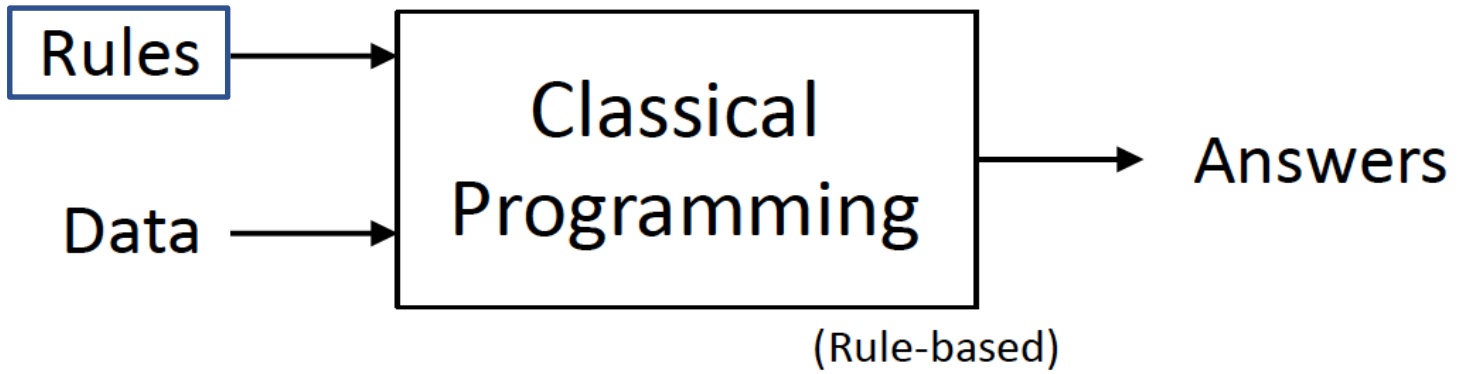
Machine Learning

Let machines replace some of the functions of the human brain.

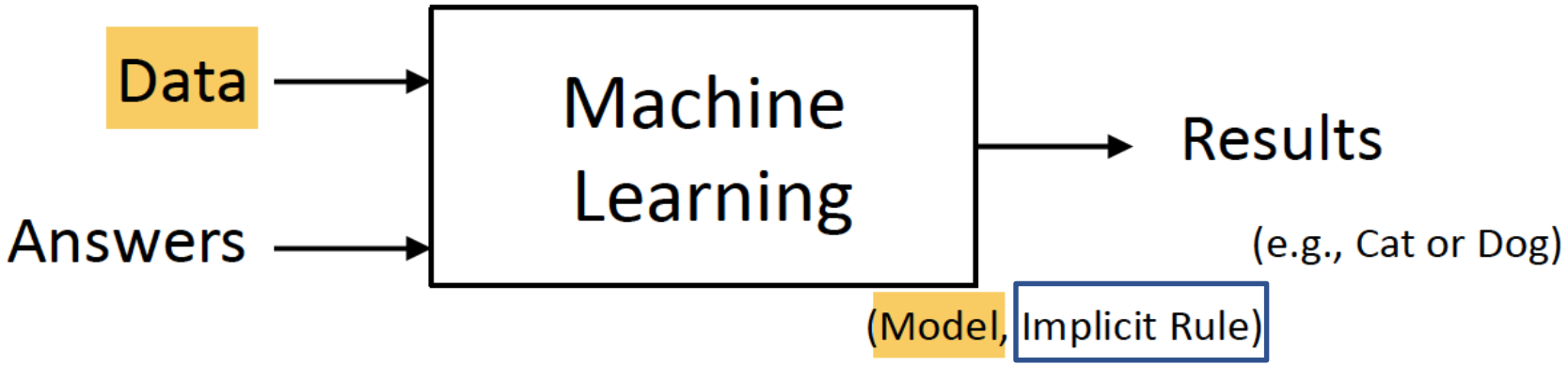




Classical Programming vs ML

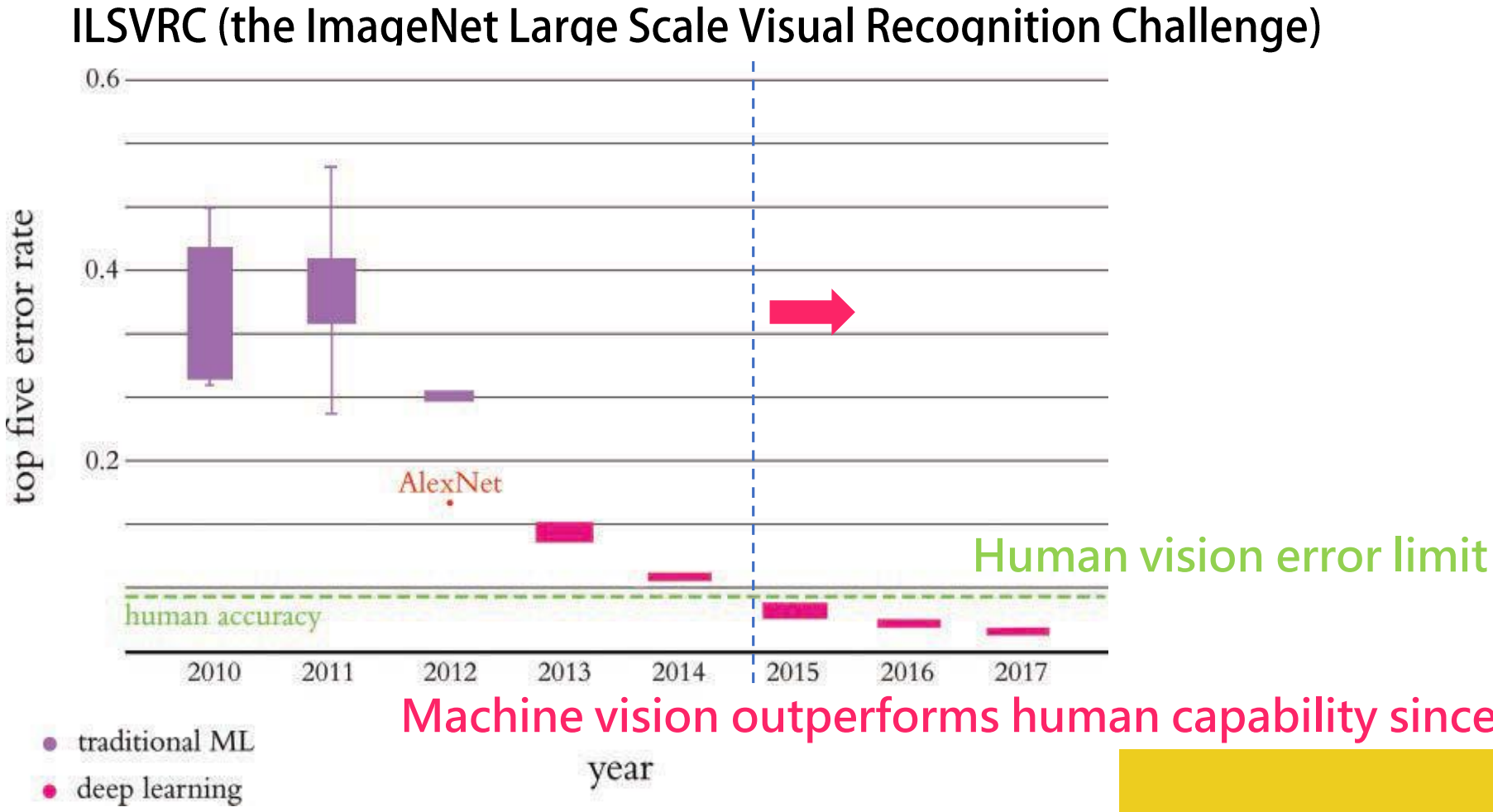


Machine Learning



02 Introduction to AI

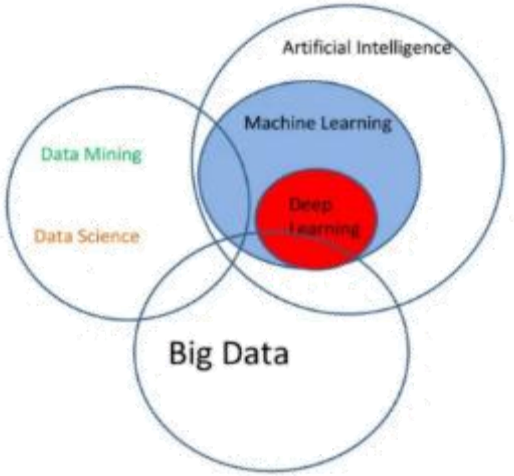
- Computer vision based on deep learning has already surpassed the limits of human eyesight.



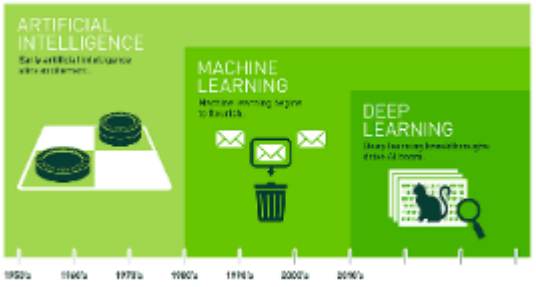
02 Introduction to AI

☐ Various terminologies concerning AI

	Machine Learning (ML)	Deep Learning (DL)	Ensemble Learning
Method	1. Supervised Learning 2. Unsupervised Learning 3. Reinforcement Learning	1. CNN 2. Regions with CNN (R-CNN) 3. Faster RCNN 4. Schematic Segmentation 5. RNN 6. LSTM	1. AdaBoost 2. XGBoost
Application	• Image and voice recognition • Computer vision, medical diagnosis • Prediction, classification,	• Voice assistant • Autonomous driving • Data augmentation • Image segmentation • Recommendation and email response system	

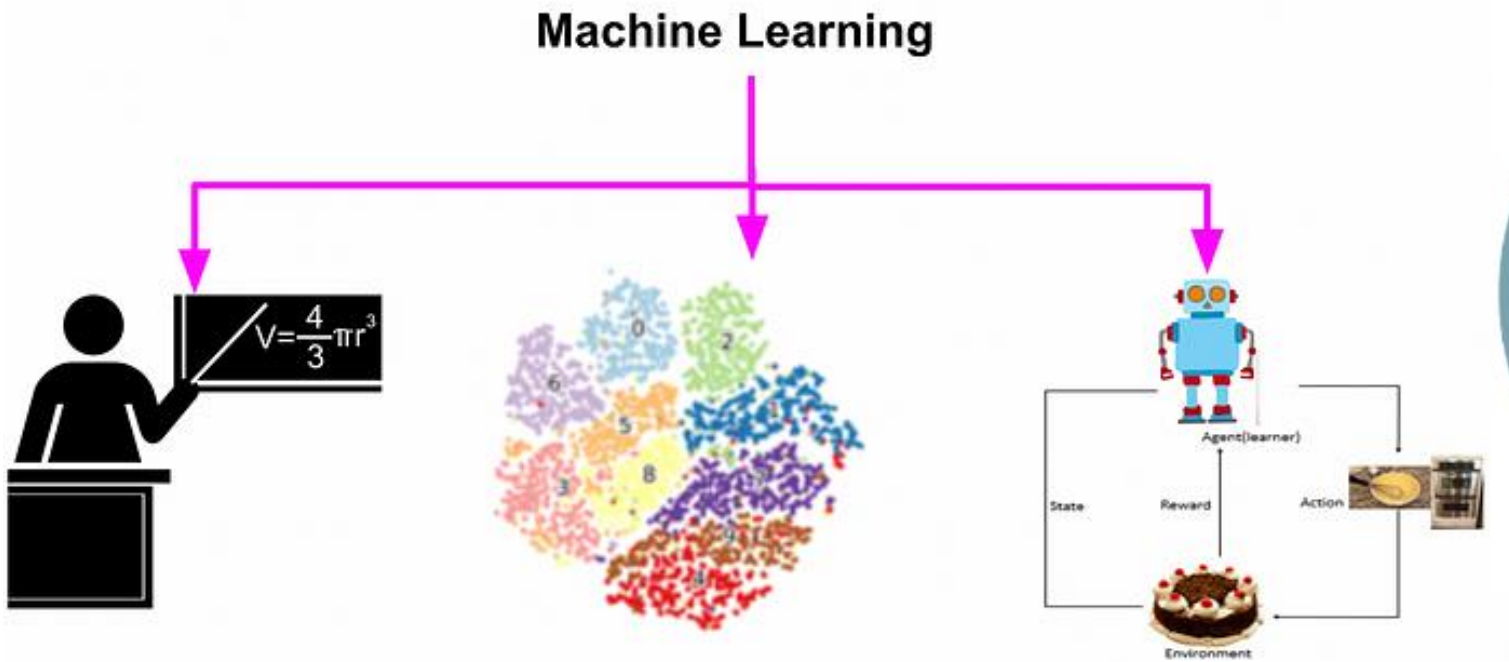


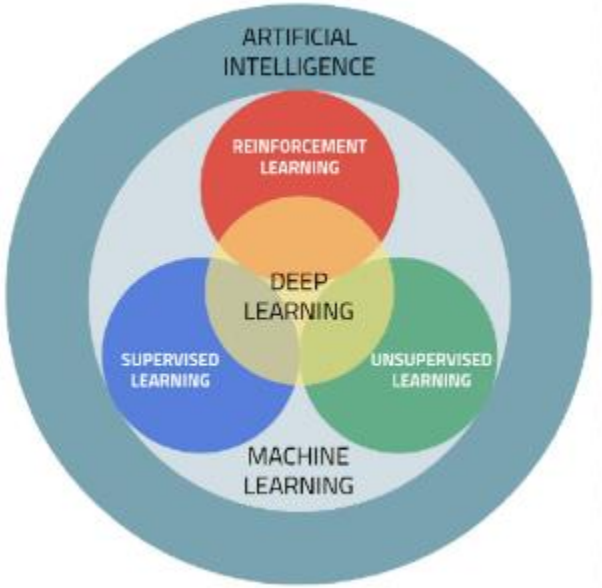
AI ≧ ML ≧ DP



ref : nVIDIA

02 Introduction to AI



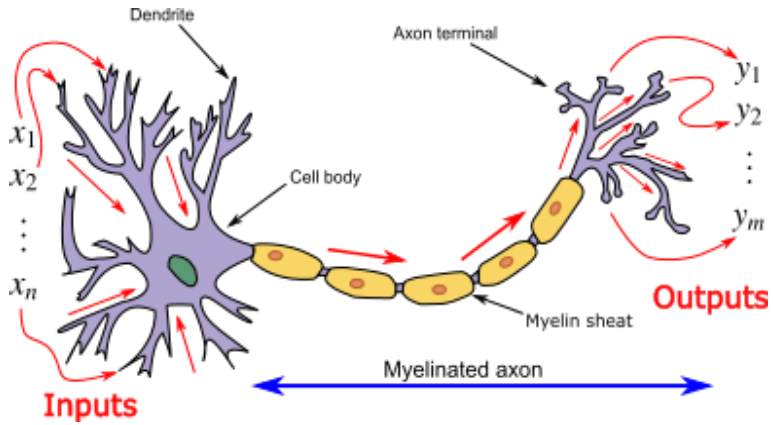


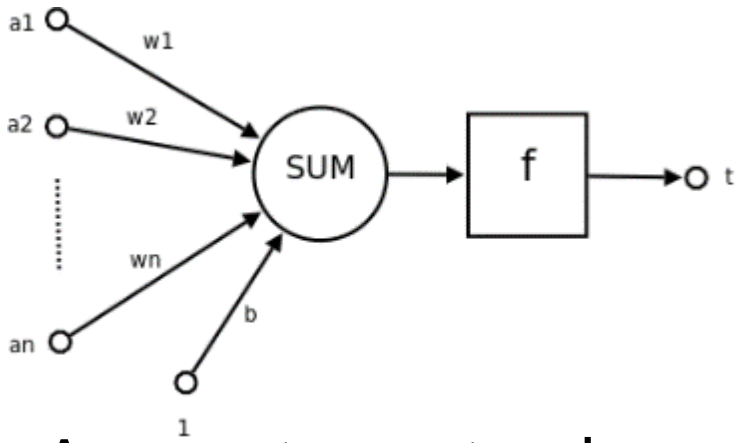
Supervised Learning	Unsupervised Learning	Reinforcement Learning
Dataset features need to be labeled	No labels, no predictions	Need feedback, not direct labels
Linear Regression、Naive Bayes、Decision Tree…	k-means、DBSCAN、dimension reduction…	Google AlphaGo (2016)

https://arshren.medium.com/supervised-unsupervised-and-reinforcement-learning-245b59709f68
https://www.silresyne.top/products.aspx?cname=supervised+learning+in+artificial+intelligence&cid=141

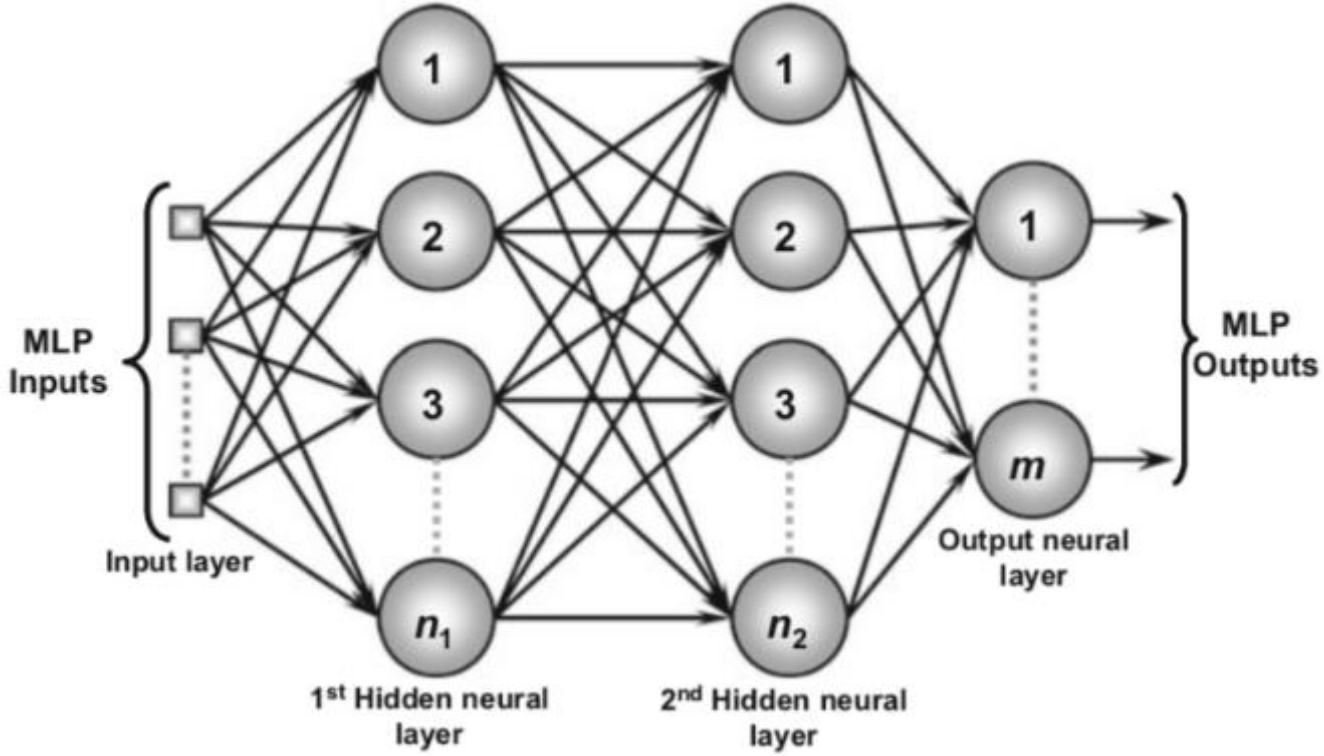
02 Deep Learning

Introduction to Neural Networks





A perceptron network

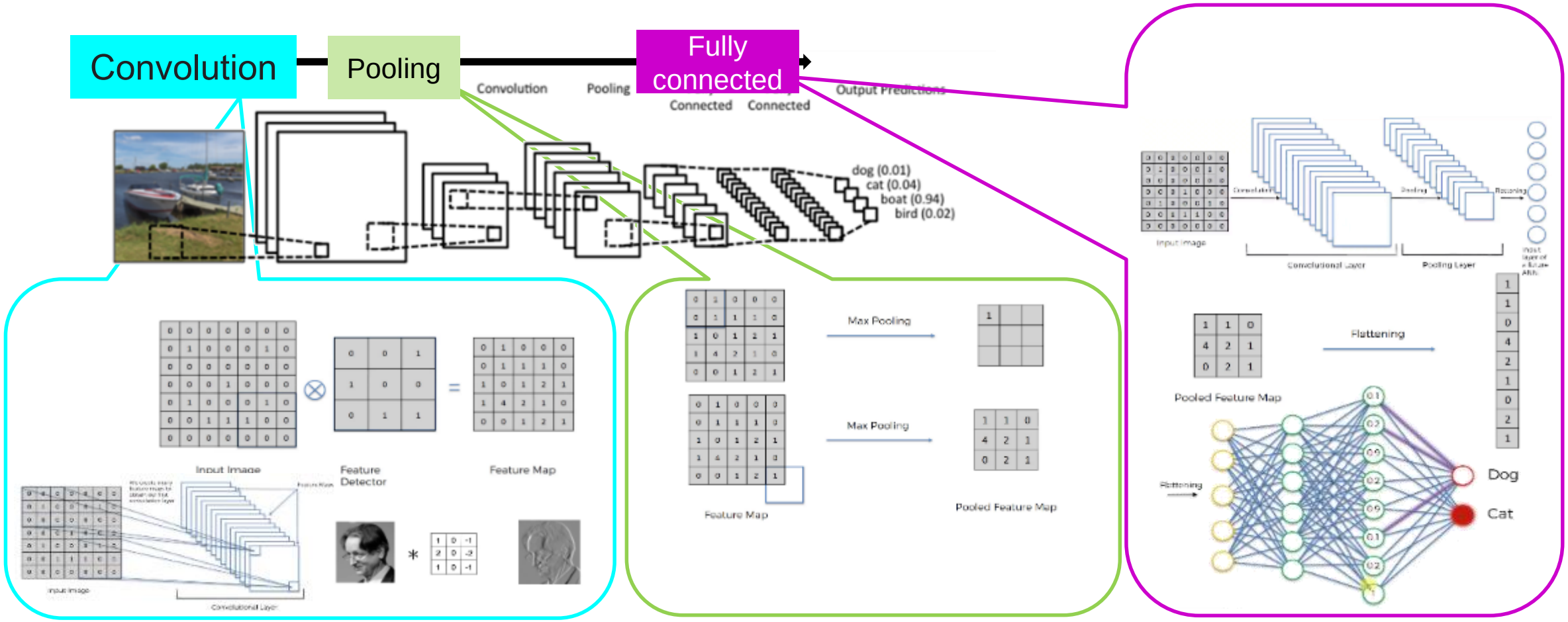


A multilayer perceptron network

Chuin-Shan Chen. “Introduction to machine learning and deep learning." (2019).

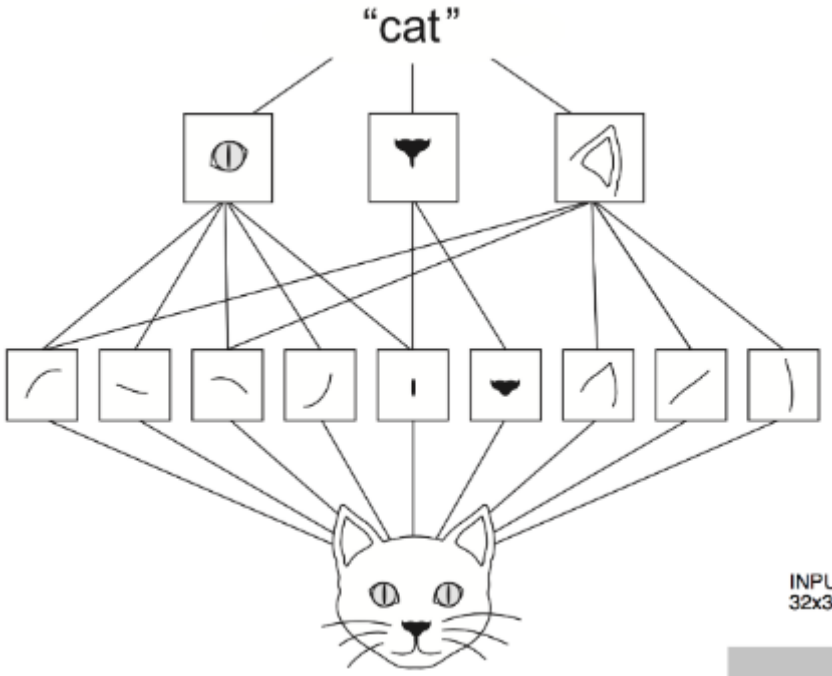
02 Deep Learning

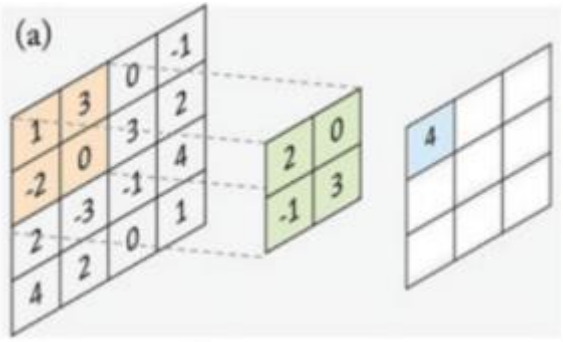
◘ Deep Learning：Convolutional Neural Network (CNN)



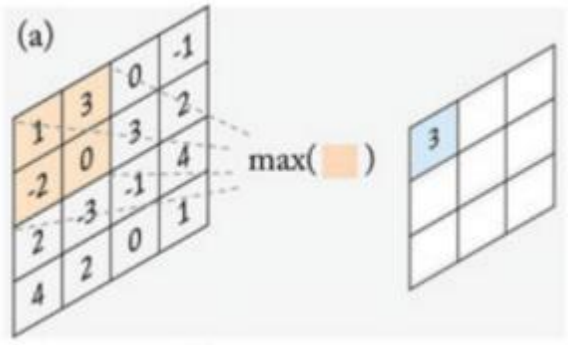
02 Deep Learning

Deep Learning：Convolutional Neural Network (CNN)

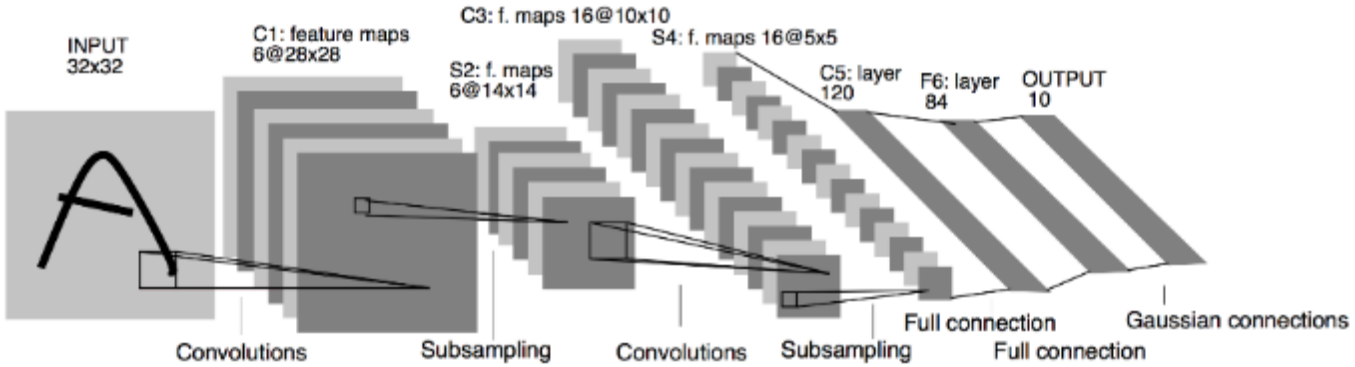




Convolution operation



Subsampling operation

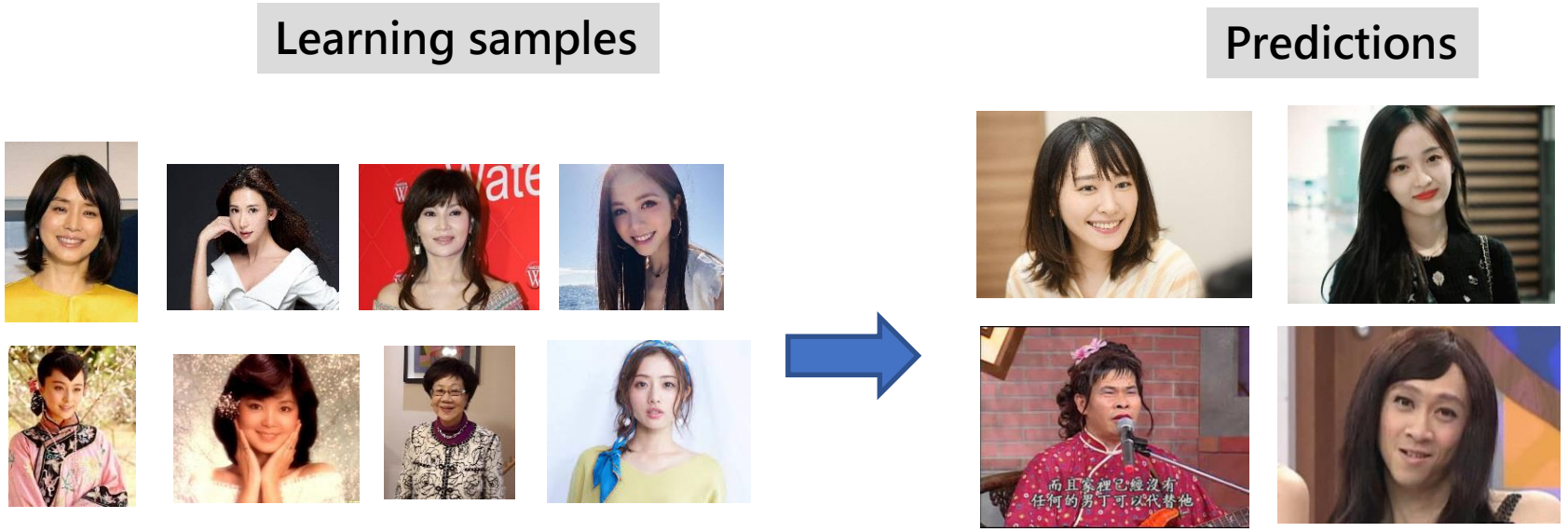


02 Deep Learning

Machine Learning vs. Deep Learning

Single neural layer（ML）：uses simple (explicit) features for learning.

Multi-layer neural network（DL）：uses multi-layer (implicit) features for learning.

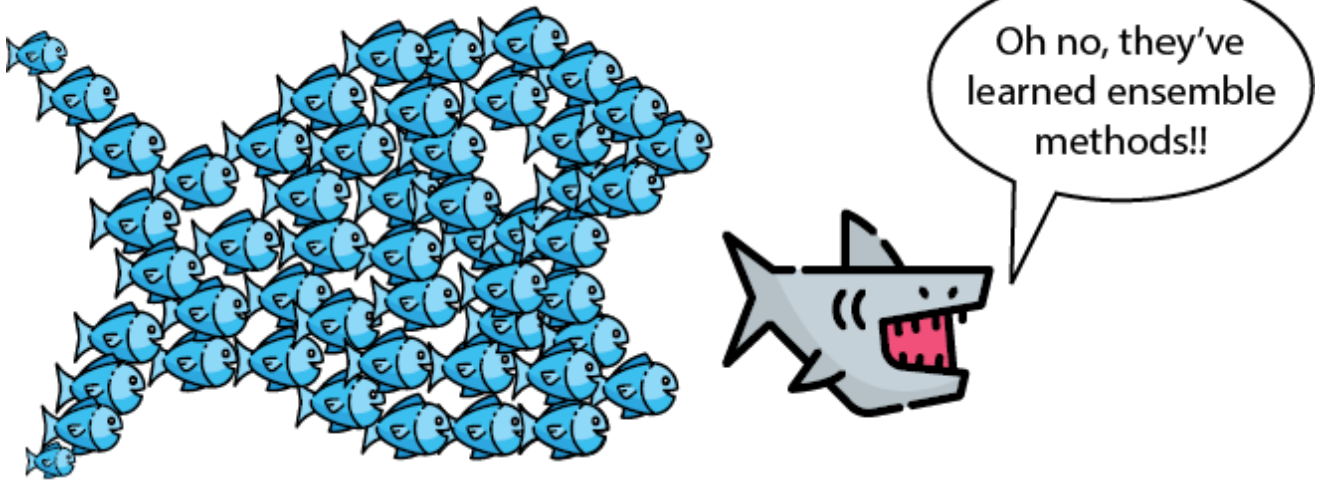


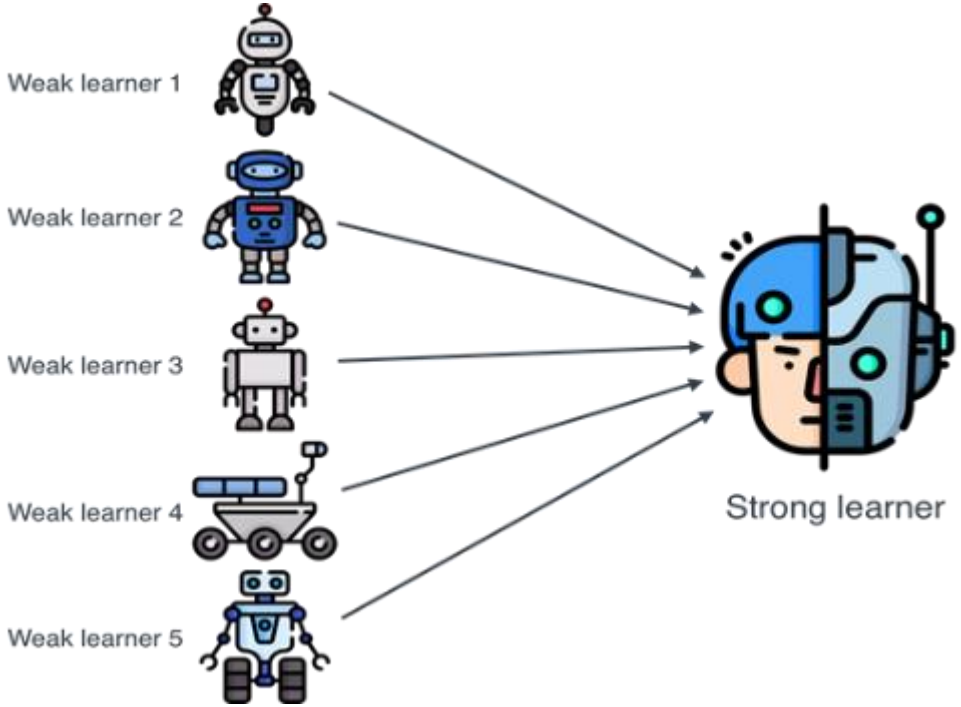
Mimics human's perception (intelligence)

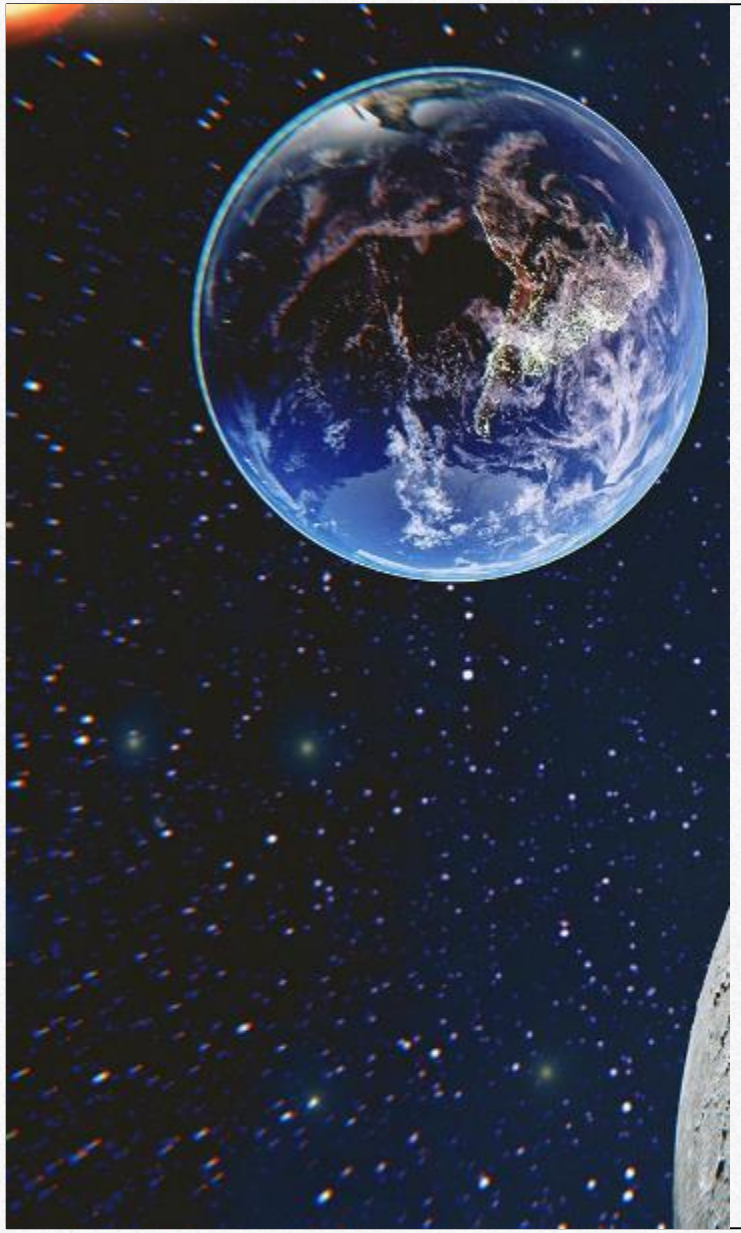
02 Ensemble Learning

◘ Ensemble Learning :

In statistics and machine learning, ensemble methods use multiple learning algorithms to obtain better predictive performance than could be obtained from any of the constituent learning algorithms alone.







03 Application Cases

UAV Application

SAR Application

UAV Applications for

Intelligent river analysis

01

3D modeling from UAV images

02

River hydraulic analysis

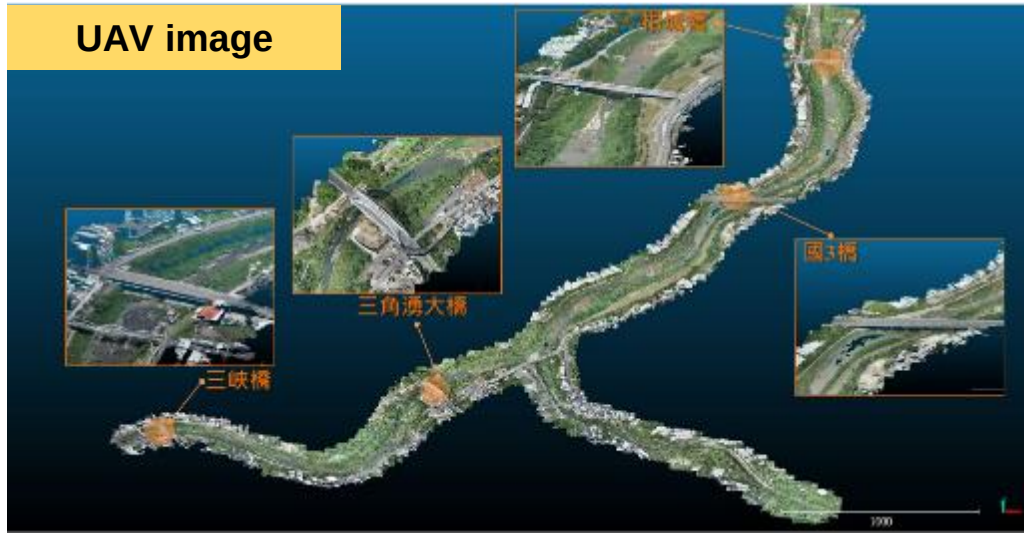
03

Flood simulation and early warning

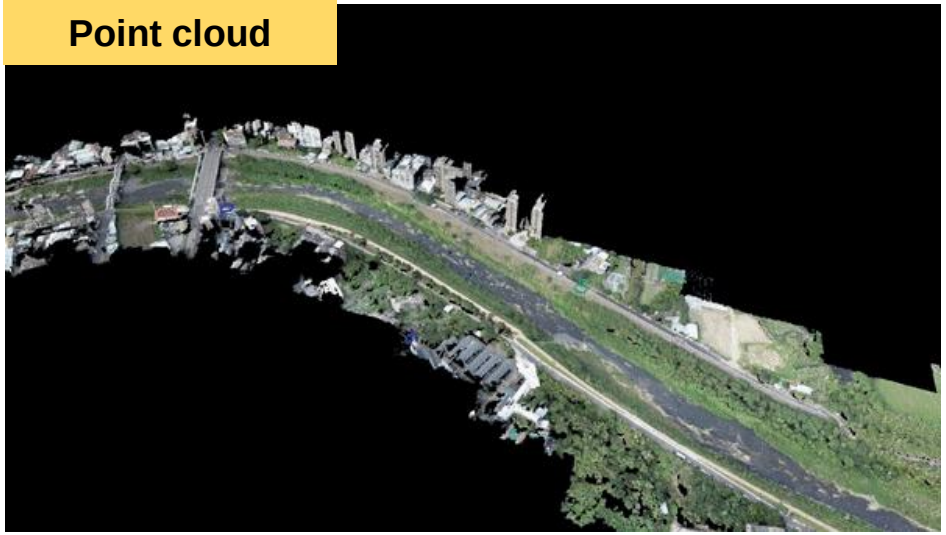
03 Intelligent river analysis

- 3D modeling from UAV images.

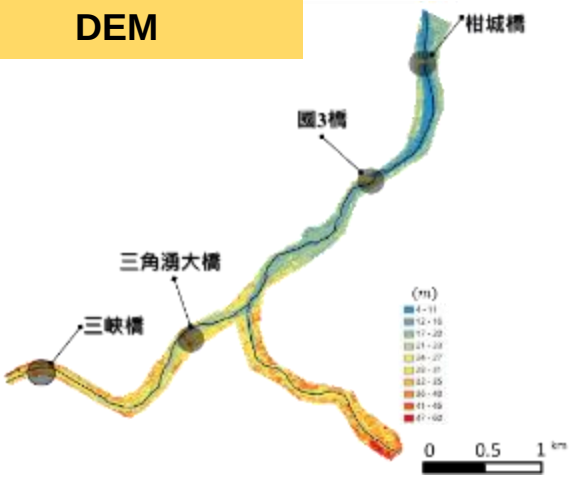
UAV image



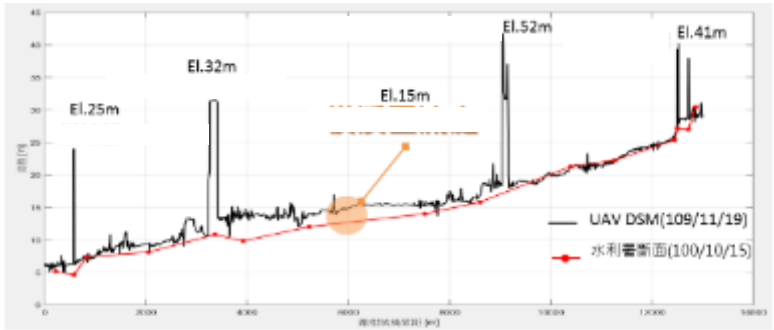
Point cloud



DEM



River slope & bridge high



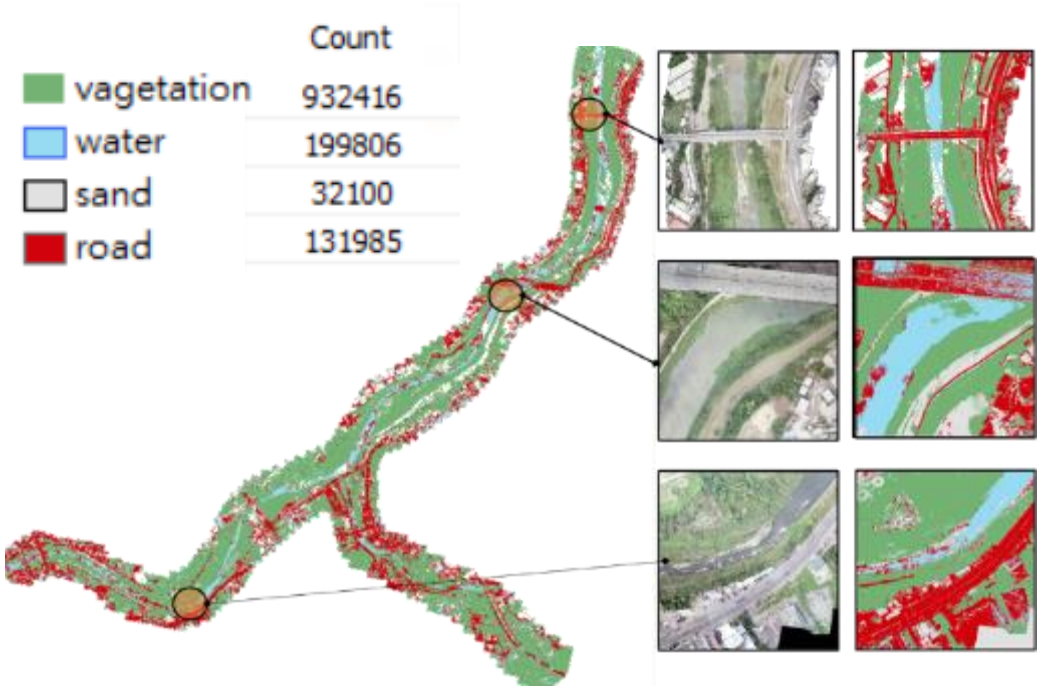
slope : $\frac{30-6M}{13000M} \times 100\% = 0.2\%$

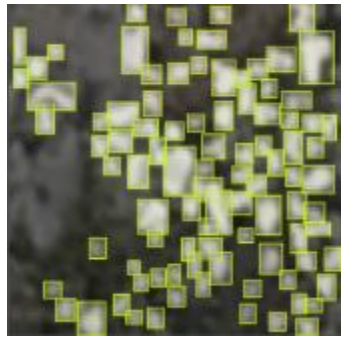
slope : $\frac{27M-15M}{3000M} \times 100\% = 0.4\%$

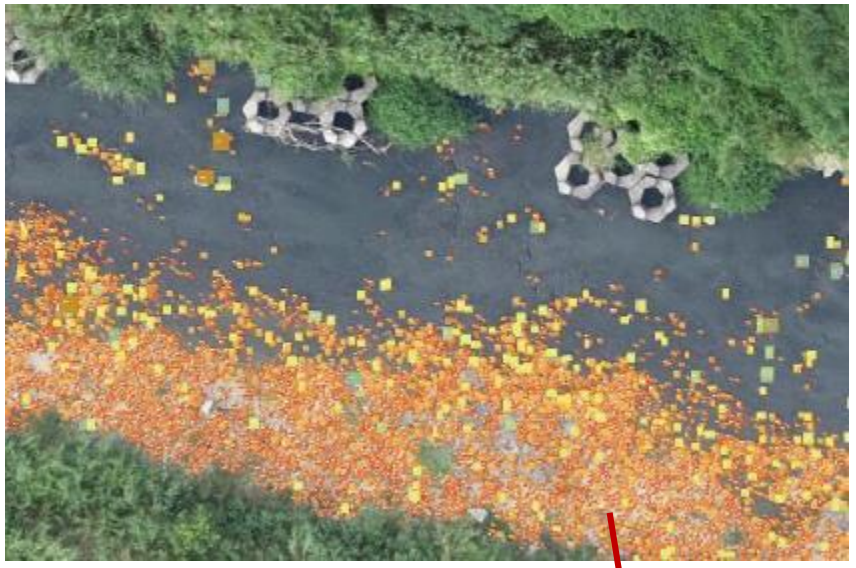
03 Intelligent river analysis

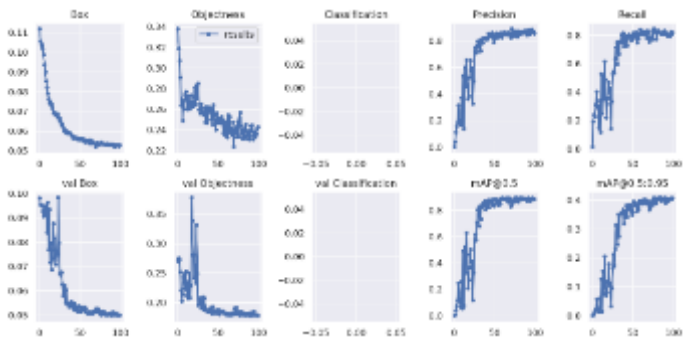
- Intelligent analysis techniques for UAV image.

Image detection → **Size analysis**







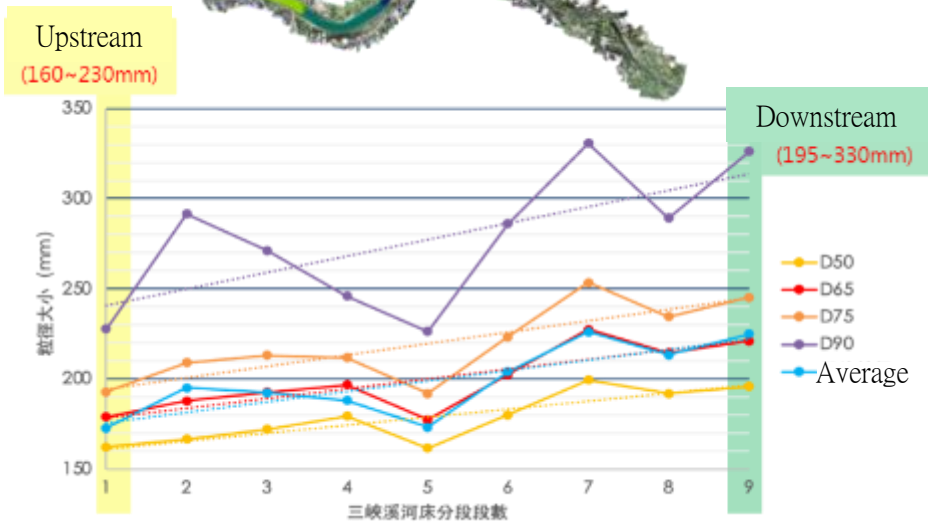


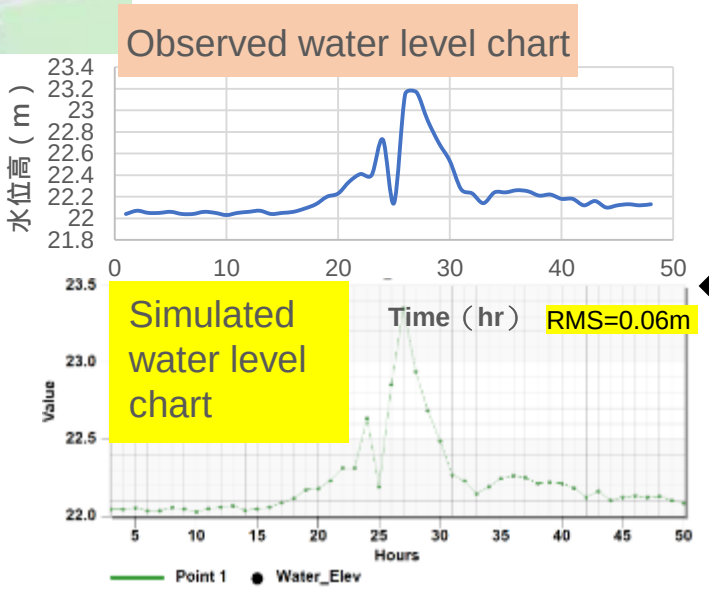
YOLOv5 training result

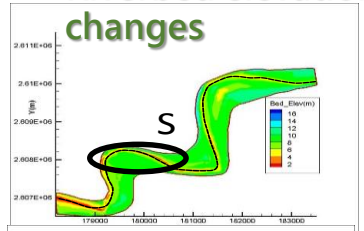
Visualization of riverbed grain size dimensions

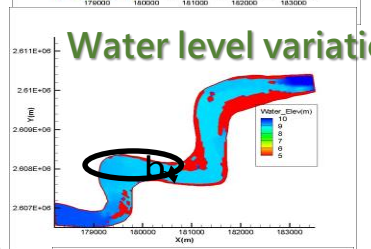
03 Intelligent river analysis

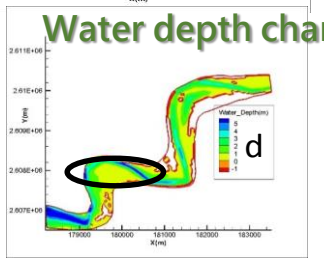
- Hydrological and hydraulic simulation: Calculating the Manning's n value, so that hydrological and hydraulic analyses can be achieved.





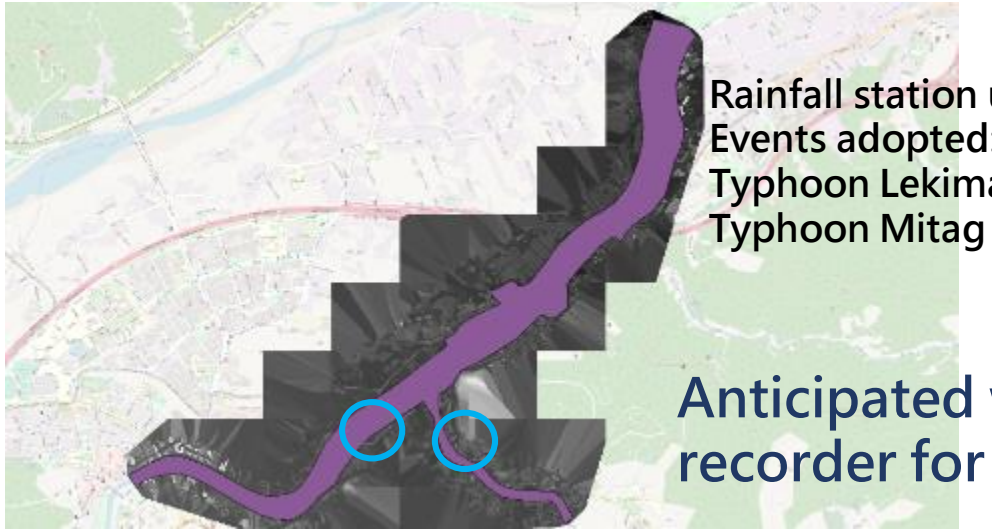






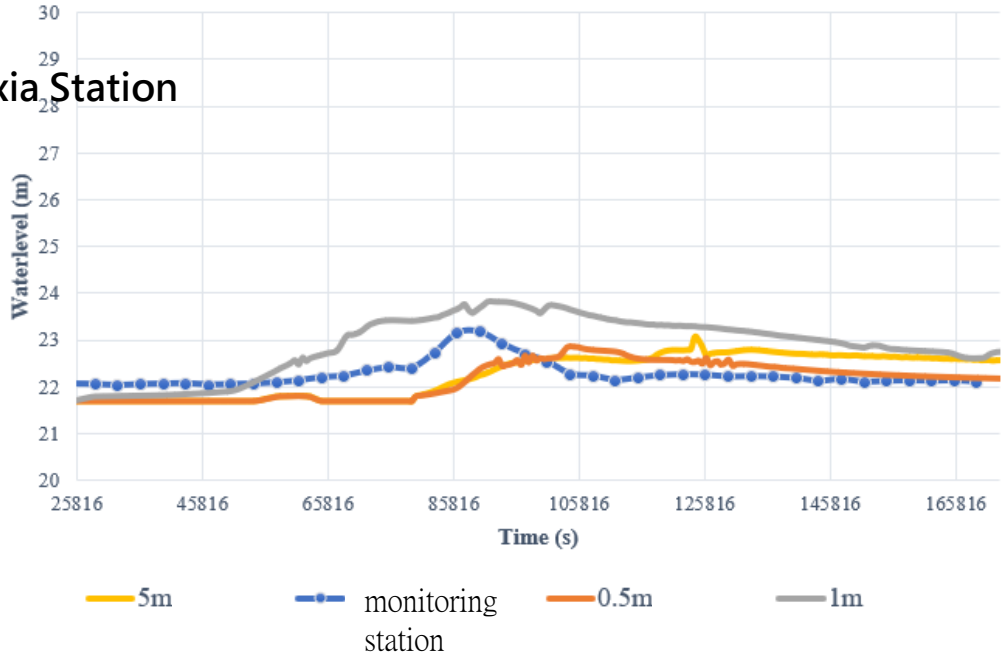
03 Intelligent river analysis

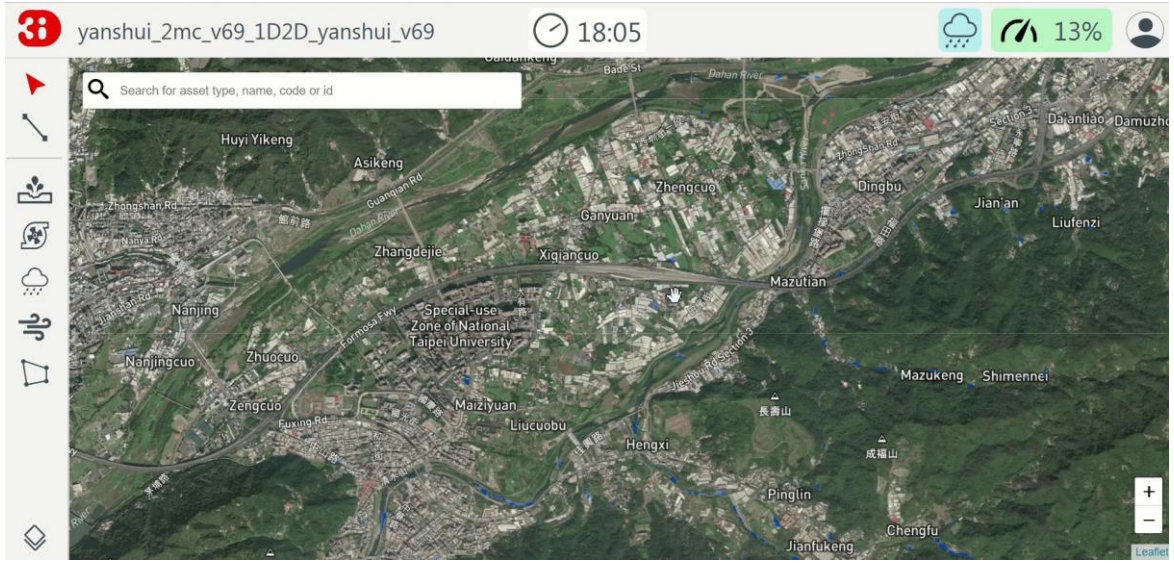
☐ Flood simulation and early warning



Rainfall station utilizes data from Sanxia Station
Events adopted:
Typhoon Lekima on 2019/08/08-8/10
Typhoon Mitag on 2019/09/30-10/01

Anticipated water level recorder for verification





Errors for estimating water level

0.5m	1.66%
1m	3.26%
5m	2.15%
20m	15.32%

UAV Application for

Land development project

+

DEM

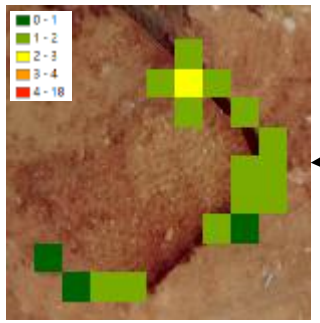
Digital Orthophoto Map

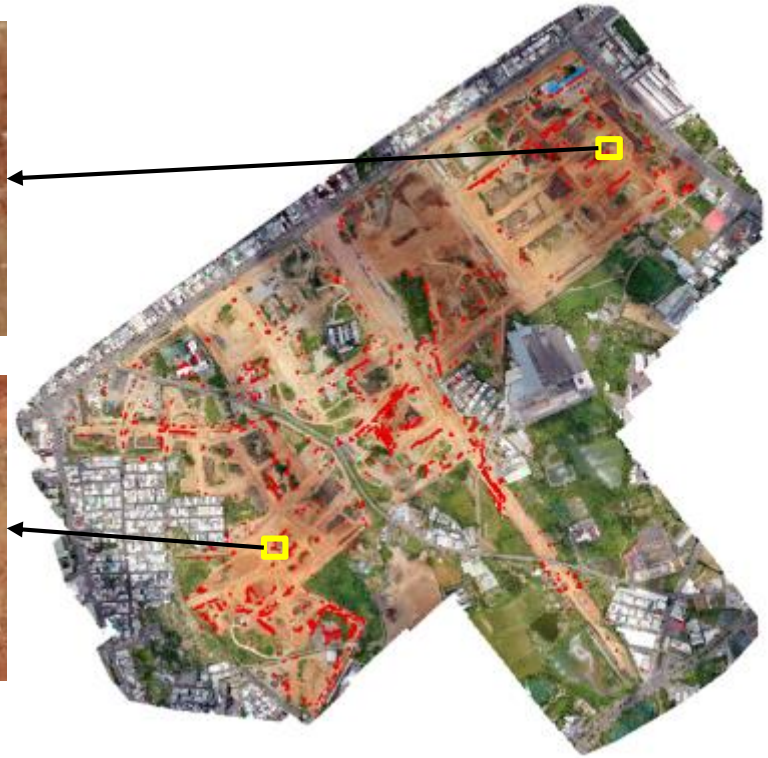
1. SVM : Create land cover change maps.
2. Yolo-v7 : Object detection, detecting target objects.
3. U-net : Semantic segmentation, category every pixel in an image.

03 UAV for land development project

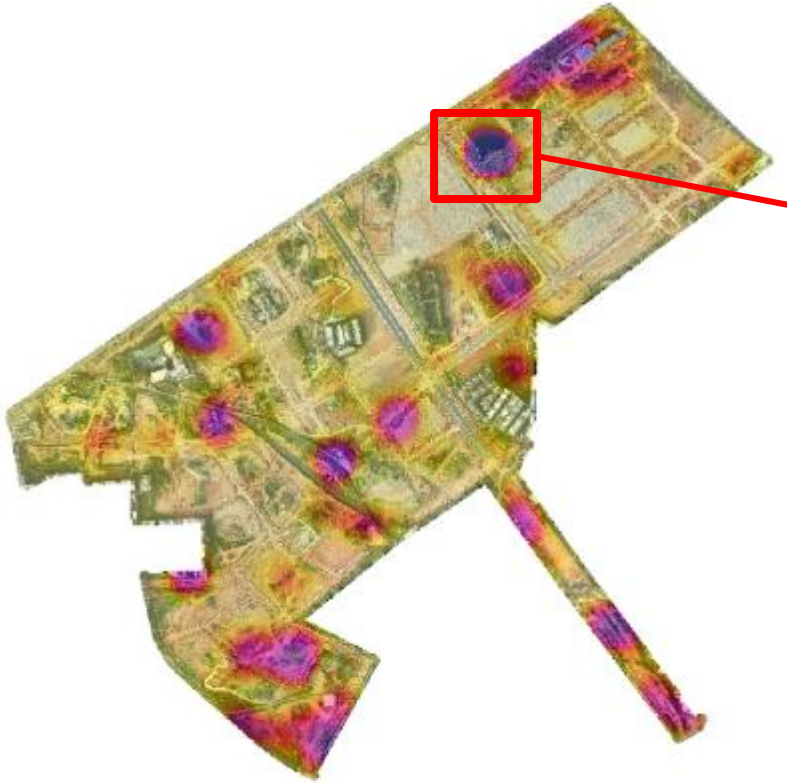
Case 1：Geomorphological Analysis for Large Height Difference Detection.

- This method enables the automated identification of regions with considerable elevation discrepancies and potential safety hazards (orthomap +DSM).





Large Height Difference Detection Map



Potential location of elevation difference

03 UAV for land development project

Case 2：Object Detection for Sewer Manhole and Shared Pipe.

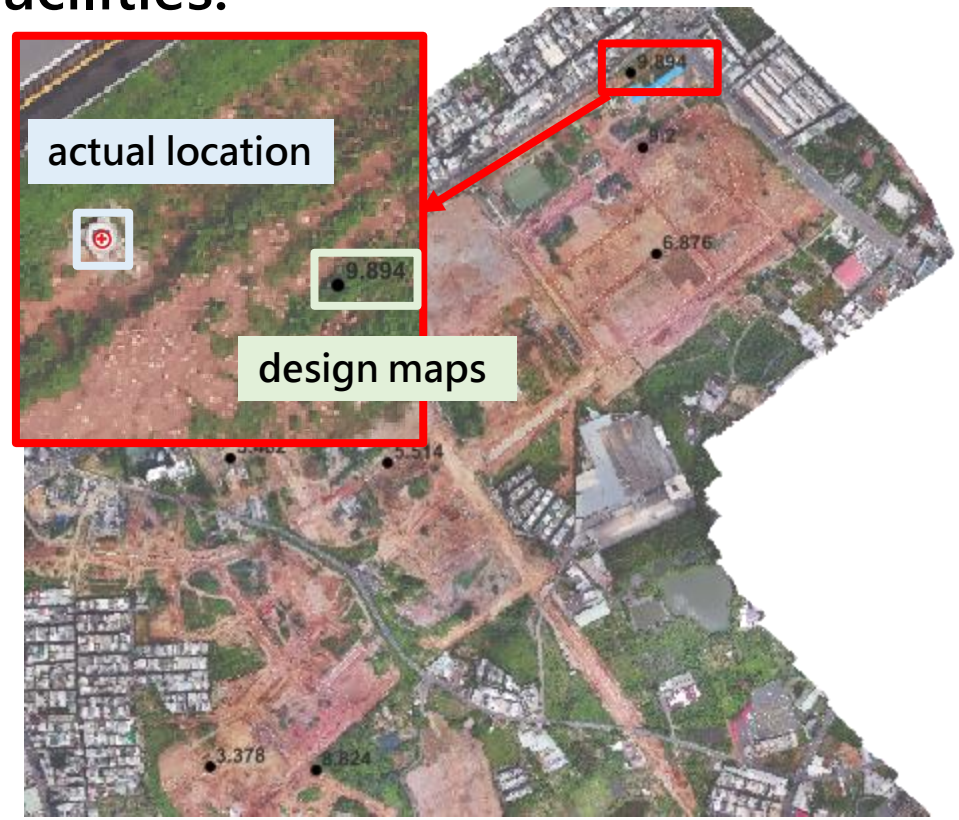
- Using ortho-images and the object detection algorithm - Yolov7, detect the manhole construction locations.
- By integrating the design maps of the construction area, verify if there are any discrepancies in the positions of the constructed facilities.

Shared pipe

Sewer manhole

Model accuracy assessment

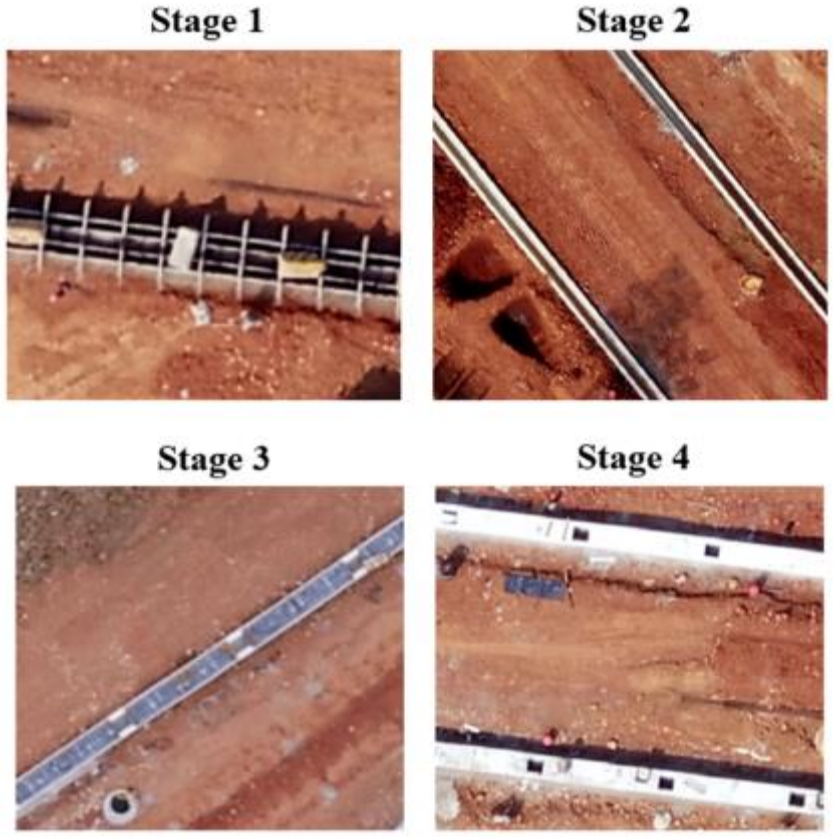
	Precision	Recall	F1	mAP@0.5
Sewer manhole	0.91	0.83	0.87	0.89
Shared pipe	0.85	0.81	0.83	0.90



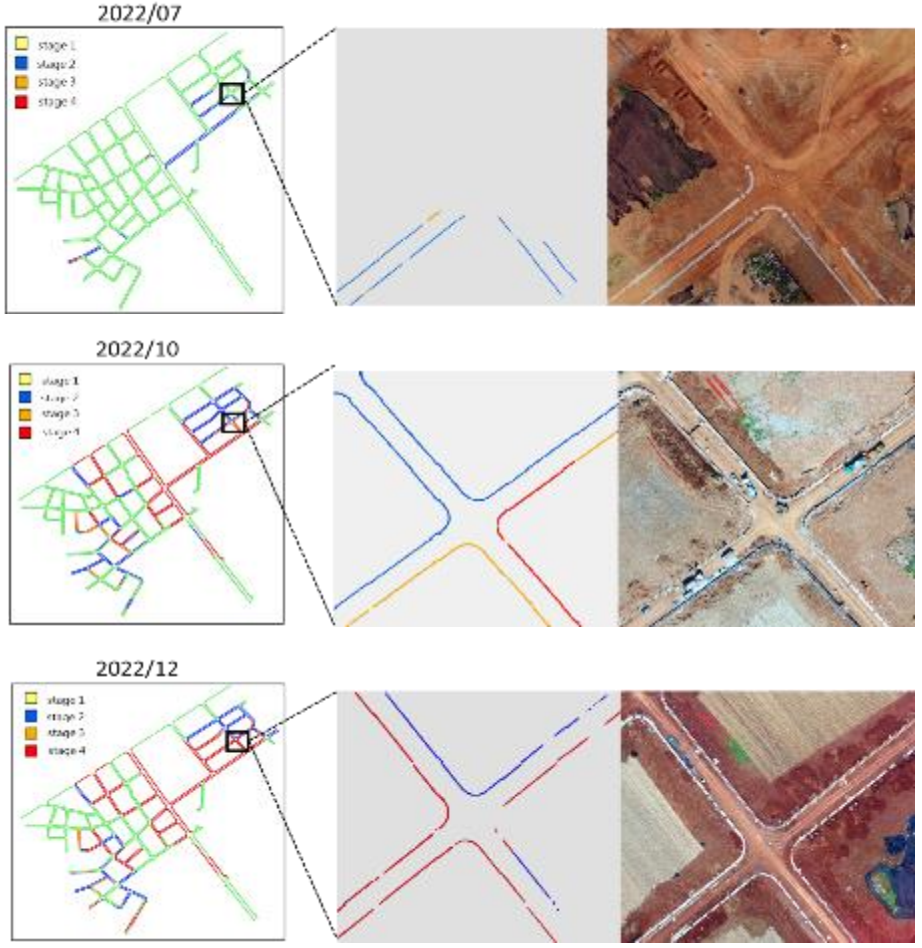
03 UAV for land development project

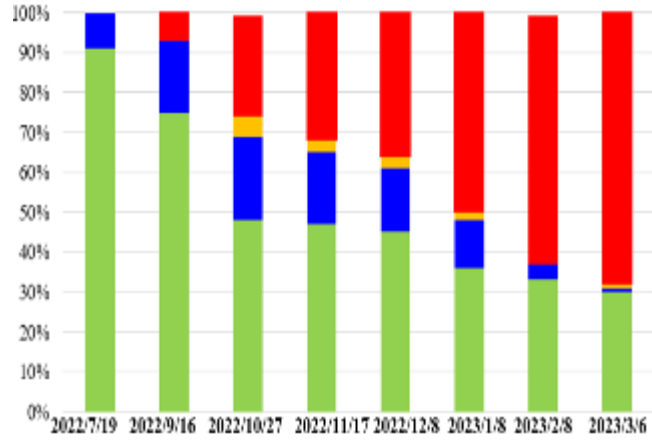
Case 3：Image Segmentation for Roadside Ditch.

- Using multi-period UAV images, U-net can automatically detect the different construction progress of roadside ditches.



Four different stages of roadside ditch construction progress

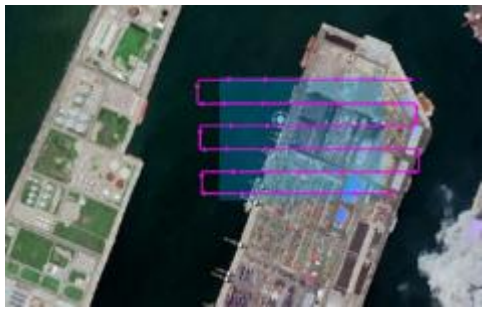


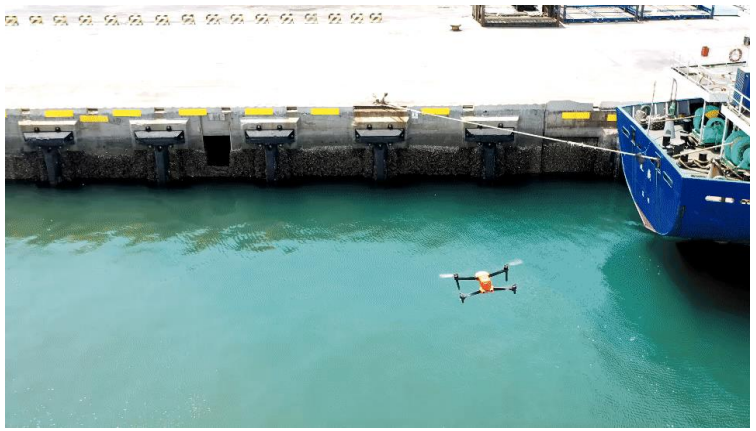


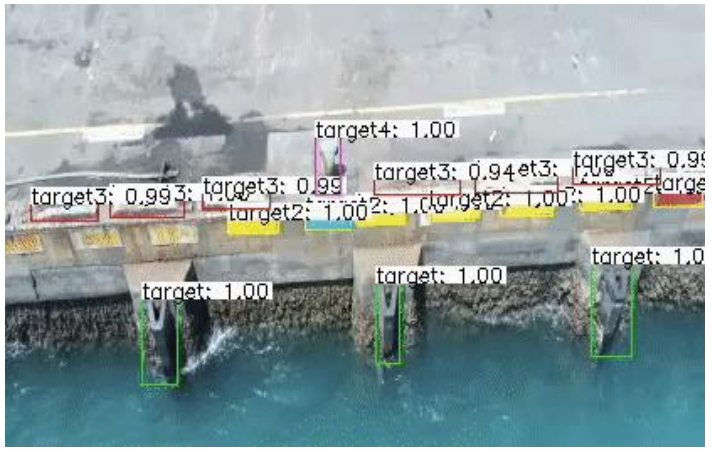
Construction progress statistics for roadside ditch

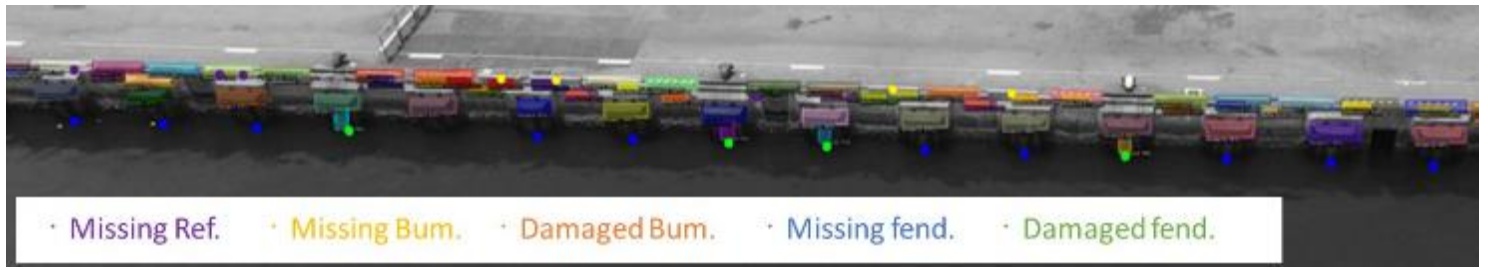
03 UAV for Port facility inspection

- Use UAV images to automatically detect the damaged (missing) facilities.



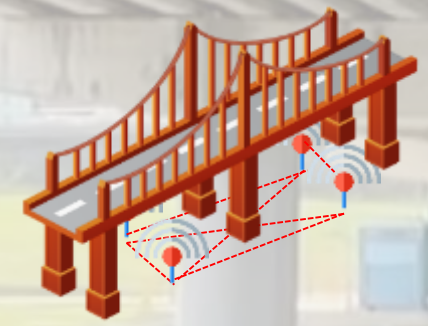






UAV Application for

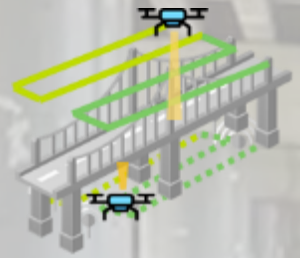
Smart bridge inspection



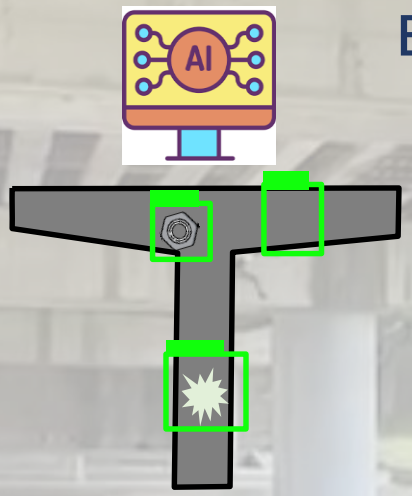
Under bridge positioning environment setup

1

UAV flight path planning



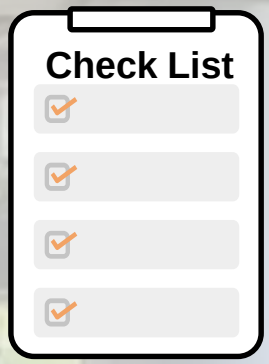
2



Detected bridge component deterioration with AI

3

Bridge assessment scale



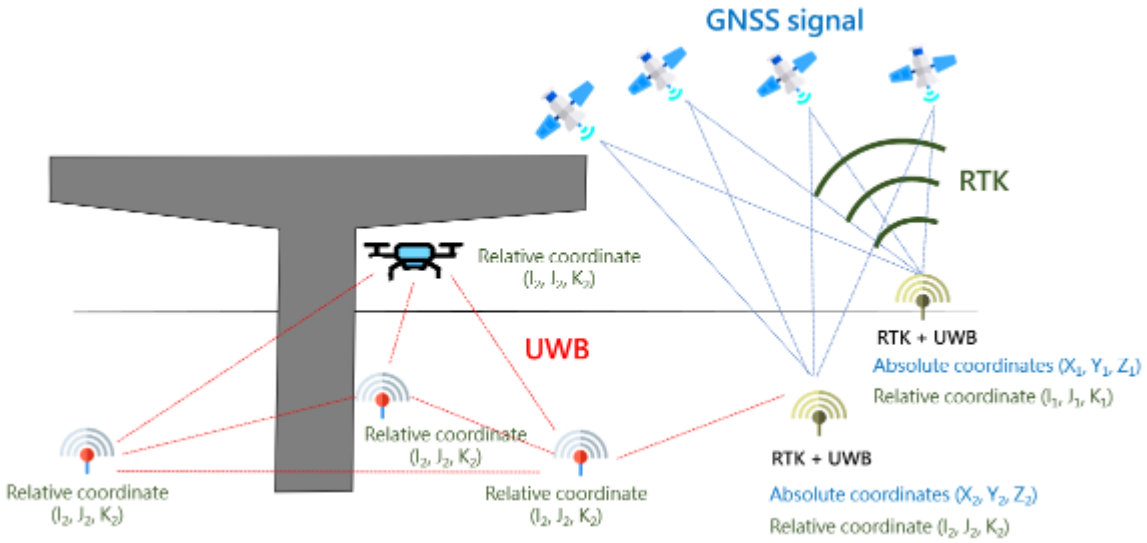
4

Bridge inspection platform

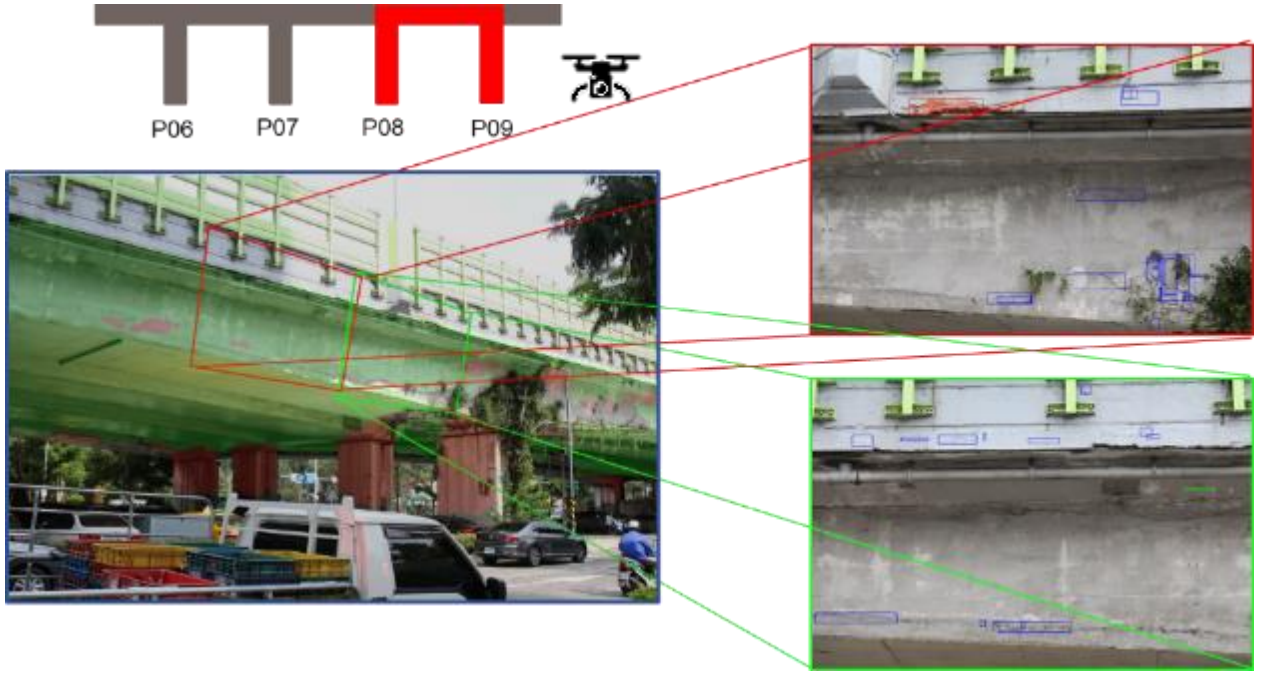
5

03 Smart port inspection

Mobile Sensing



Smart Inspection



Exposed reinforcing steel

crack

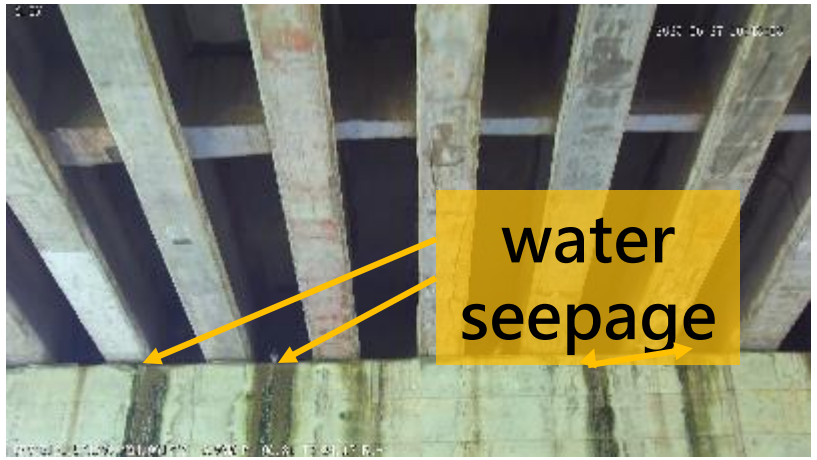
03 Smart port inspection

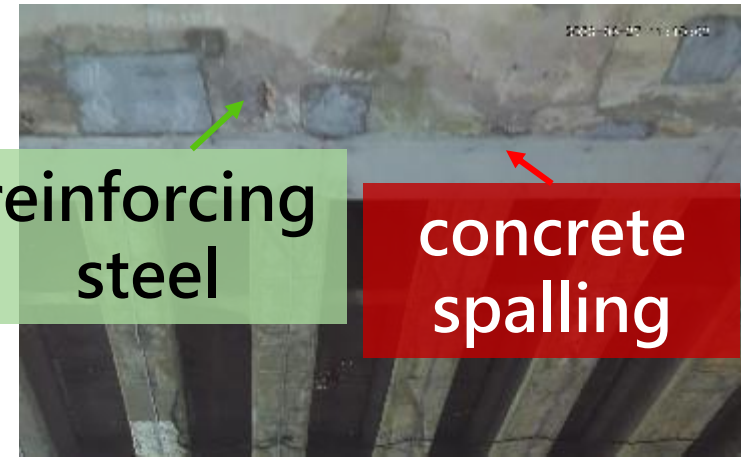
- Field inspection of in-service bridge：

- UAV image：

03 Smart port inspection

- Detected bridge component deterioration with AI.





Blue：crack；Red：concrete spalling；Green：reinforcing steel ；Orange：water seepage

03 Smart port inspection

- Connected detection results to bridge assessment scale– DER & U。

檢測項目	位置	編號	D	E	R	U	損壞位置	劣化類型
主梁			1	1	1	1	1G1	concrete spalling

建議維修工法	數量	單位	單價
混凝土修復	1	處	

concrete spalling 1 location，area about 0.04 m^2

檢測項目	位置	編號	D	E	R	U	損壞位置	劣化類型
帽梁			1	1	1	1		water seepage

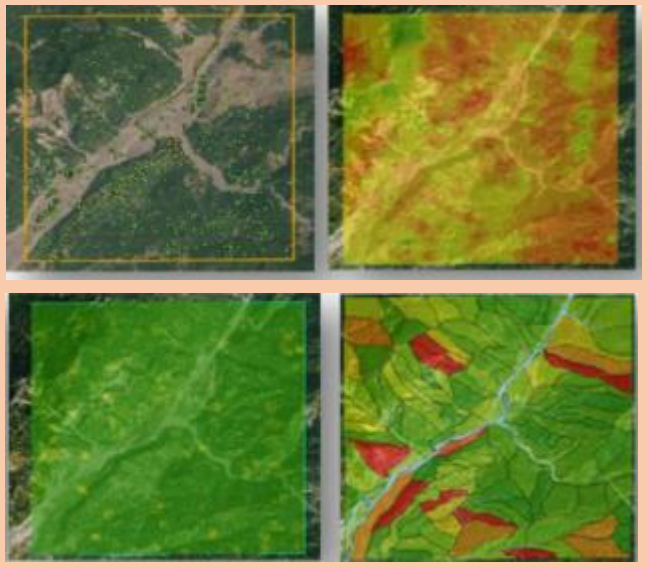
建議維修工法	數量	單位	單價
混凝土修復	2	處	

water seepage 2 locations，
area about 4.0 m^2

Remote Sensing Application for

Landslide Susceptibility Analysis

InSAR



Modern Remote Sensing

Lidar、multispectral imagery

Slope related topographic factors

Precipitation

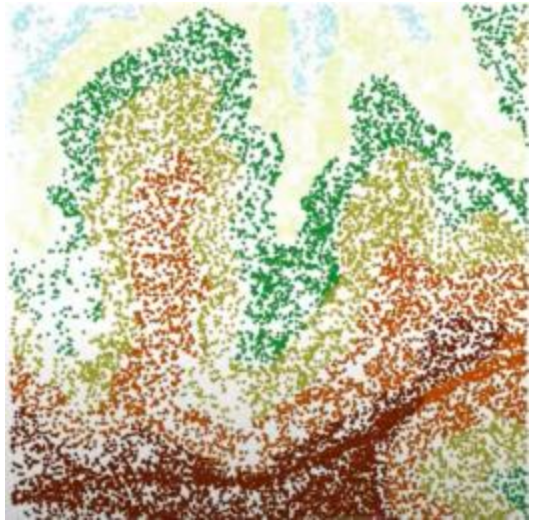
Geologic factors

Machine Learning Algorithm

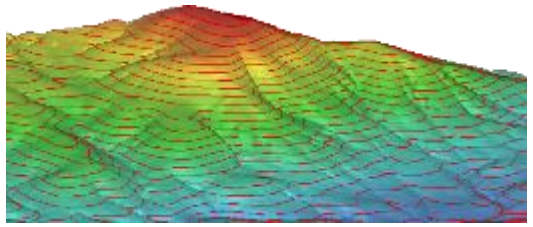
Landslide Potentials

03 Landslide Susceptibility Analysis

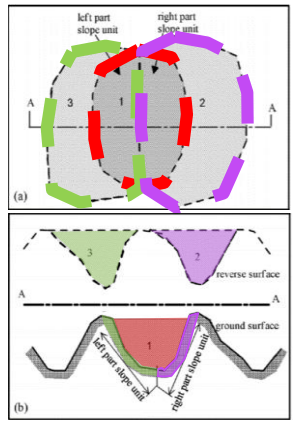
◘ Lidar derived：DEM、Slope、Aspect、Profile curvature



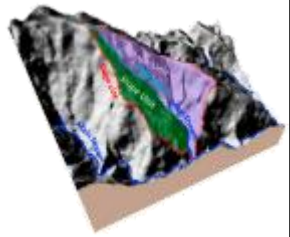
Point cloud from LiDAR

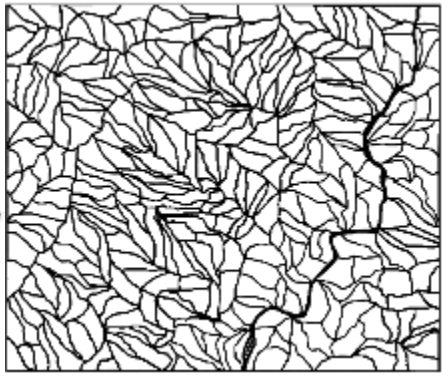


DEM



Overlap method of catchment areas(Xie et al. 2004)

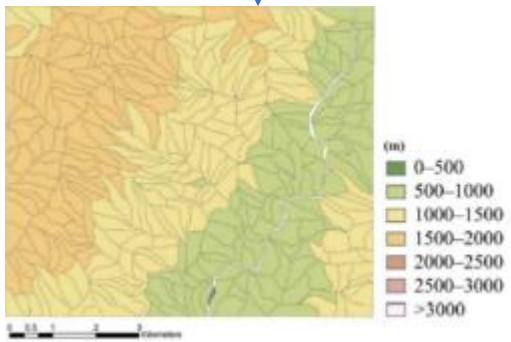




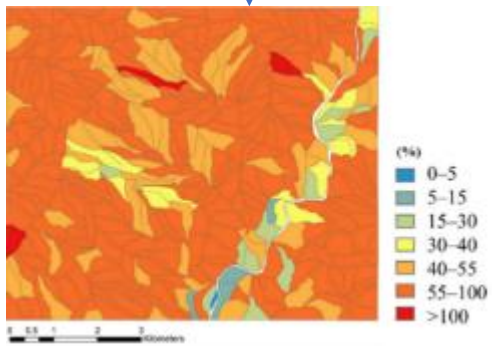
Unit of 3D slope (Tsai et al., 2019)

Defining the minimal unit of slope by drainage system

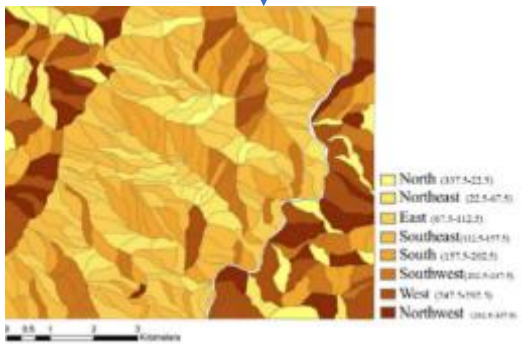
Topographic attribute data



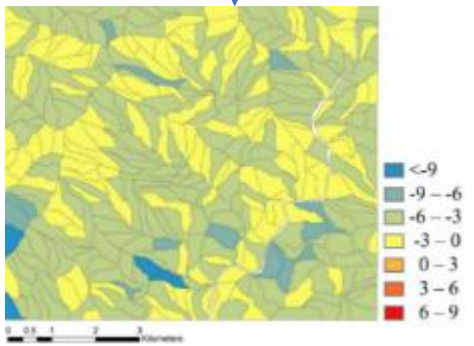
Elevation



Slope



Aspect

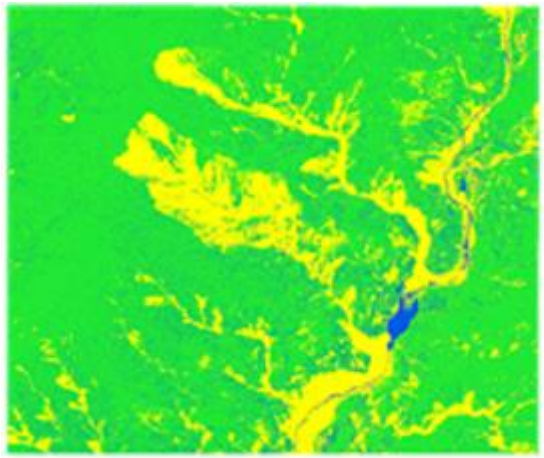


Profile curvature

03 Landslide Susceptibility Analysis

- SPOT image derived land cover factors.

Maximal likelihood classification



SPOT -6、7

Launching time : 2012、2014

Owner: AIRBUS

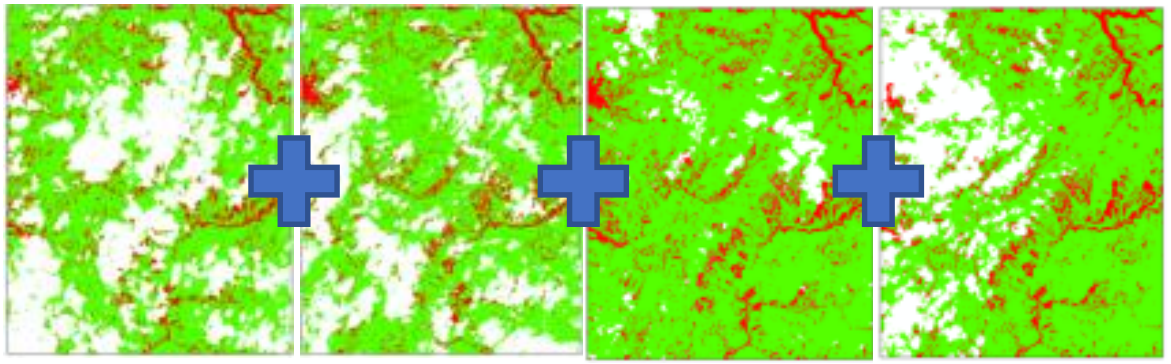
Payload: B, G, R, NIR,

Resolution: 6 m, 1.5 m

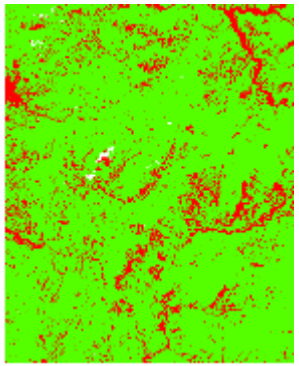
Image sheet: 60 km

Cycling time: 1-3 days

Fusion of adjacent cloudy images

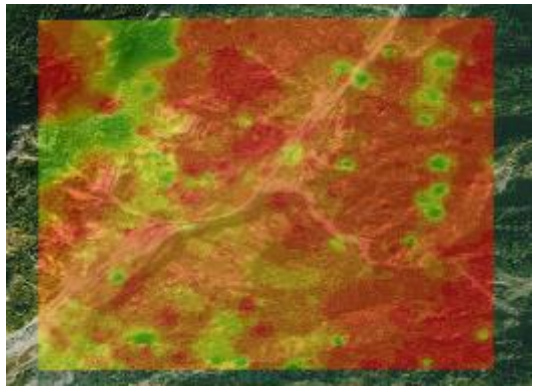


Cloud-free image

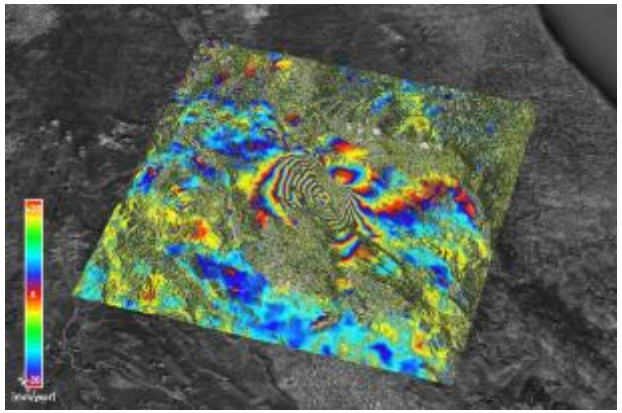


03 Landslide Susceptibility Analysis

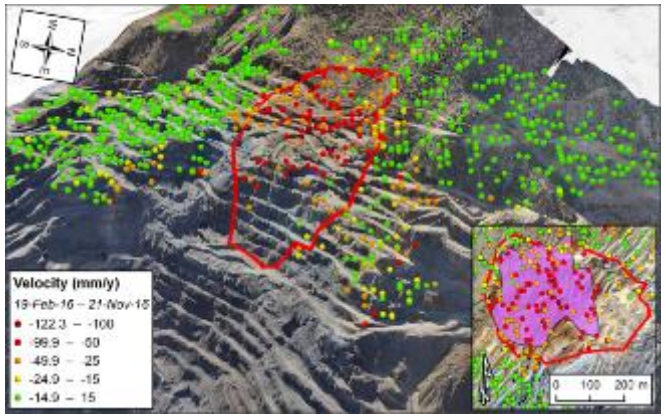
☐ InSAR-derived ground velocity gradient：



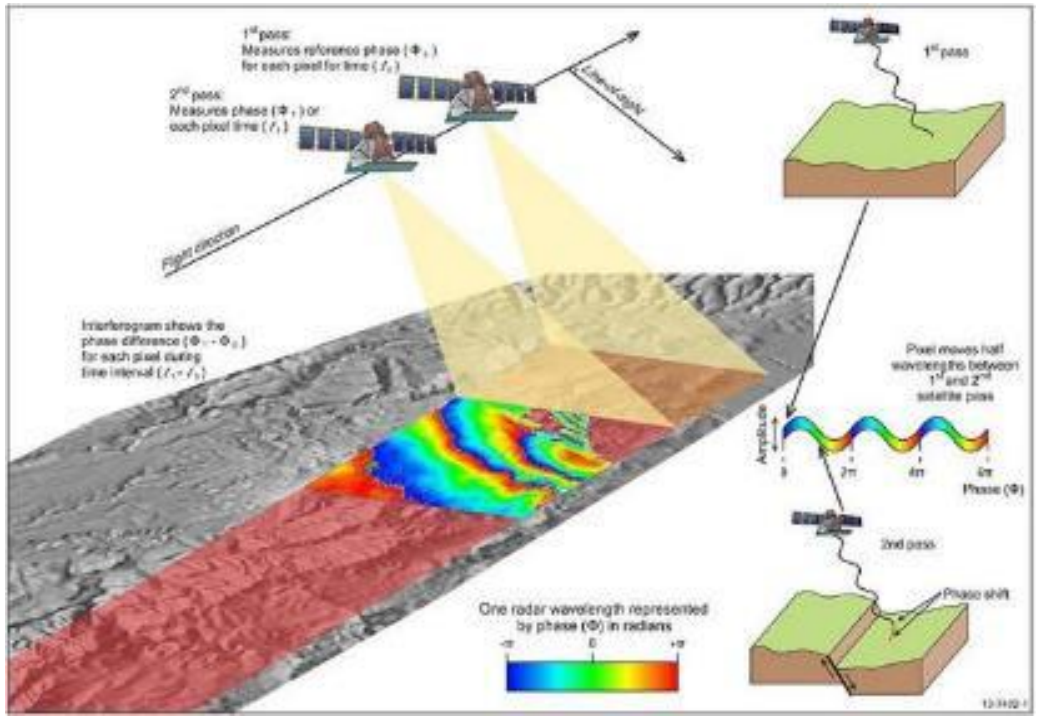
Ground velocity gradient



SAR images



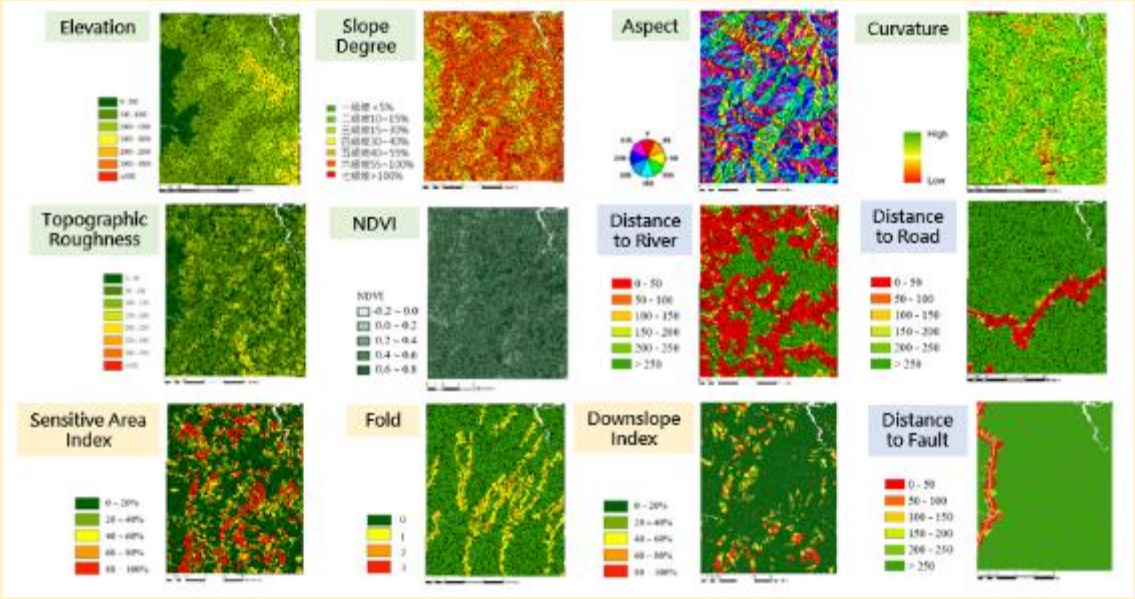
InSAR-derived displacement

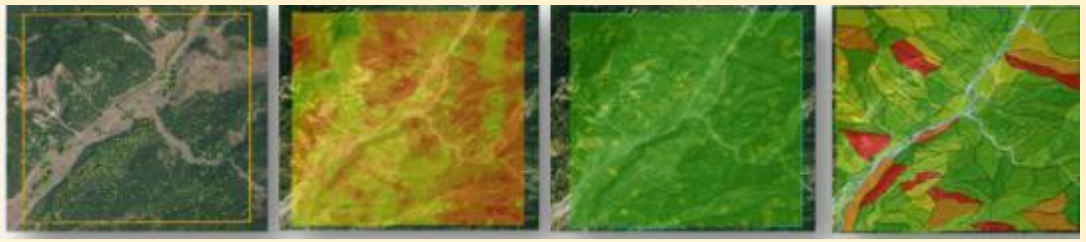


03 Landslide Susceptibility Analysis

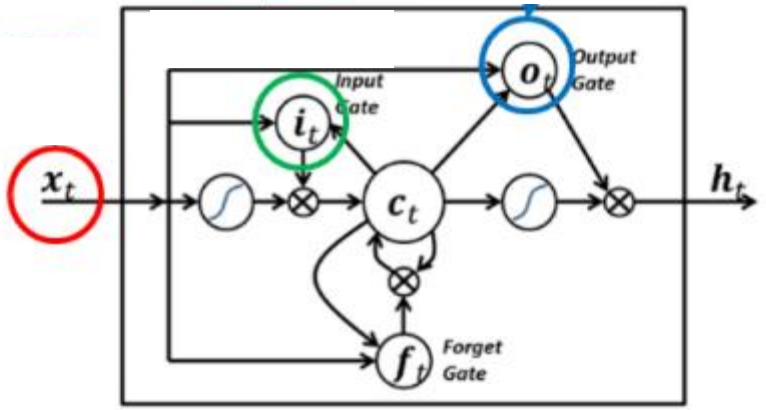
- Multiple factors + Machine Learning Algorithms

Multiple factors





InSAR-derived factor



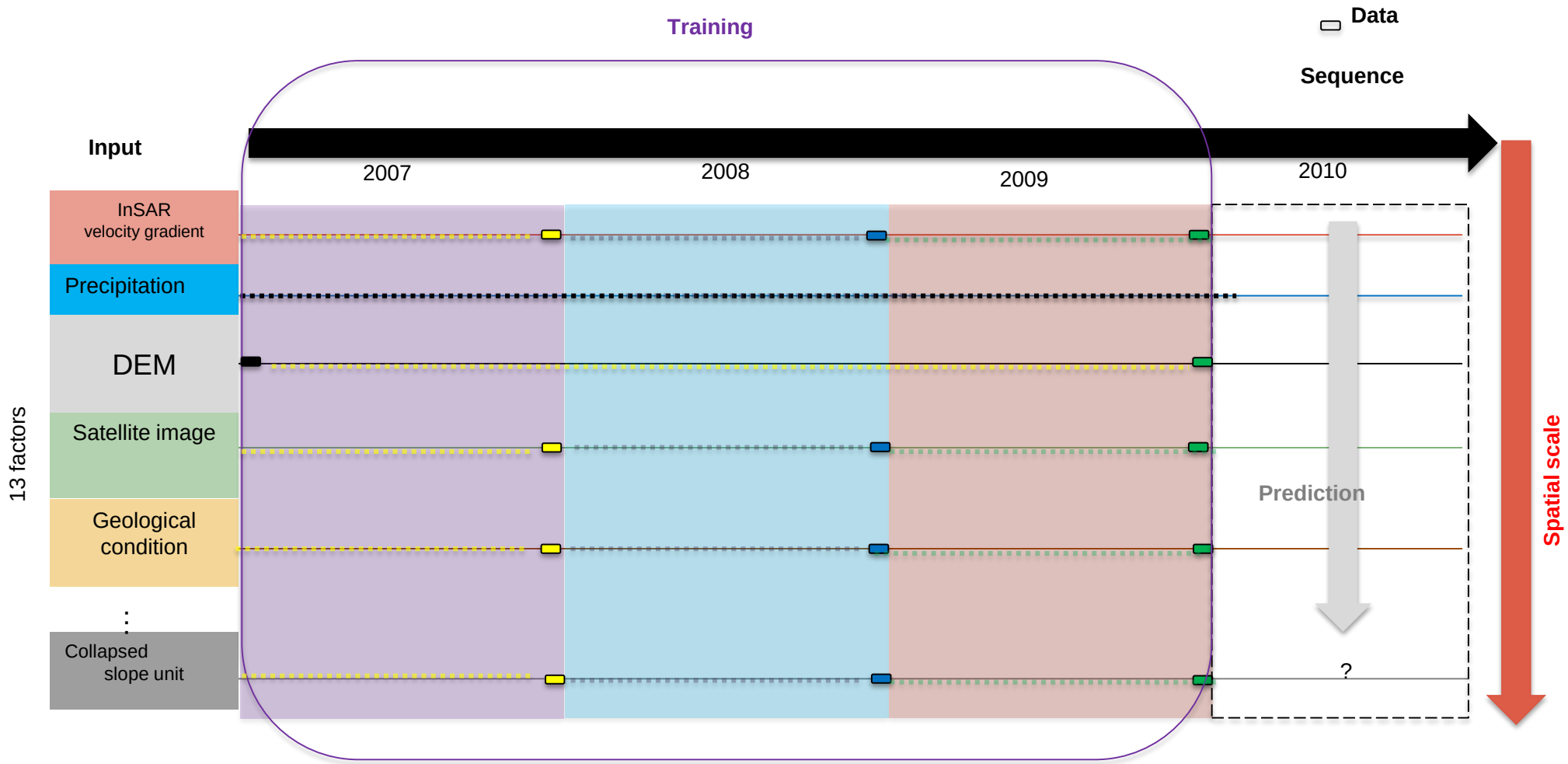
Output

Landslide Potential	AI
High	Ai
High-middle	Bi
Middle	Ci
Low	Di

**i = initial

03 Landslide Susceptibility Analysis

- InSAR complements the low update rate of traditional map data.



03 Landslide Susceptibility Analysis

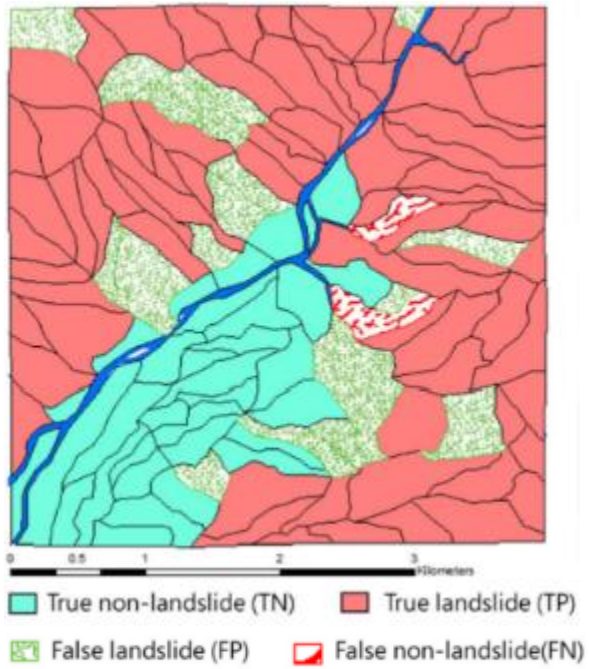
Case study-Siaolin Village (prediction results)

ML result map

Ground truth map

Predicted landslide area for 2010 based on training data between 2007~2009.

Accuracy evaluation



Average prediction accuracies before and after including InSAR data in different ML methods

ML	Siaolin Village	
	With InSAR (%)	Without InSAR (%)
Naive Bayes	70.93	70.85
DT	68.02	62.02
Random Forest	82.95	79.84
AdaBoost	78.49	77.52
XGBoost	79.31	75.97

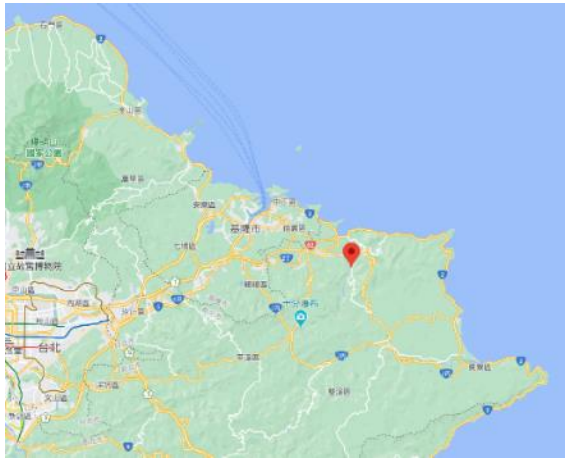
Up to 8% improvement if InSAR data is used.

Actual landslide area in 2010

Model extension- Houtong case

Case location

WGS84：25.097207,



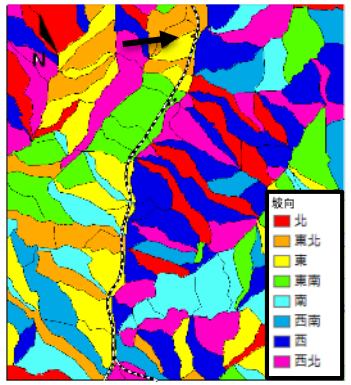
(source: google map)

(source: MOTC)

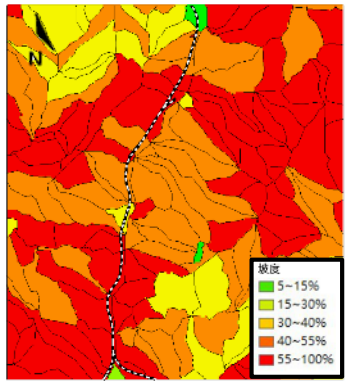
Landslide on 2020/12/04

Applying the previously developed ML model using local data in another case.

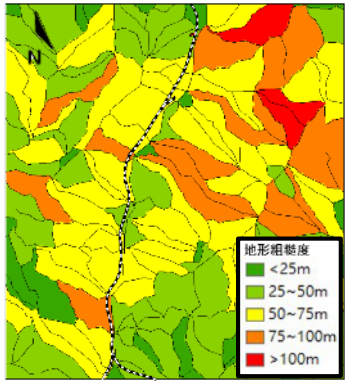
Aspect



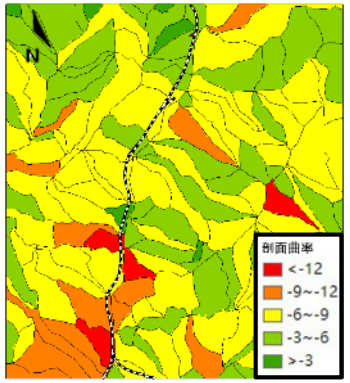
Slope



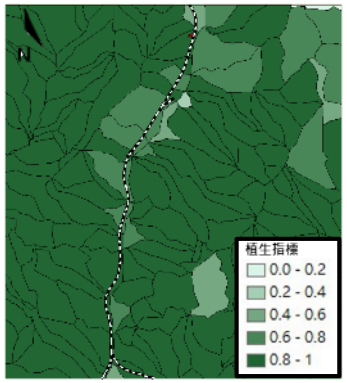
Roughness



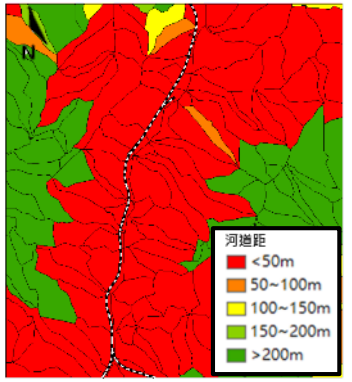
Curvature



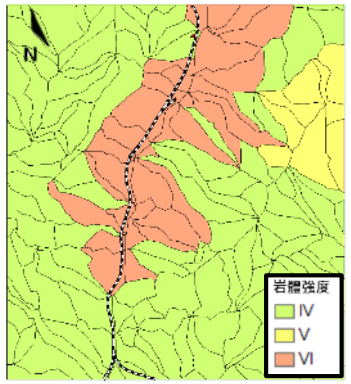
Vegetation



River distance

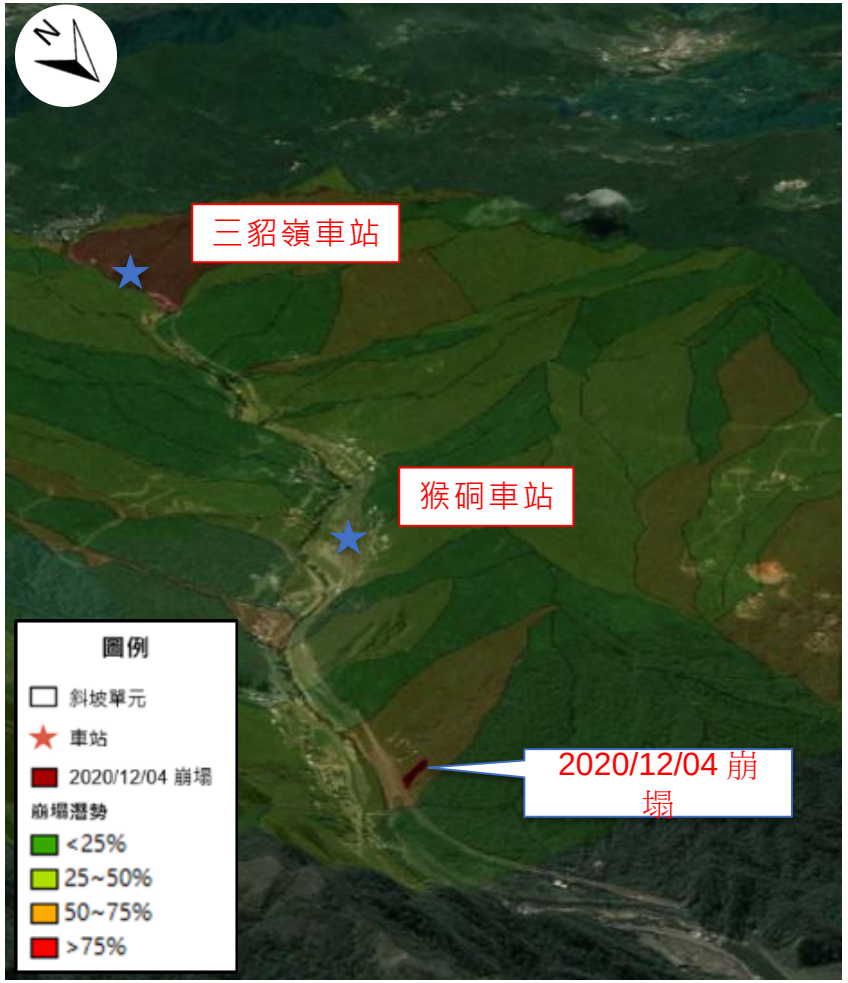


Rock intensity

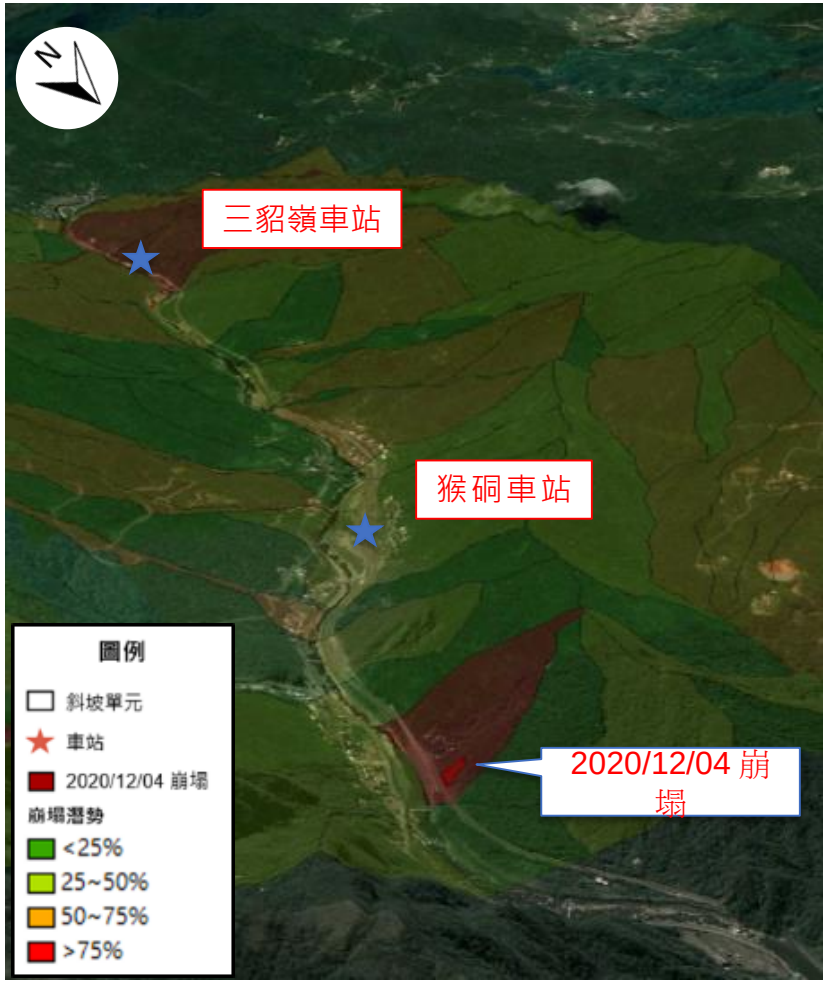


Model extension- Houtong case

Prediction results for Houtong based on the model developed for Siaolin Village



Mid-to-high landslide potential (before using InSAR)



High landslide potential (after including InSAR)

Conclusions

Modern remote sensing technology enables an accurate and efficient acquisition of multiple spatial data for a wide area.

Various information can be automatically extracted from these remotely sensed data using AI techniques.

AI technique contributes to the optimal use of all available data so that the complicated mechanism of a subject can be better analyzed and modeled.

With the improved accuracy and efficiency of analysis model, physical problems can be better solved, contributing to our knowledge of the real world.

Conclusions

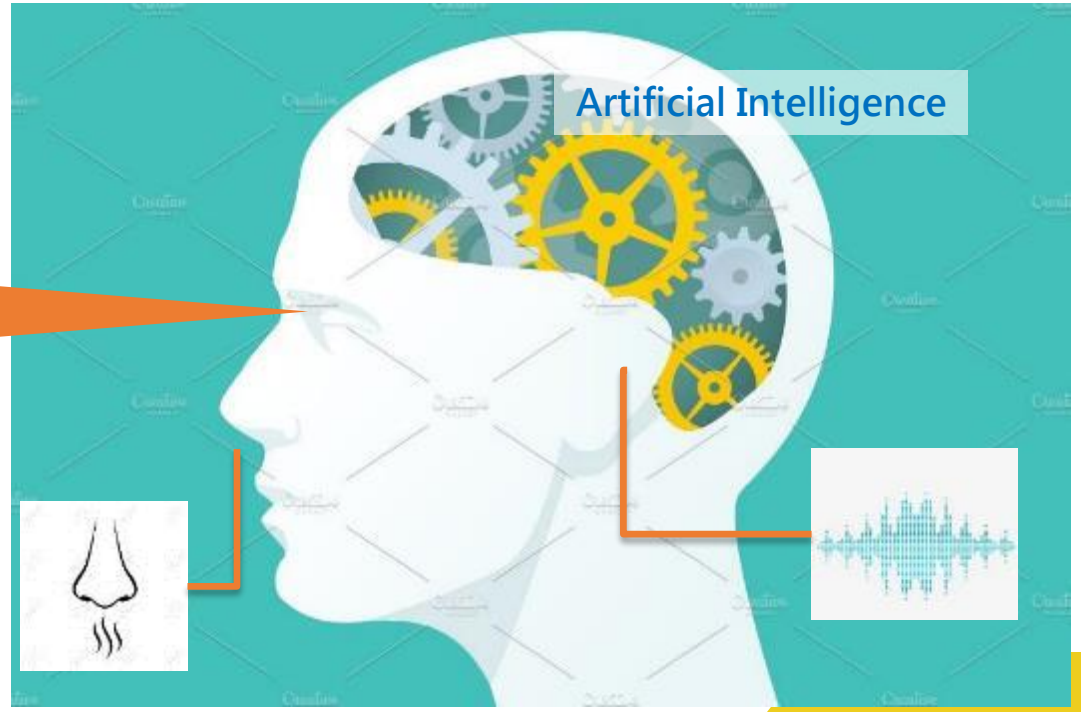
Mobile platform (UAV, Air plane, Satellite)
Multiple Sensing

+

Accurate and efficient analysis (AI)

→ Super power to kill problems

聰明 = 耳聰目明



Sensing

UAV, air plane, satellite

CHRU

www.gsc.ce.ntu.edu.tw/

感謝聆聽