Advanced Road Design-Principal and Practice

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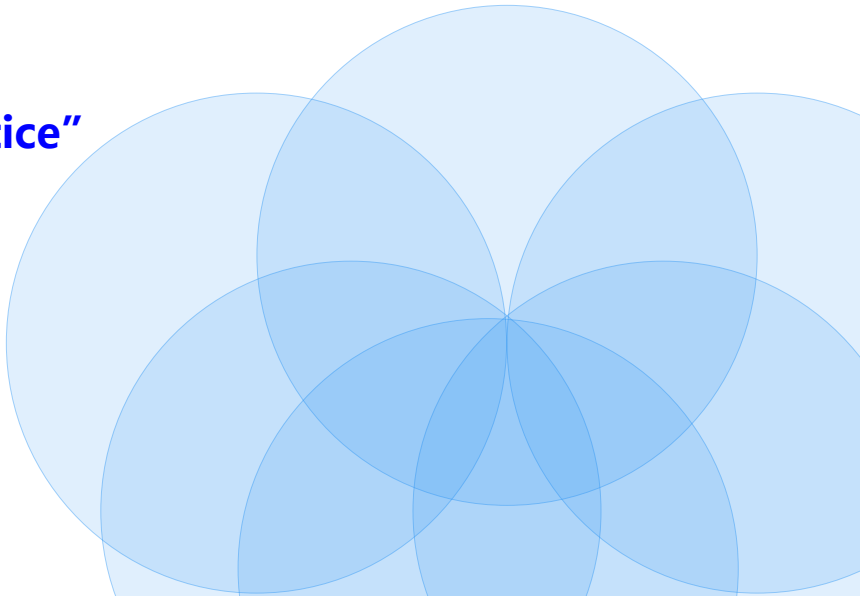
Evolution of this course

☑ before 2003，“道路CAD基本原理”

☑ 2004 - 2006，“计算机辅助公路工程”

☑ 2007，“Advanced Road Design”

☑ 2010，“Advanced Road Design- Principle and Practice”

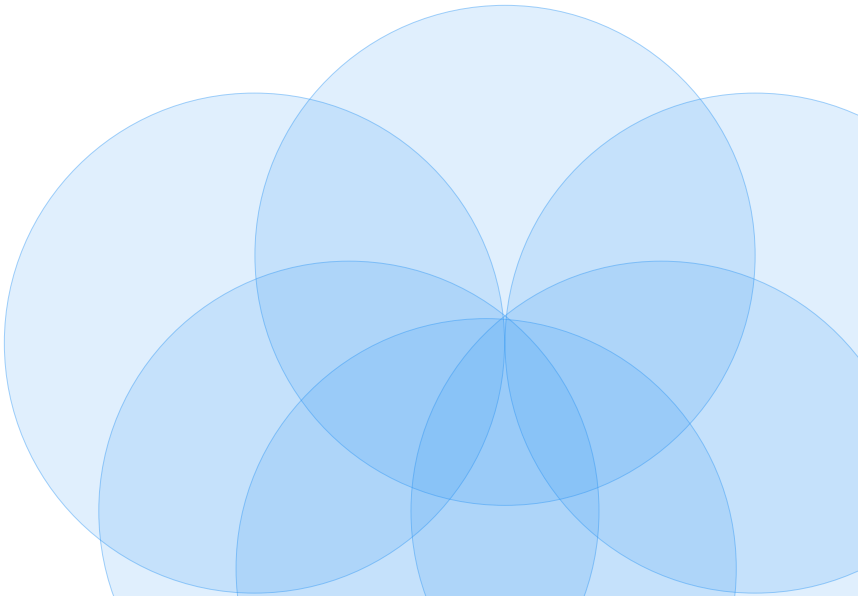


References

- ☑ 新理念公路设计指南 （交通部公路司编著人民交通出版社，2005）
- ☑ 降低造价公路设计指南（同上）
- ☑ FHWA Flexibility in highway design 1997
- ☑ 汪双杰 等，公路运行速度设计理论与方法，人民交通出版社
- ☑ 公路工程技术标准 JTG B01-2014
- ☑ 公路路线设计规范 JTG D20-2018
- ☑ 城市道路工程设计规范 CJJ 37—2016
- ☑ 公路勘测规范 JTG C10-2007
- ☑ 公路项目安全性评价指南 JTG/T B05-2015
- ☑ AASHTO： A Policy on Geometric Design of Highways and Streets 2011

1. Specifications of road

- ☑ Comprehensive study of integration of “drive-vehicle-road”
  - ☑ 3D sight distance for example
- ☑ Grade design (efficiency and safety)
- ☑ Operation speed and design speed methods
- ☑ Comparisons of specifications wordwidely



2. Modern data acquisition methods and applications in planning and design

- ☑GIS
- ☑GPS
- ☑RS
- ☑LiDAR
  - ☑GPS和IMU（Inertial Measurement Unit，惯性测量装置）to form DTM (digital terrain model)

3. New design method and tool

☑2D to 3D design method

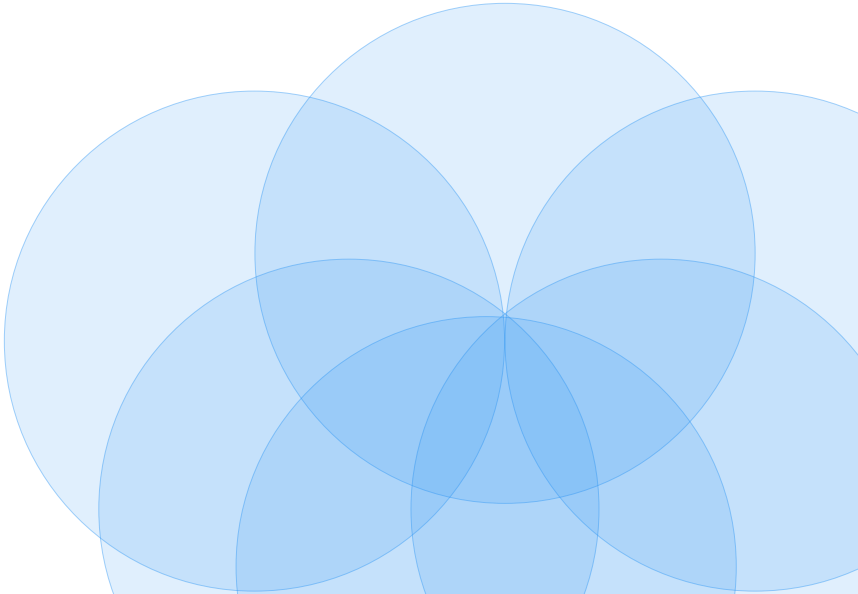
☑CAD to BIM

☑3D design philosophy

☑Design criterion facing Autonomous Vehicle

4. Road safety and environment

- ☑ **Traditionally, for road planning and alignment design**
  - ☑ **Study the relationship between the geometric elements and traffic accident rate so as to improve the safety of road infrastructure**
  - ☑ **Study the effects of traffic signs, traffic guidance and safety protection facilities on road safety**
  - ☑ **Operation speed audit**
- ☑ **Driving simulation based on ergonomics**



Object

This course will take the latest theories, methods and techniques of road engineering in plan, survey and design as the main line of instruction:

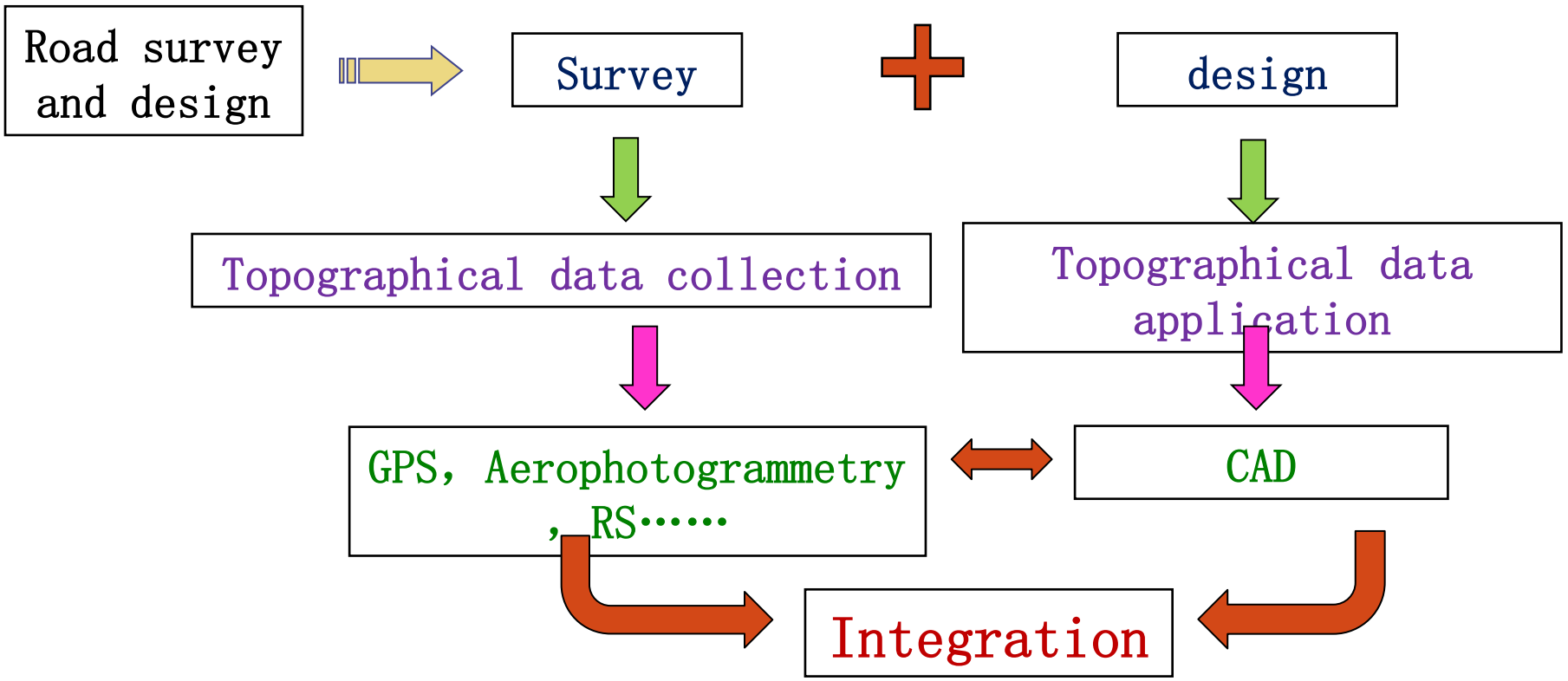
- **The new concept of planning and design (CSD, flexibility, tolerance etc.)**
- **new survey technologies (including photogrammetry, remote sensing and digital terrain model)**
- **new design method (geometric design theory, optimization of horizontal and vertical design, design, design and evaluation of roadside safety, IHSDM)**

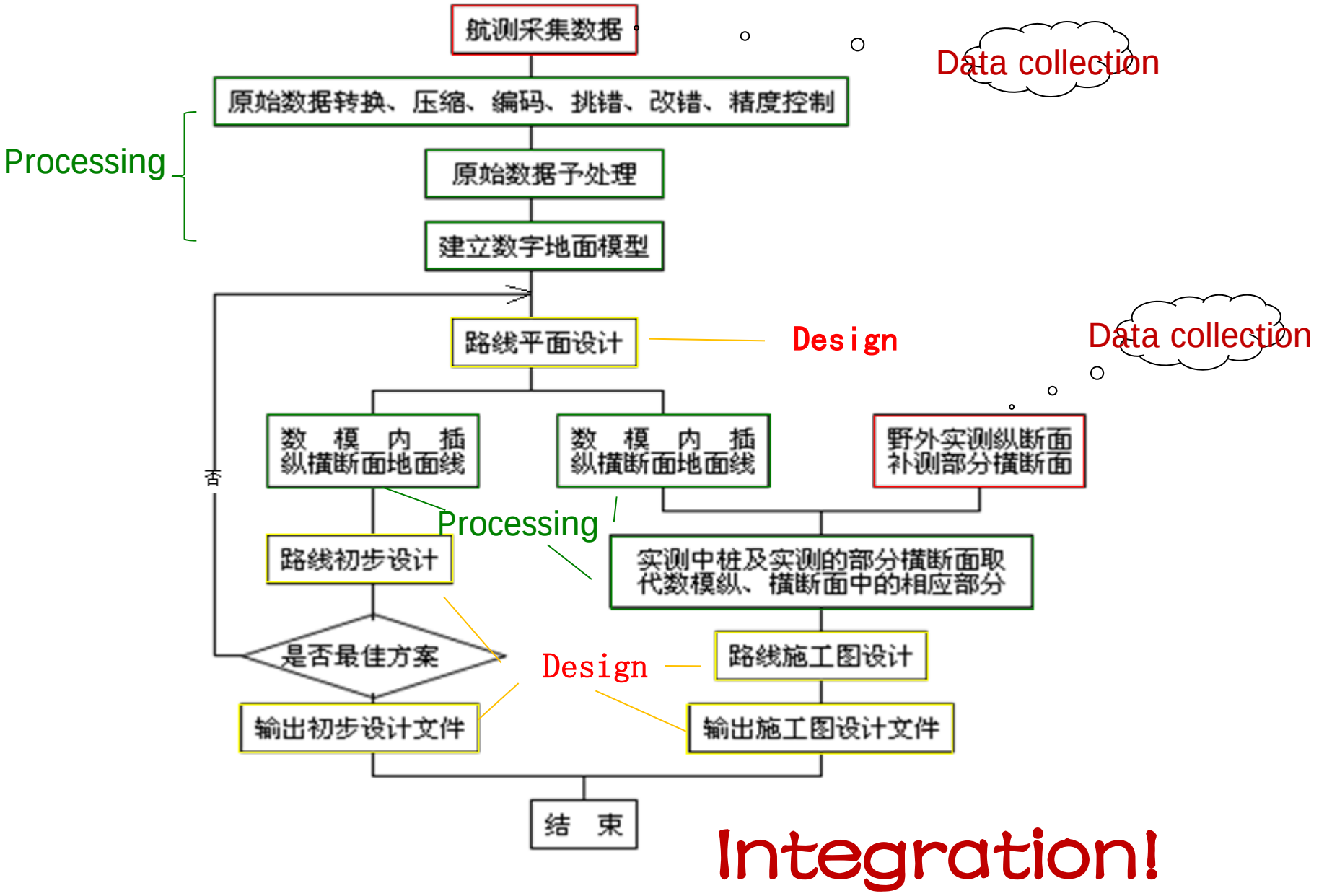
Requirement

- Think independently, team collaboration ;
- Learn to search and review, “stand on the shoulders of giants”
-
- Dare to use English, have an international view
- Complete homework seriously and timely. Plagiarism is absolutely forbidden.

CH 2: Topographical data collection

Integration of survey and design




航测采集数据
Data collection
原始数据转换、压缩、编码、挑错、改错、精度控制
Processing
原始数据予处理
建立数字地面模型
路线平面设计
Design
Data collection
数模内插纵横断面地面线
数模内插纵横断面地面线
野外实测纵断面补测部分横断面
否
Processing
路线初步设计
实测中桩及实测的部分横断面取代数模纵、横断面中的相应部分
是否最佳方案
Design
路线施工图设计
输出初步设计文件
输出施工图设计文件
结束
Integration!

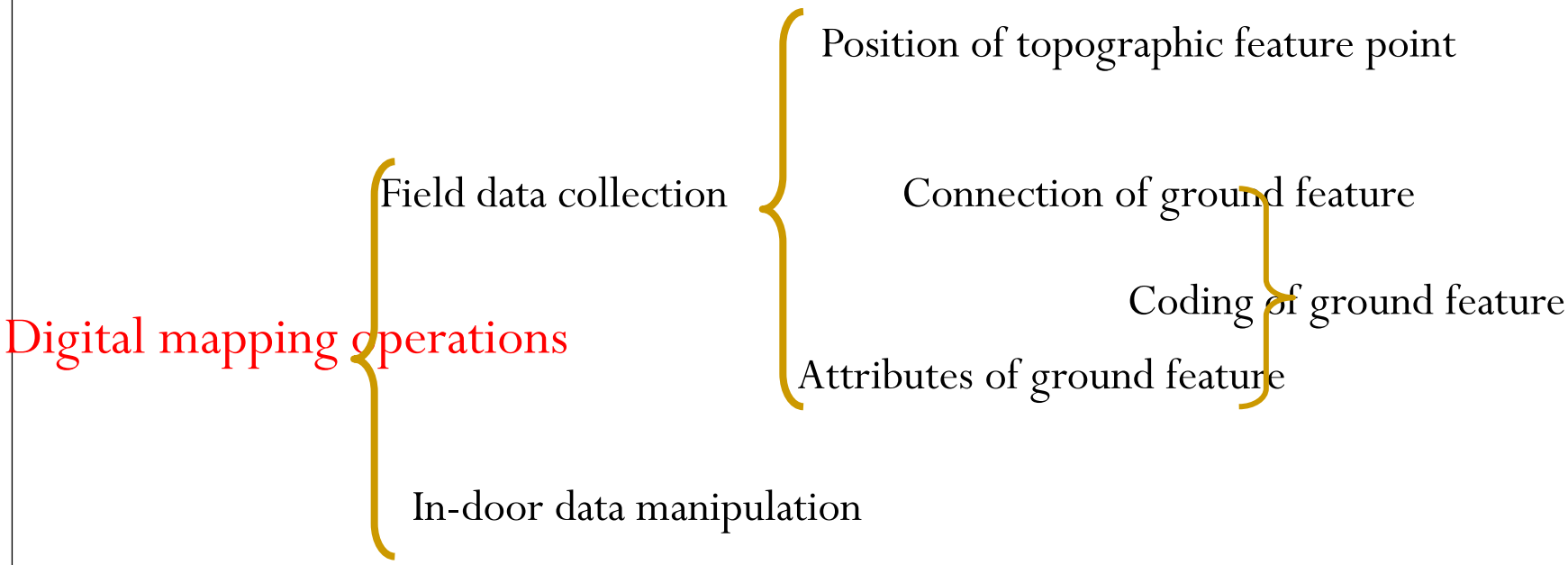
Data collection method

- Total station
- GIS
- Remote sensing
- Aerophotogrammetry
- Oblique photography （倾斜摄影）
- LiDAR（激光雷达）

Field data collection by total station

- Outline
  - Data coding
  - Principal and method of detail point measure
  - Measure and record method(测记法) of field data collection
  - PDA method of field data collection

Data coding


Digital mapping operations
Field data collection
Position of topographic feature point
Connection of ground feature
Coding of ground feature
Attributes of ground feature
In-door data manipulation

Concept of data coding

- Field data collection with only points position (coordinates) of total station or other geodetic instrument can not meet the requirements of computer automatic mapping
- Must record the connection relation of object point and ground feature attribute information (feature class, etc.)
- Uses a string of symbols constituted by certain rules to represent the ground features and connections and other information
  - ***Data coding***

Content of coding

- Coding of ground features(地物特征码、地物属件码、地物代码);
- Coding of connection (连接点号、连接序号、连接线);
- Surface object filling code(面状地物填充码)
- Data coding :6-11
  - some all use digital representation
  - some with digital, character mixed representation.

Classification and coding of national standard terrain elements

- Coding form: terrain code + information code

  Terrain code : Topographic map elements

  Info. Code : connect relationship

- 《基础地理信息要素分类与代码》（GB/T 13923-2006）和《城市基础地理信息系统技术规范》（CJJ100-2004）中对比例尺为1：500、1：1000、1：2000的代码位数的规定是6位十进制数字码，分别为按数字顺序排列的大类、中类、小类和子类码，

×　×　××　××

大类　中类　小类　子类

图　碎部点编码规则

- 代码的每一位均用0～9表

大类：1为定位基础（含测量控制点和数学基础）；2为水系；3为居民地及设施；4为交通；5为管线；6为境界与政区；7为地貌；8为植被与土质。

《城市基础地理信息系统技术规范》（CJJ100-2004）代码位数规定是6位十进制数字码。

× × ×× ××

大类 中类 小类 子类

图 碎部点编码规则

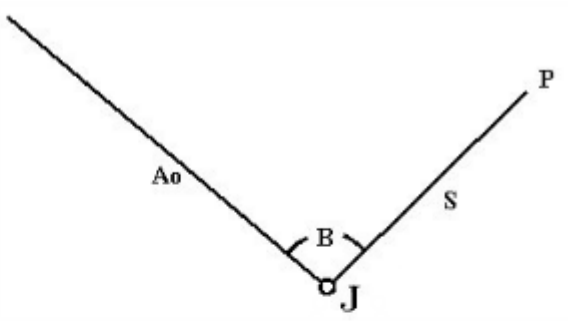
表 1:500 1：1000 1:200基础地理信息要素部分代码

分类代码	要素名称	分类代码	要素名称
100000	定位基础	310000	居民地
110000	测量控制点	310100	城镇、村庄
110101	大地原点	310300	普通房屋
……	……	310500	高层房屋
110103	图根点	310600	棚房
110202	水准点	311002	地下窑洞
110300	卫星定位控制点	340503	邮局
……	……	380201	围墙
300000	居民地及设施	380403	凉台

Principal and method of detail point measure

- Coordination data
  - Height of total station (I)
  - Station orientation
  - Height of prism (V)
  - Measure (S B T)
  - To calculate coordinate and height

(x, y, z)



$$P_x = J_x + S \cdot \cos(Ao + B)$$

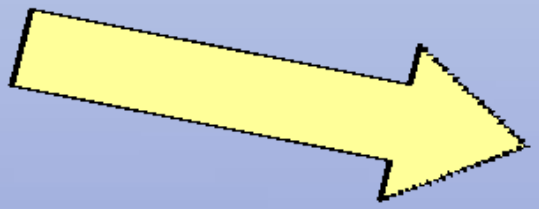
$$P_y = J_y + S \cdot \sin(Ao + B)$$

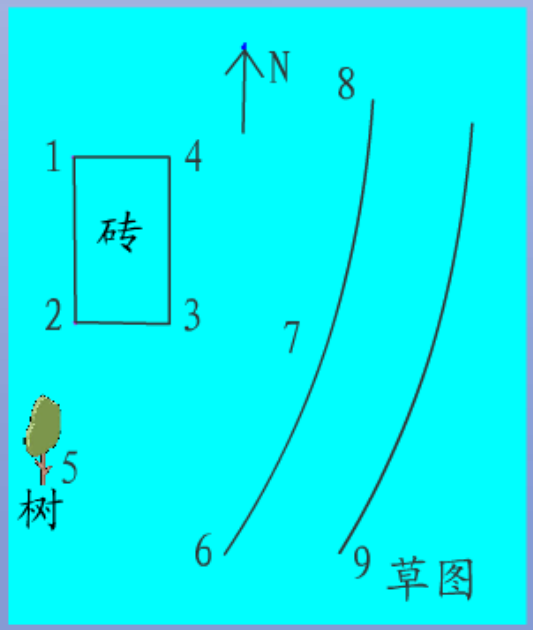
$$P_h = J_h + S \cdot \tan(T) + I - V$$

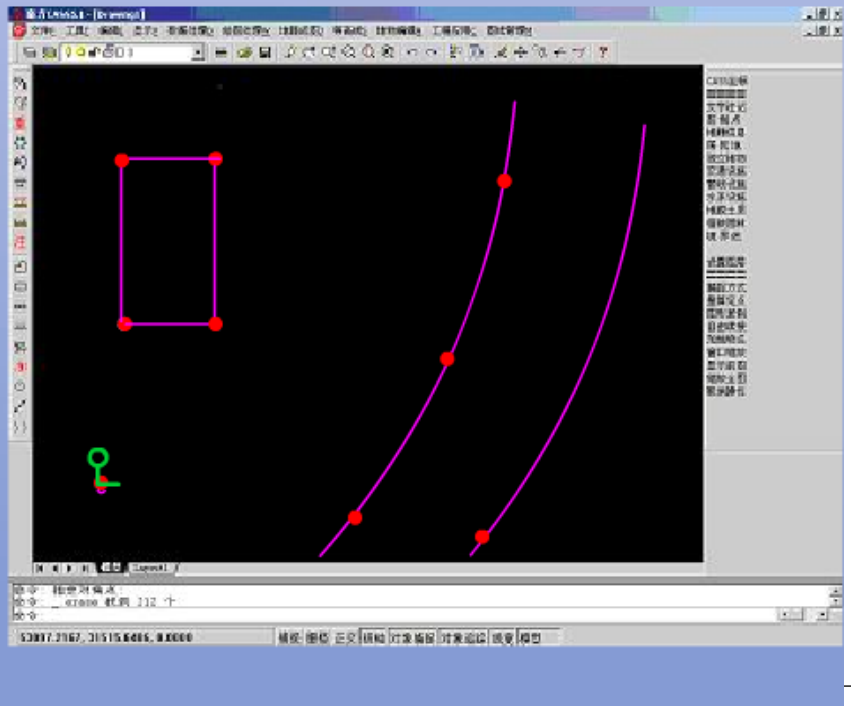
Measure and record method(测记法) of field data collection

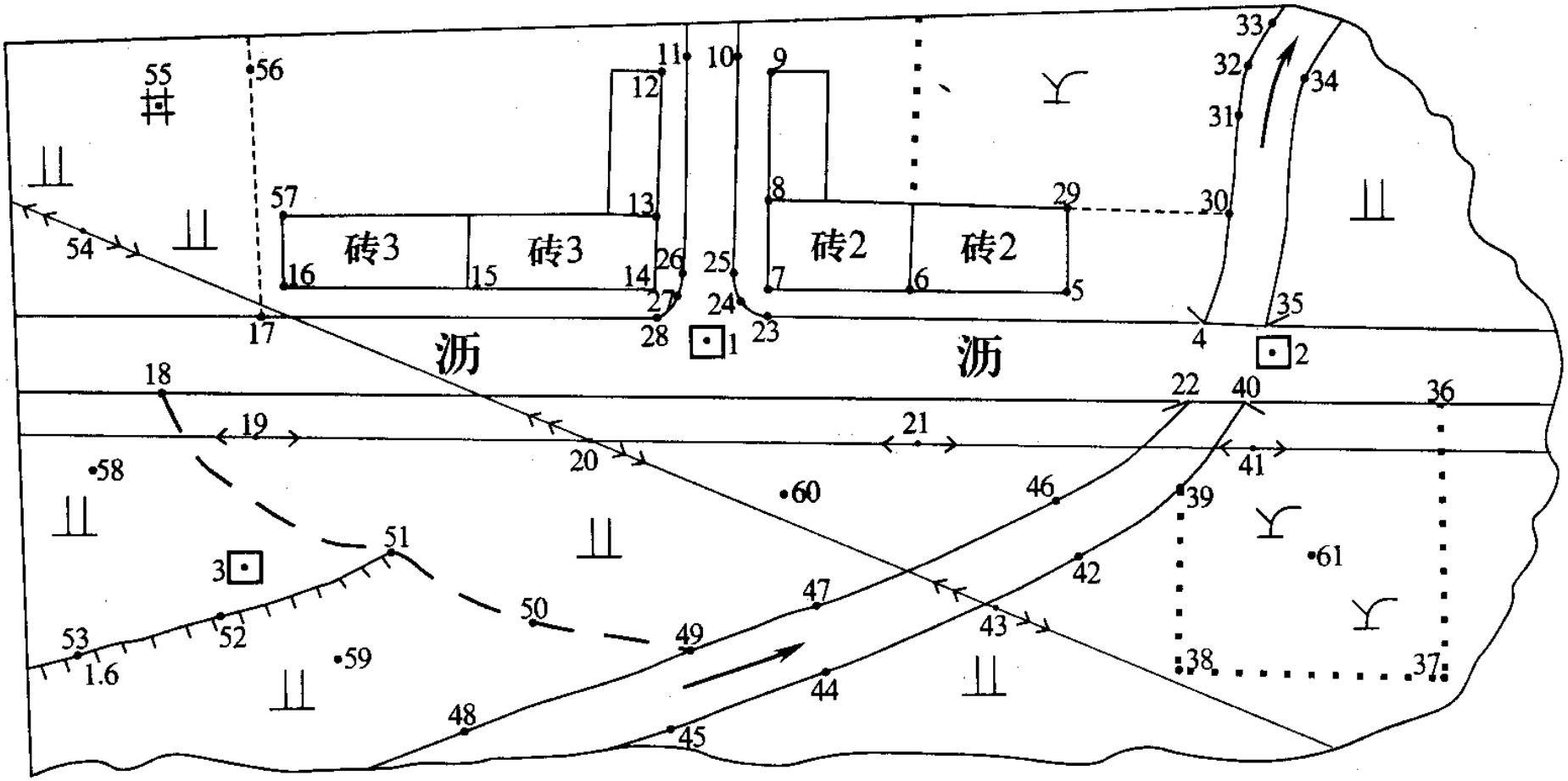
- It is to draw the working sketch and record the name of the terrain element and the connection of the broken part in the working draft.
- Then the broken part is displayed on the computer screen in the room, according to the working sketch, the broken part is connected with the human computer interaction mode to generate graphics.

Measure and record method








砖3
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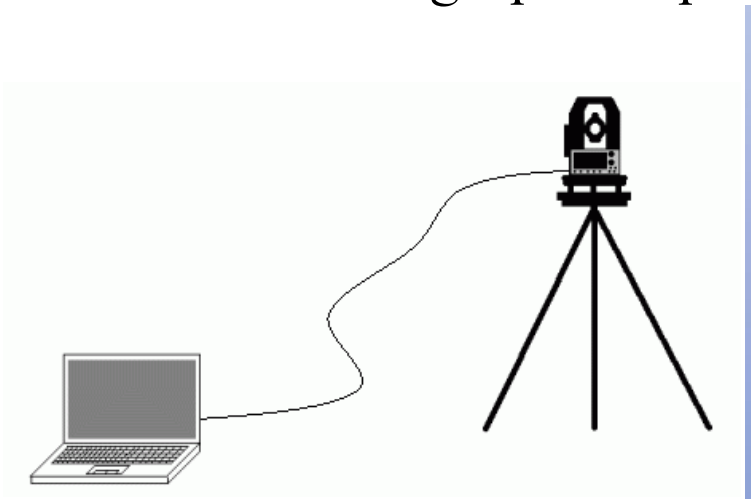
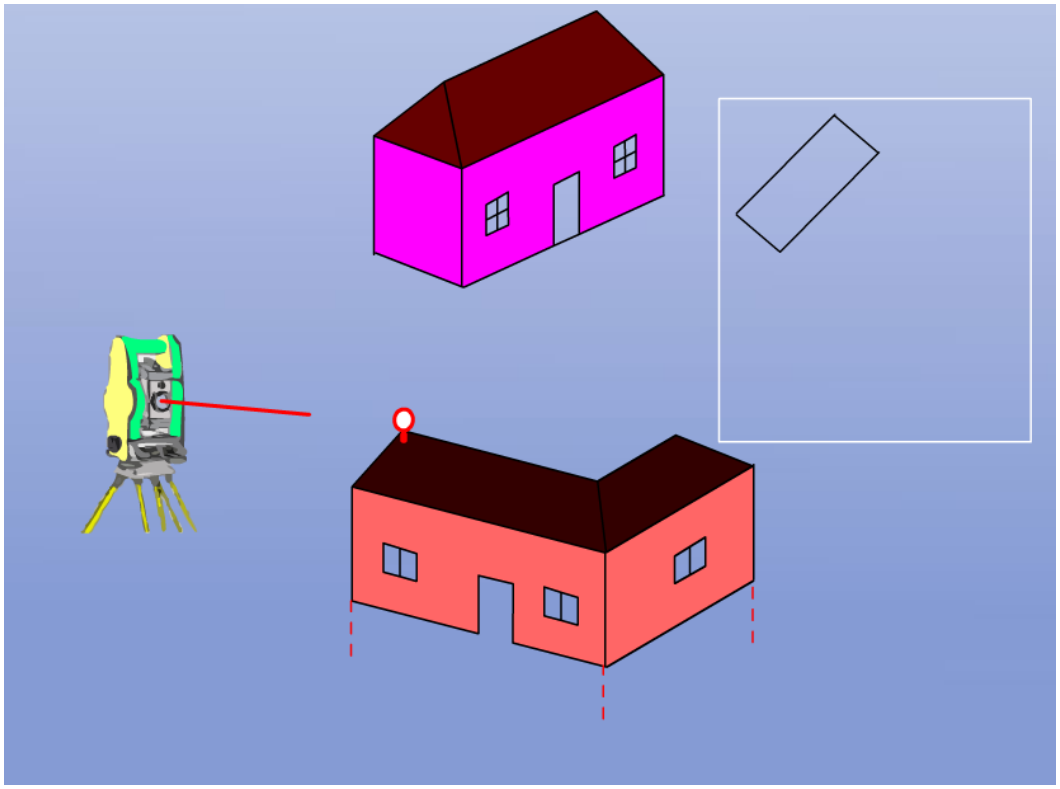
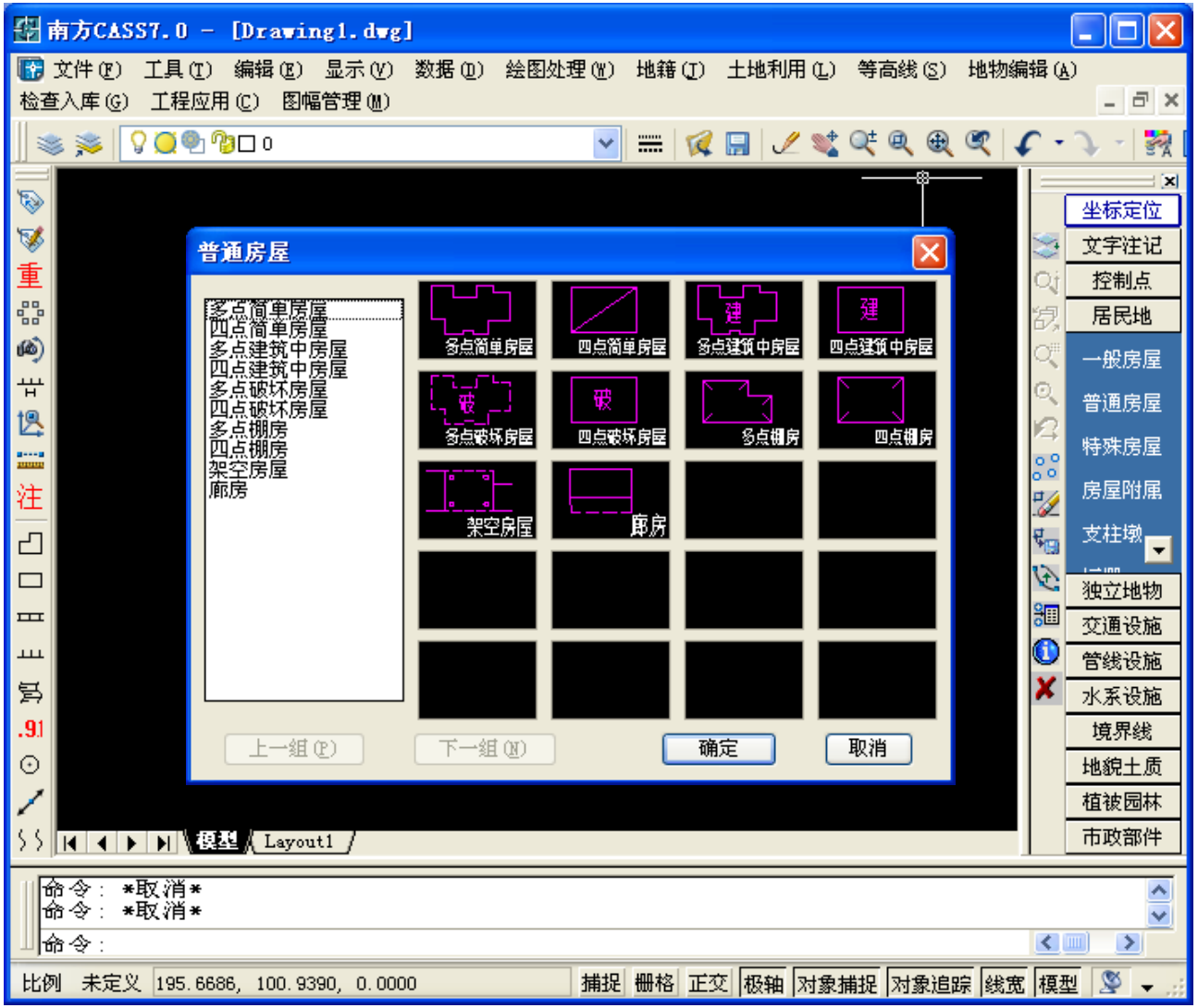
PDA method of field data collection

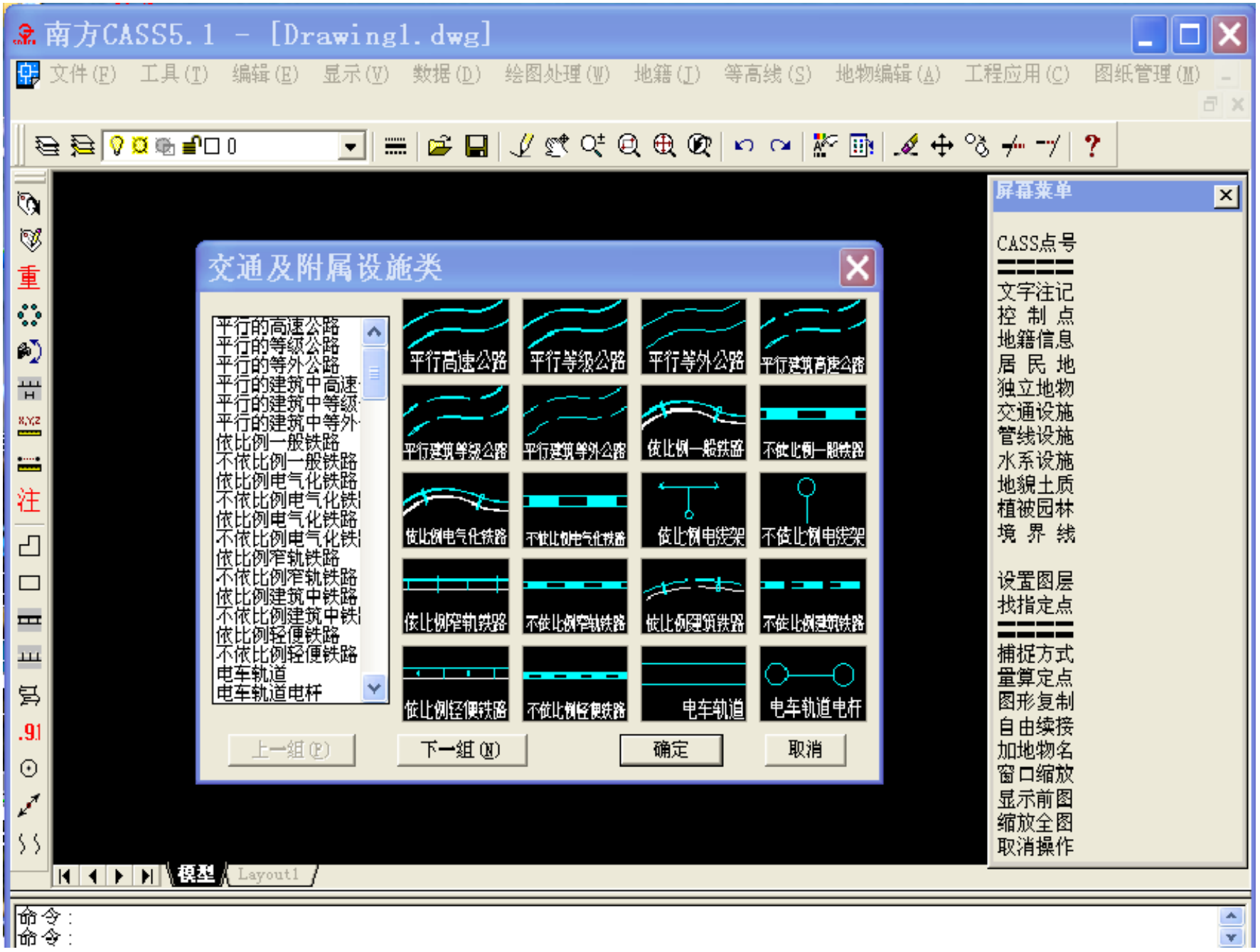
- Use PDA as field data acquisition recorder; after measuring the scattered points, generate graphics with the control of the actual graphic input information





- 1）利用屏幕的右侧菜单功能 选择地物属性

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文件(F) 工具(T) 编辑(E) 显示(V) 数据(D) 绘图处理(W) 地籍(J) 等高线(S) 地物编辑(A) 工程应用(C) 图纸管理(M)
交通及附属设施类
平行的高速公路
平行的等级公路
平行的等外公路
平行的建筑中高速
平行的建筑中等级
平行的建筑中等外
依比例一般铁路
不依比例一般铁路
依比例电气化铁路
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电车轨道
电车轨道电杆
平行高速公路
平行等级公路
平行等外公路
平行建筑高速公路
平行建筑等级公路
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依比例建筑铁路
不依比例建筑铁路
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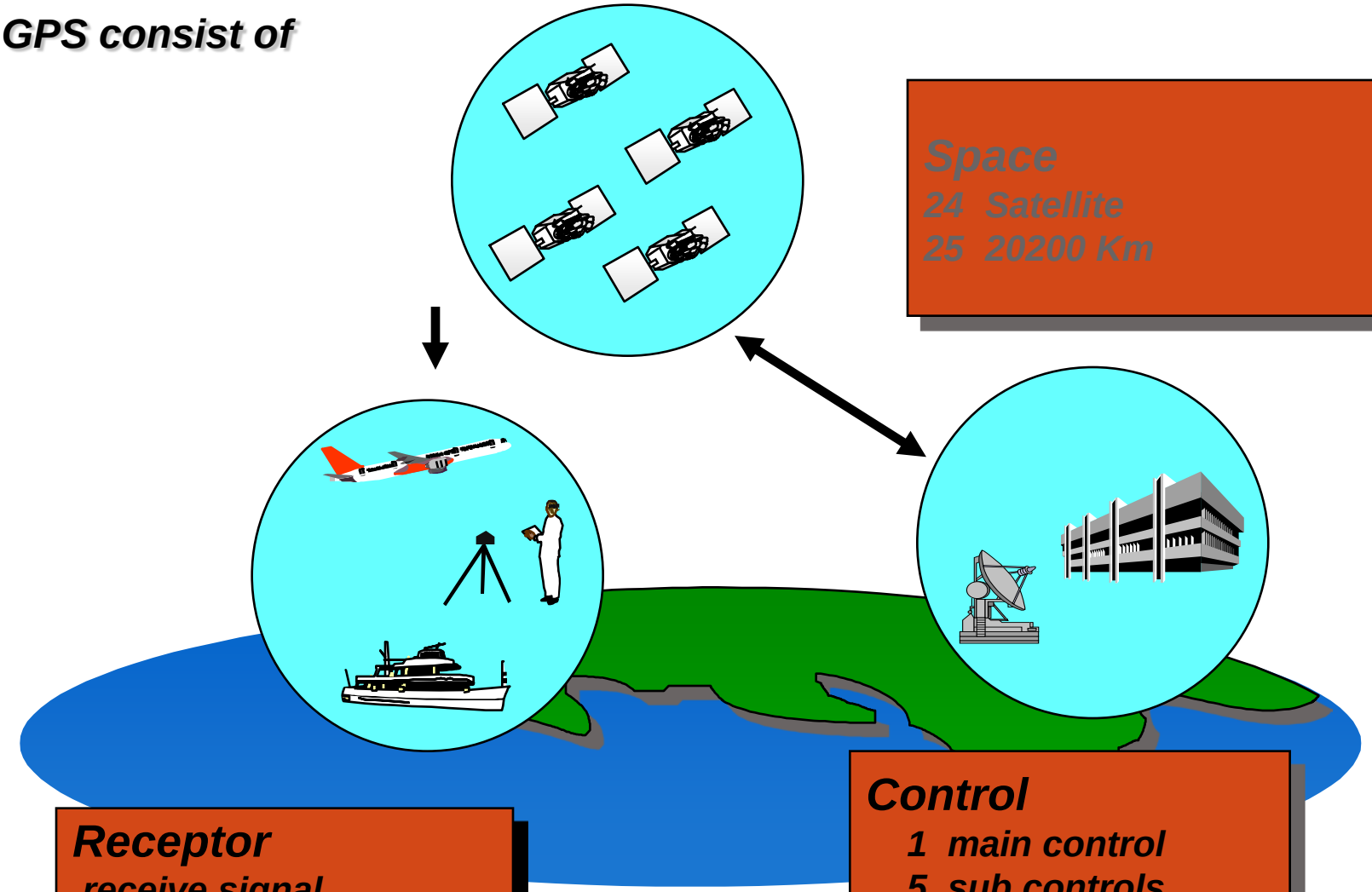
不依比例轻便铁路
电车轨道
电车轨道电杆
上一组(P)
下一组(N)
确定
取消
屏幕菜单
CASS点号
文字注记
控制点
地籍信息
居民地
独立地物
交通设施
管线设施
水系设施
地貌土质
植被园林
境界线
设置图层
找指定点
捕捉方式
量算定点
图形复制
自由续接
加地物名
窗口缩放
显示前图
缩放全图
取消操作
模型
Layout1
命令:
命令:

Sec 2: GPS measurement

- GPS(Global Positioning System), revolutionary impact in surveying industry
  - Unconstrained by the weather
  - Not requirement of visibility
  - High precise of measurement
    - Satisfy the measure requirement of fourth-order leveling
  - Day and night operation
  - Unified coordination system
  - Cheap
  - etc

GPS consist of

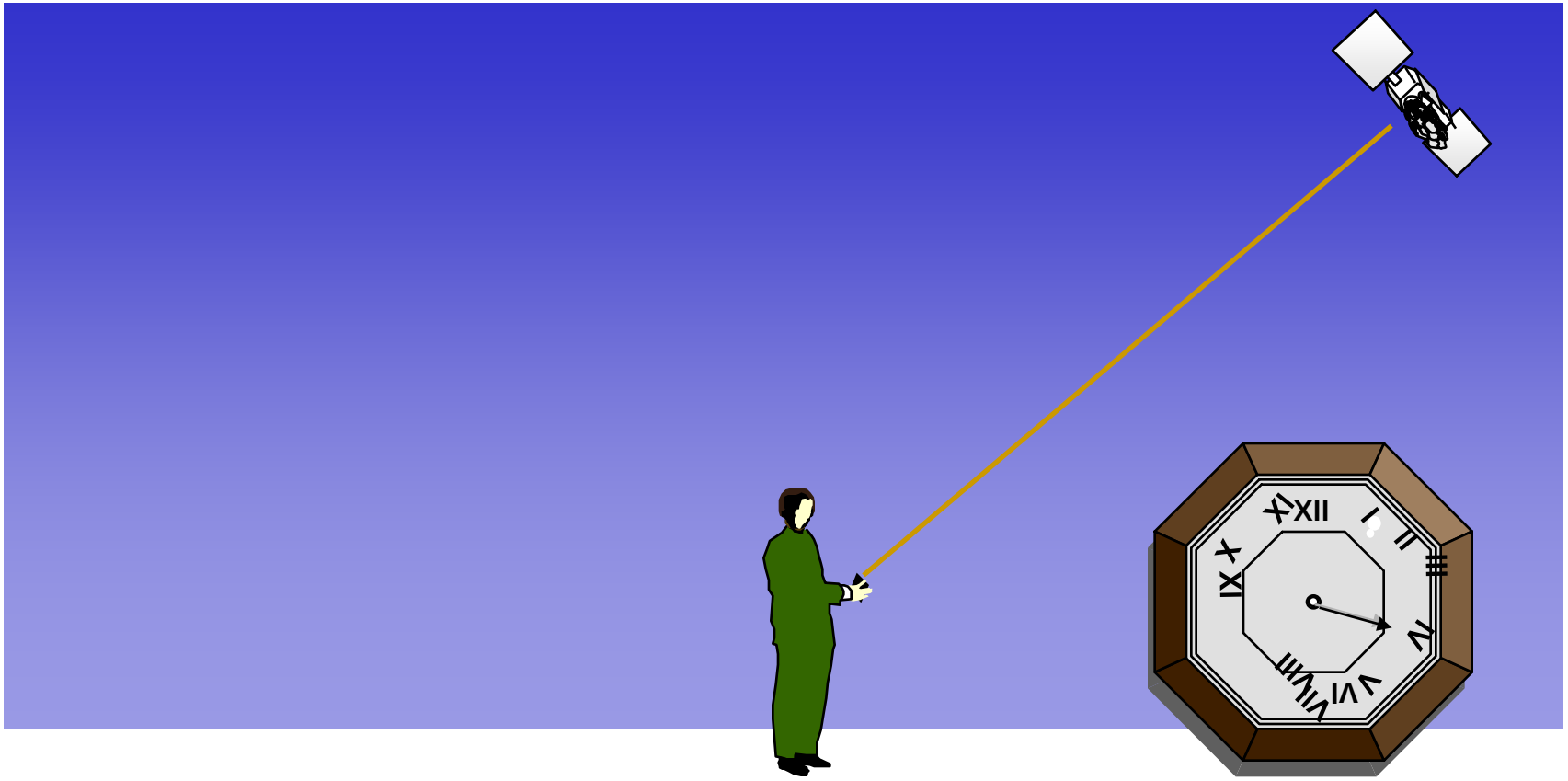


Space
24 Satellite
25 20200 Km

Receptor
receive signal

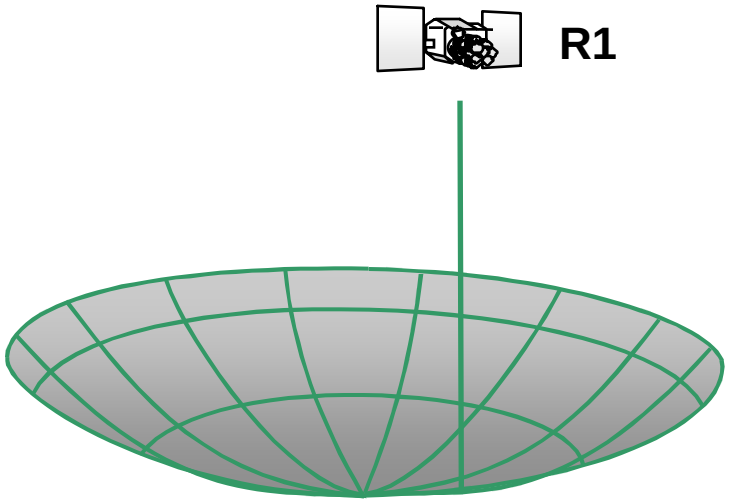
Control
1 main control
5 sub controls

Principal of measurement



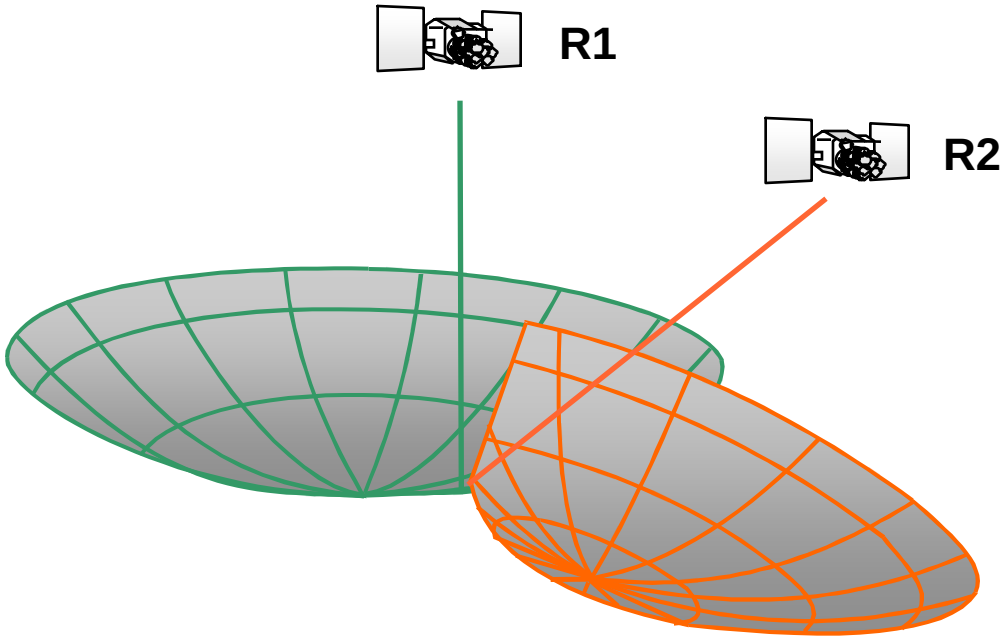
Distance = time x speed of light

Principal of point identification



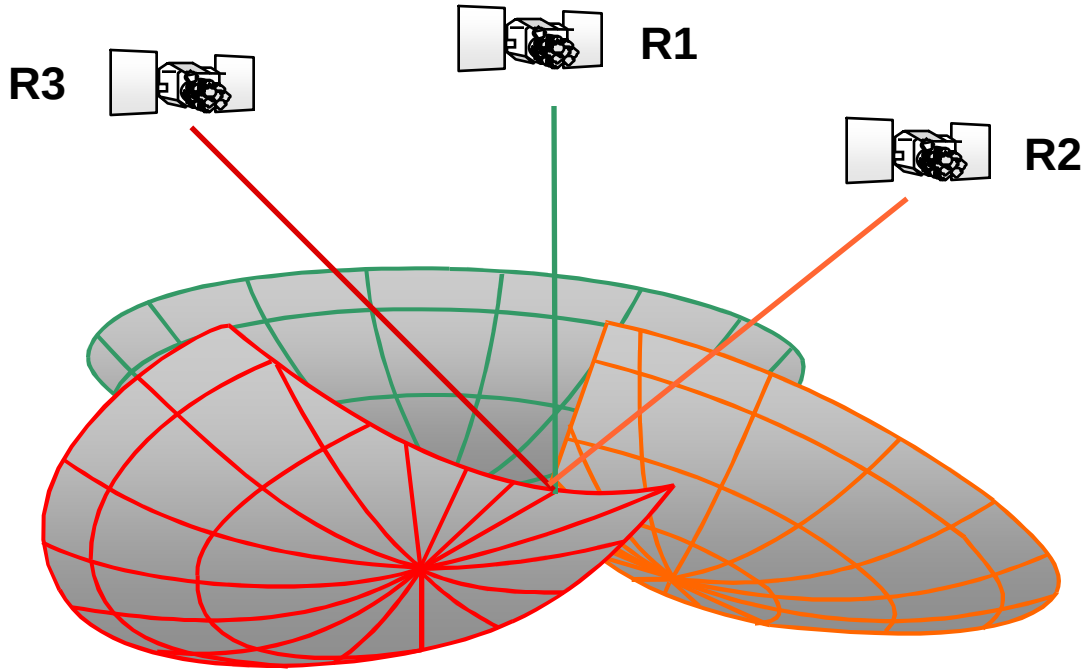
We stand on one point of sphere with a diameter of R1

Principal of point identification



2 spheres intersect to form a curve, of which the the arc is restricted to.

Principal of point identification



3 spheres intersect at one point

3 distances can determine latitude, longitude, and elevation

The space position of the point is determined

GPS

1. NAVSTAR/GPS
   Navigation Satellite Timing And Ranging/Global Positioning System

2.格洛纳斯（GLONASS）
   前苏联，卫星颗数为24+1，1996年1月18日正常运行

3. 北斗卫星导航系统(BeiDou Navigation Satellite System）
   中国，2020年前后，建成北斗全球系统

4.伽利略定位系统（Galileo Positioning System）
   欧洲，2019年具备完全工作能力

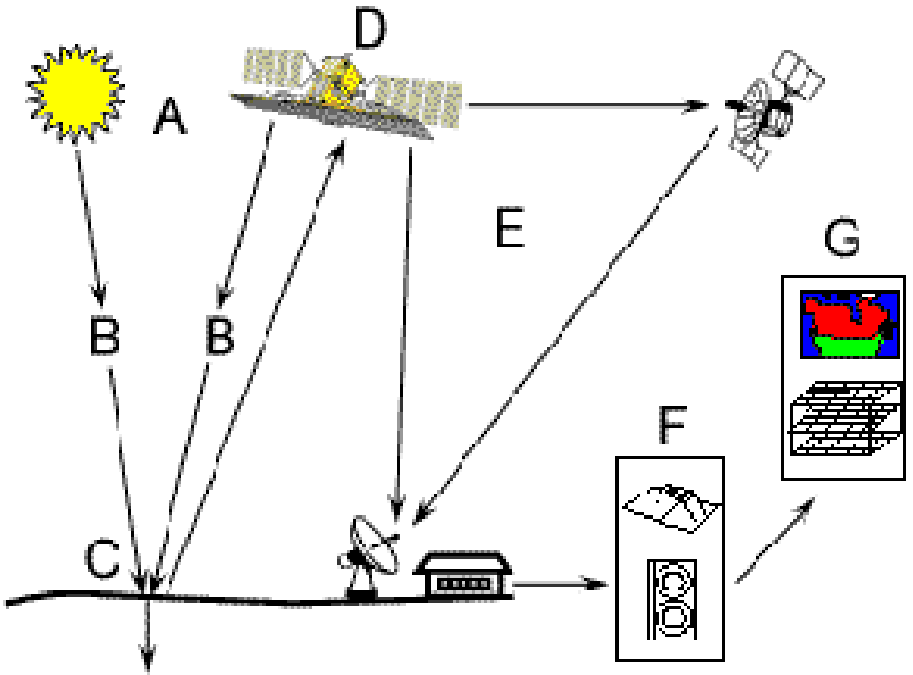
JSCORS

江苏省全球导航卫星连续运行参考站综合服务系统

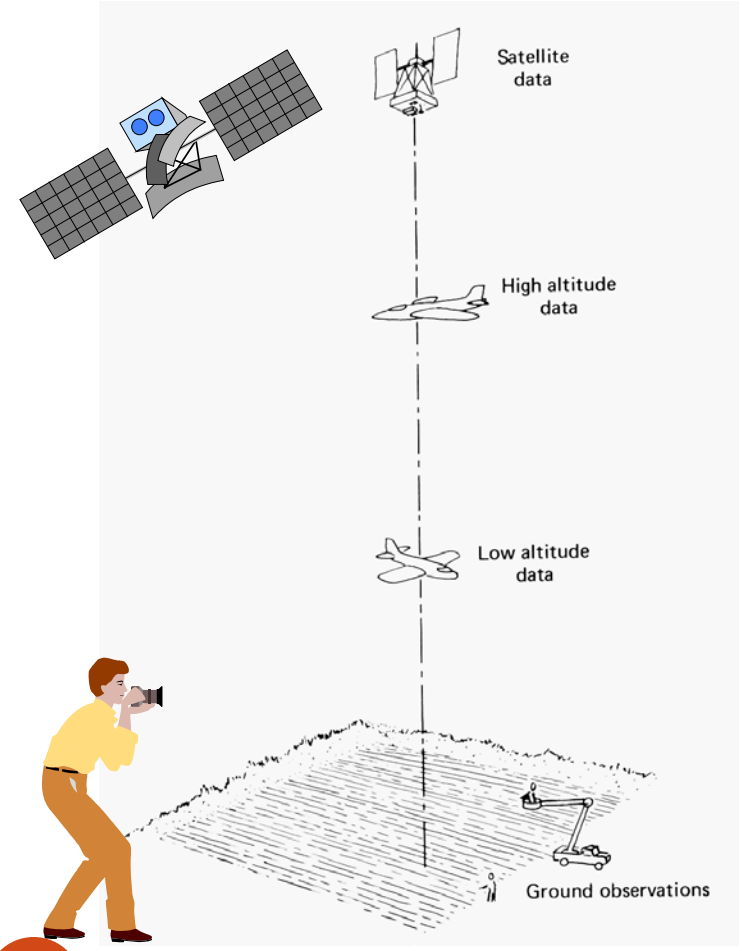
Integrated service system of Jiangsu global navigation satellite continuous operation reference station

Remote sensing

- Remote Sensing is a technology for sampling electromagnetic radiation to acquire and interpret non-immediate geospatial data from which to extract information about features, objects, and classes on the Earth's land surface, oceans, and atmosphere.



Platforms



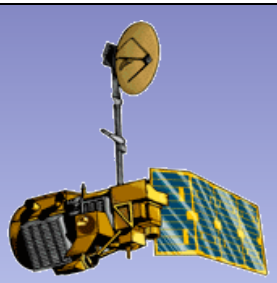
Platforms are:

- Ground based
- Airborne
- Spaceborne

Sensing from 1 meter to 36,000 km height

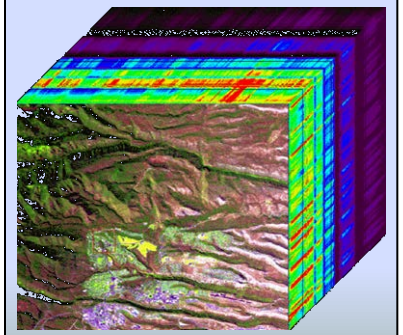
Remotely Sensed Data

Aerial Camera



Multispectral Satellite

Radar Satellite



Hyperspectral Sensor

Landsat/Ikonos/Quickbard

Hyperion

Application of RS in road engineering

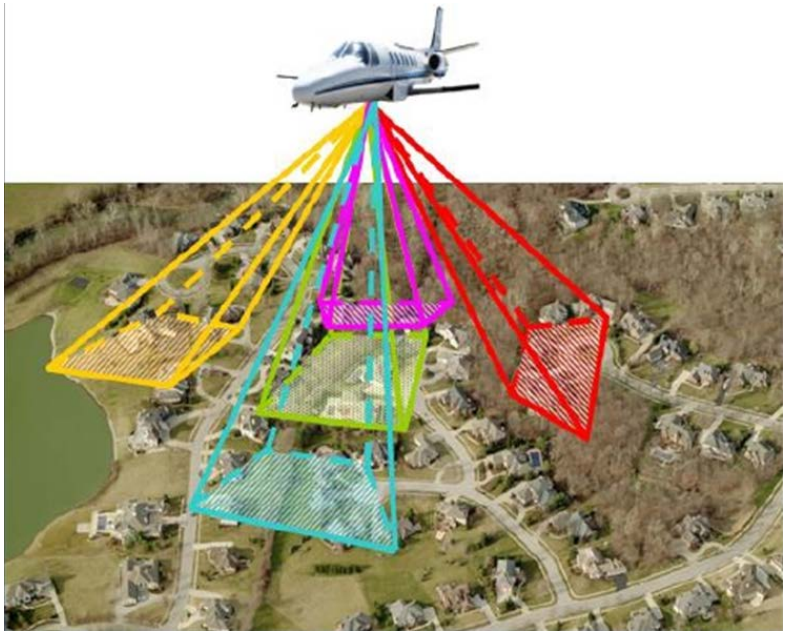
- Evaluation of layout of critical projects
- Identification of adverse geology area
- Stability analysis of long tunnel and bridges
- Detect underlying structure in plain area

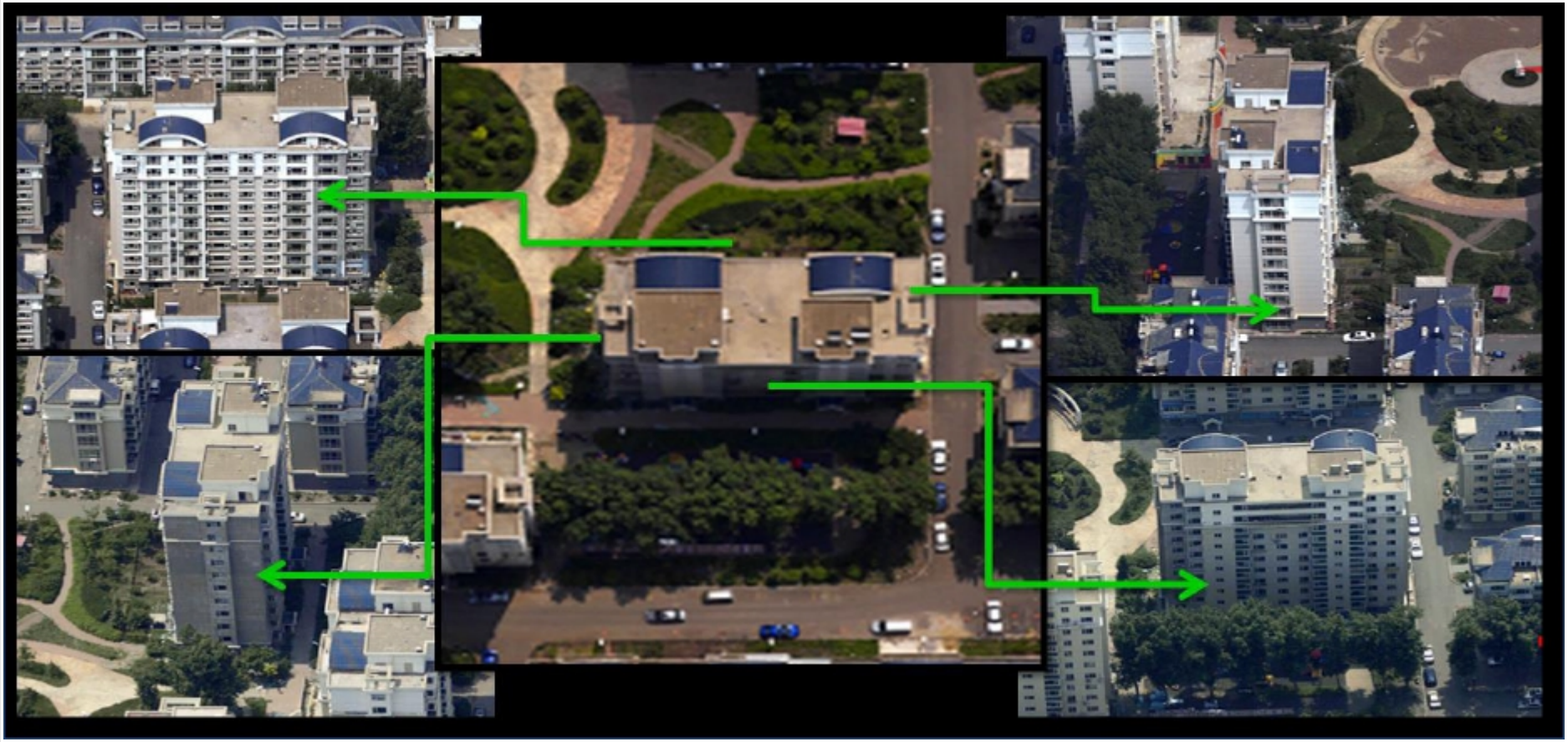
Aerophotogrammetry

- continuously taking photograph of objects on the ground with aerial apparatus in the plane in order to draw the topographic map
- Normally used in map of scale of 1:10,000~1:100,000

Oblique photography

- By carrying multiple sensors on the same flight platform, images are collected from different angles such as one vertical and multiple side views, etc



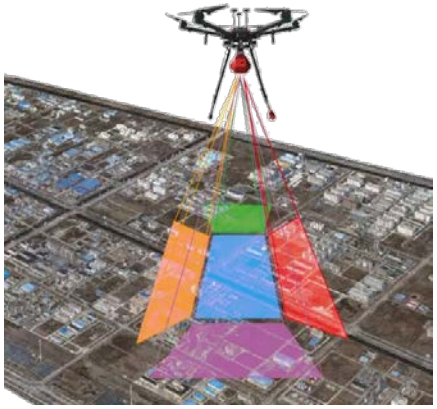


❖ Oblique photography

➢ Working flow

Drone

Camera



Images

Indoor modeling& Optimization

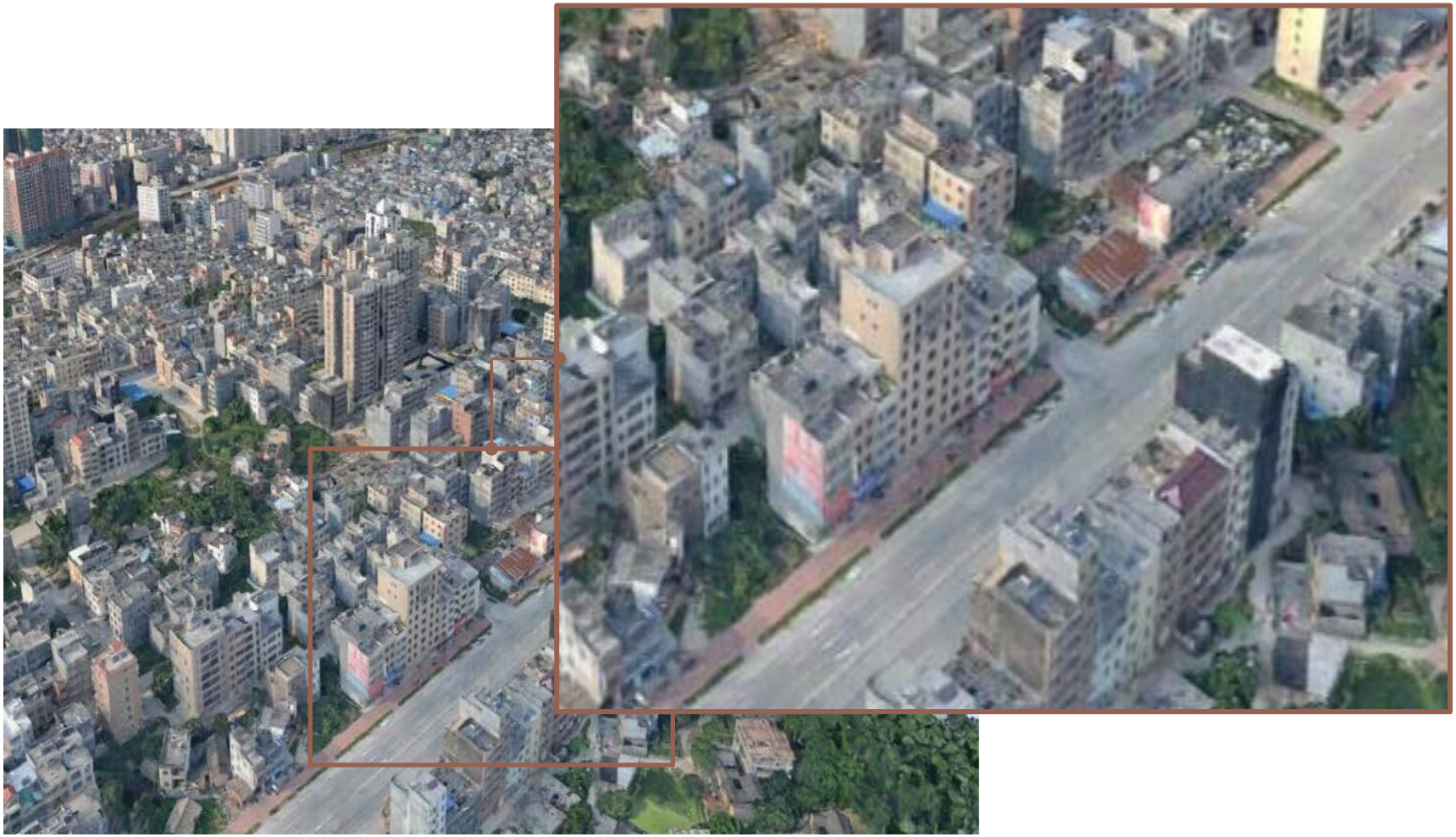
- Multi angle image with a certain degree of overlap
- Automatic generation of 3D model

GIS platform

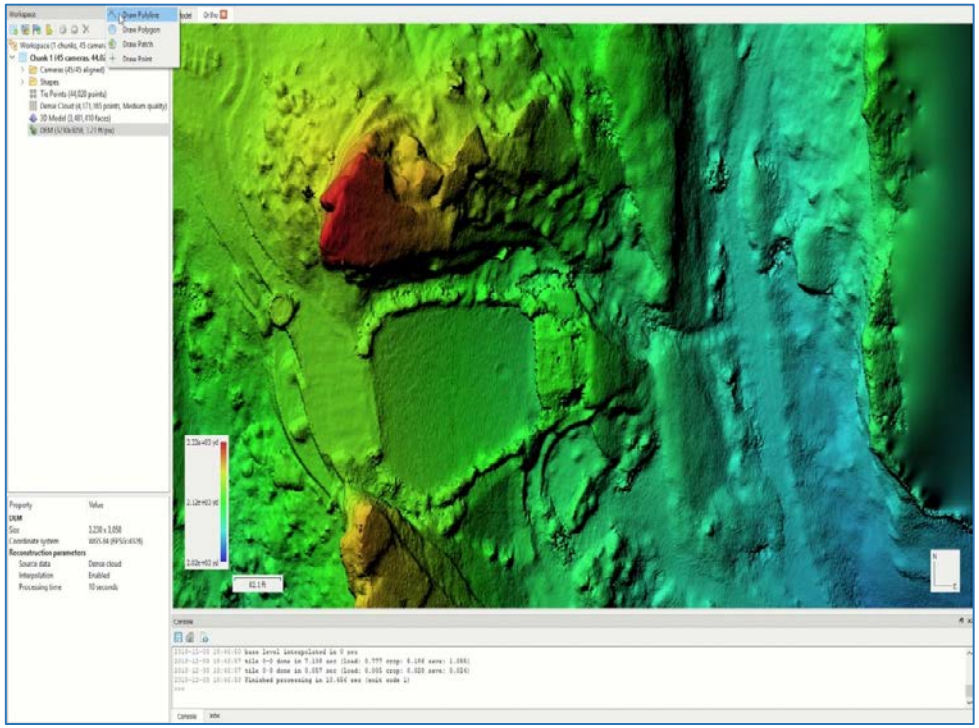
Outcome

- 3D urban infrastructure model
- DEM
- Fast earthwork calculation……

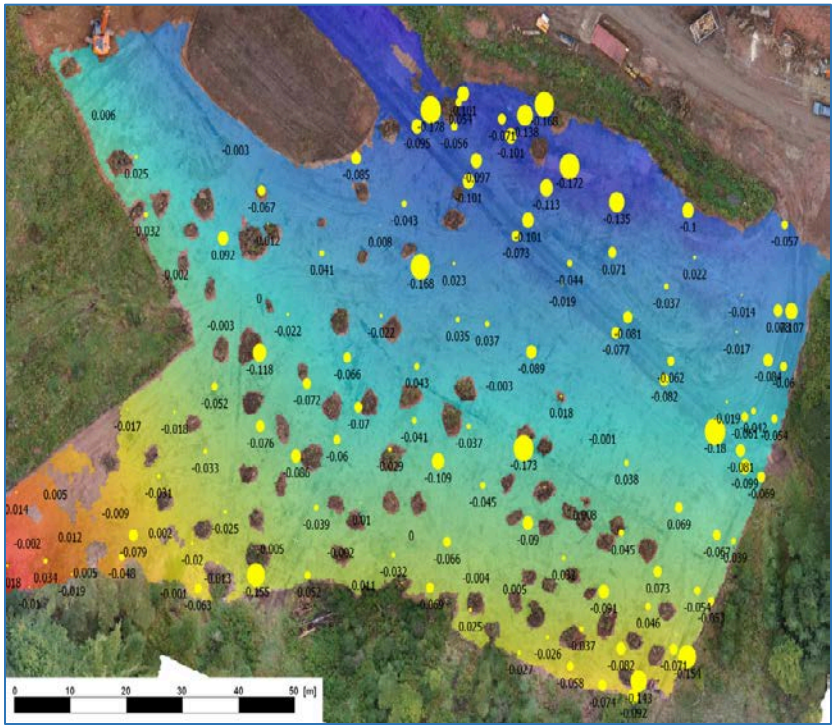
➢ 3D scene model



➢ DEM + Earthwork calculation



DEM



Earthwork calculation

➢ Road point cloud

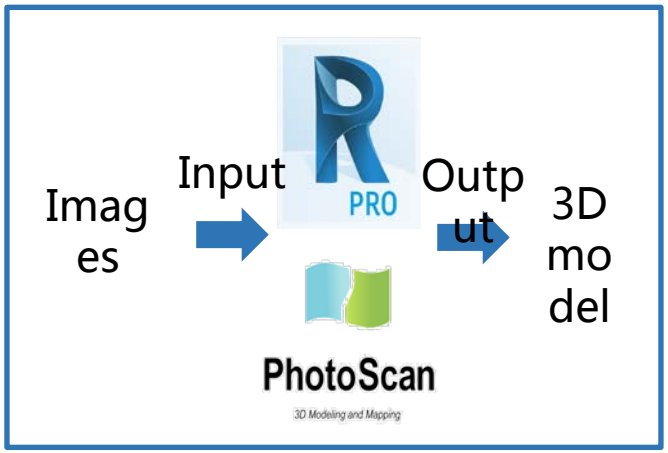
[Video]

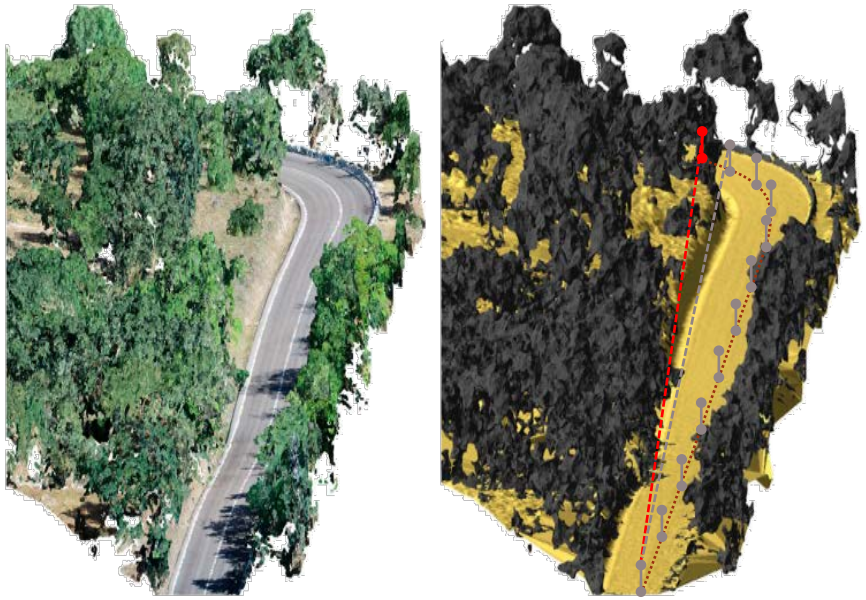
➢ Weakness

- details under tree crown and bridge cannot be obtained
- Influenced by weather
- distortion of camera lens results in the deviation of modeling details
- Relatively low accuracy, suitable for low-cost scenarios

➢ Application in roadway

- Automatic and rapid site survey to improve work efficiency
- DEM
- Earthwork calculation
- road safety analysis
- Using 3D point cloud to extract road range (for low precision requirements)

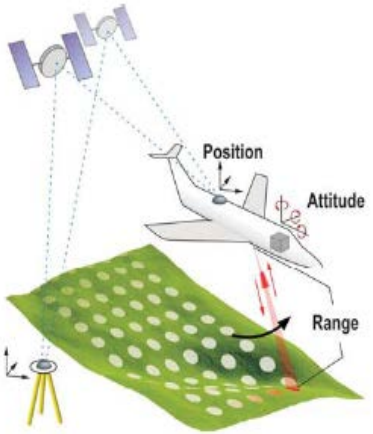


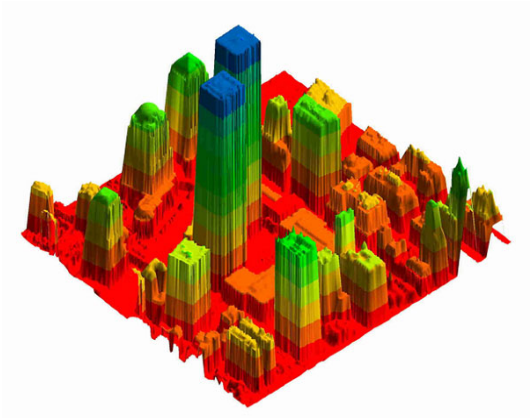


Sight distance analysis

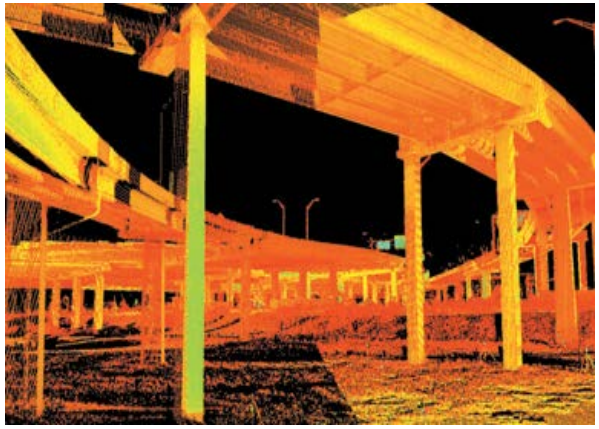
激光扫描技术（Light Detection And Ranging ,LIDAR）

a. airborne





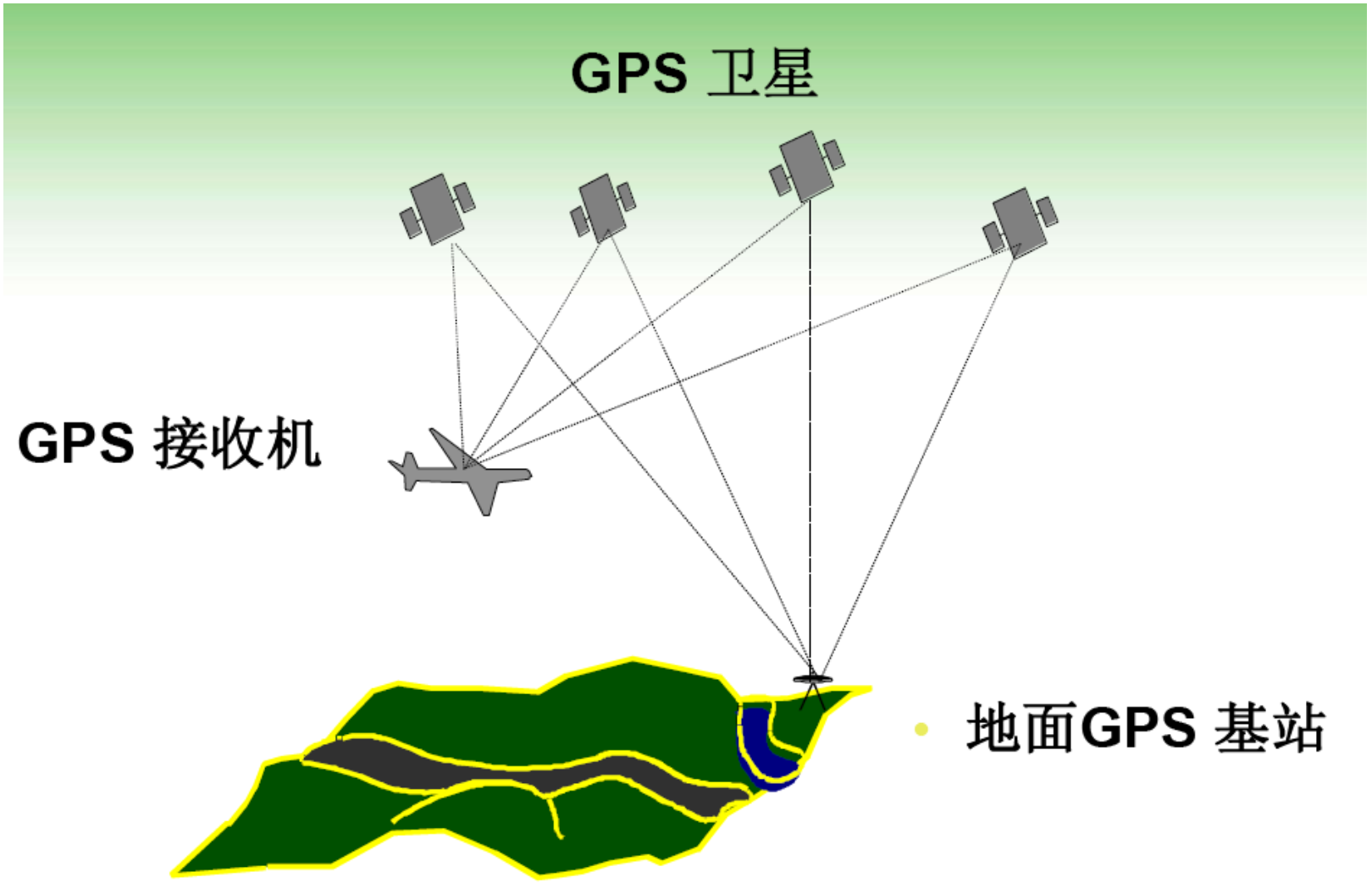
b. ground



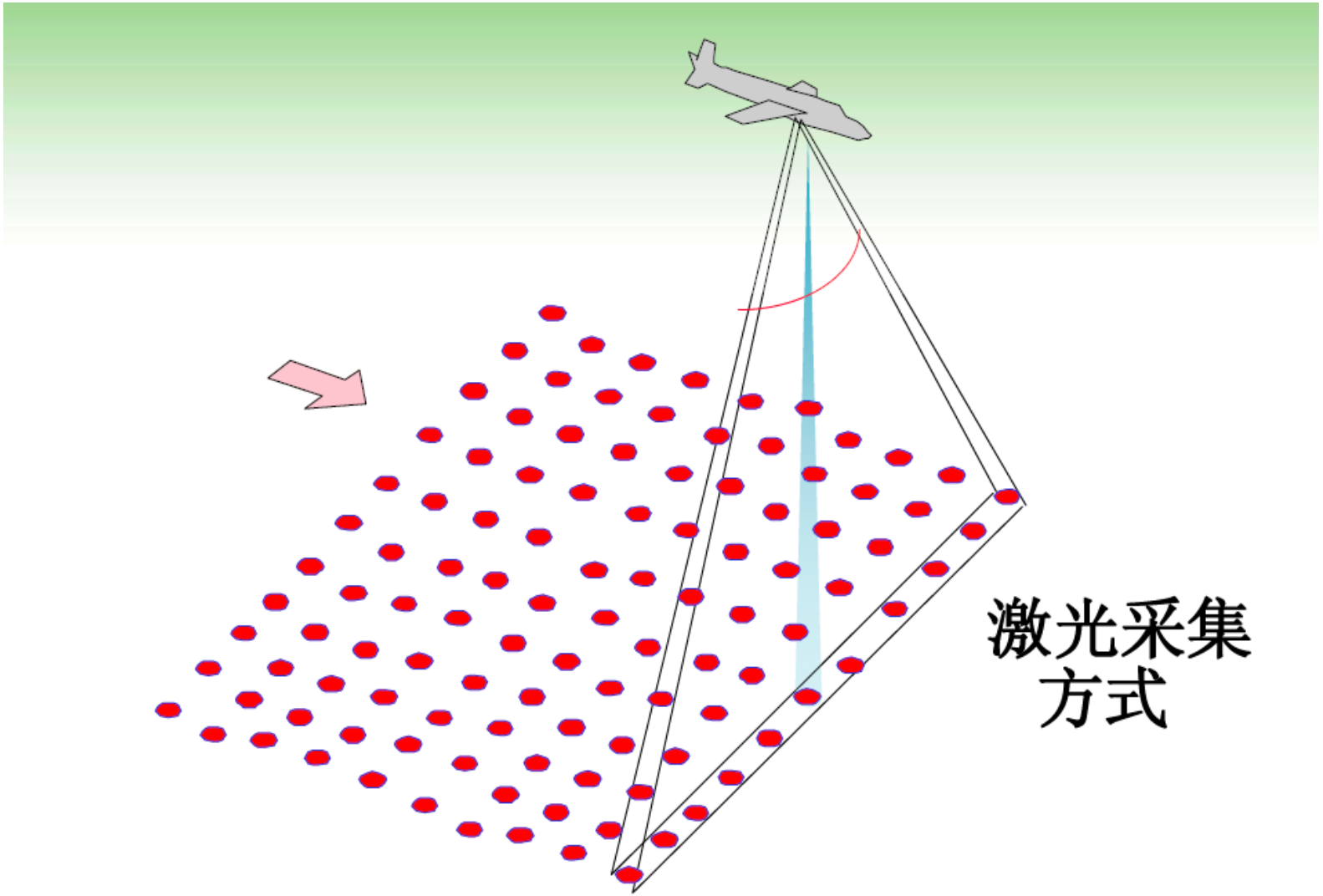
LiDRA

- LiDAR is a new type of fast measurement system, which utilizes a variety of measuring techniques
  - GPS
  - IMU
  - Laser scanning
  - Digital image
- Continuously measure the 3d coordinate of ground object

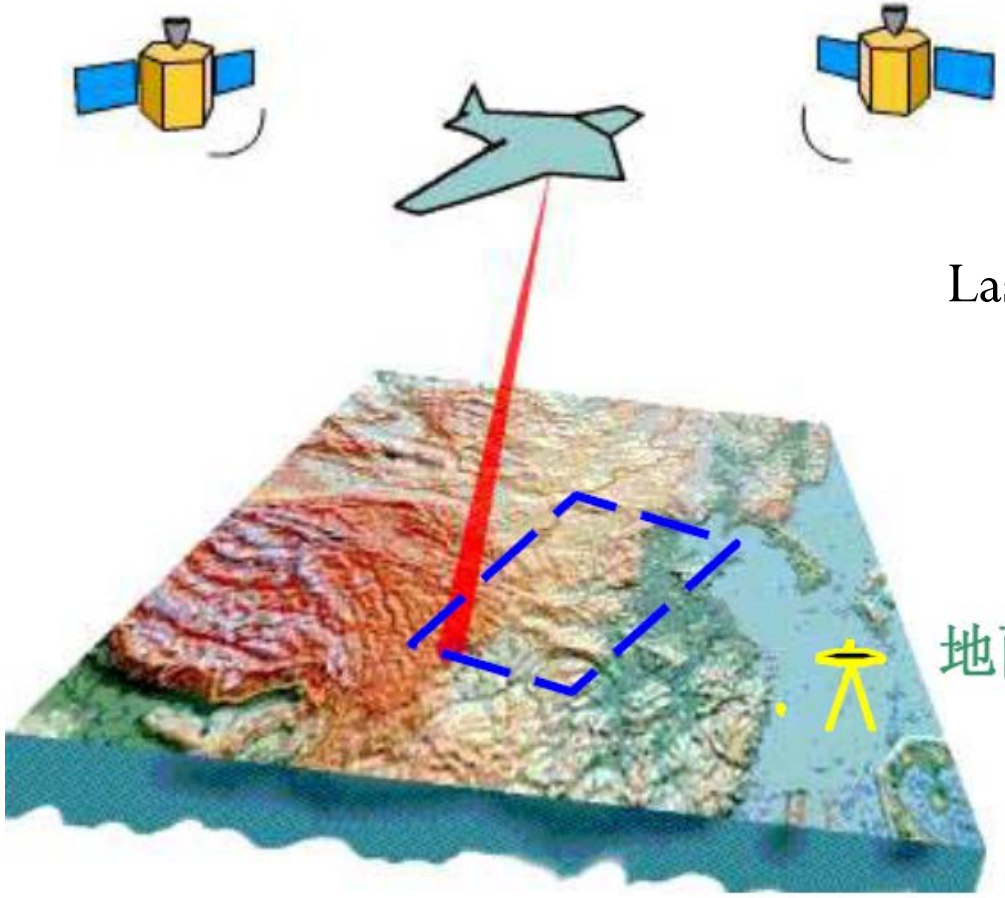
LiDAR-operation mode



LiDAR-operation mode



LiDAR-operation mode



Laser and video work jointly

Feature

- High collection density: flexibly adjust the laser spot collecting interval of different ground surface (0.5~2.0), which is very helpful for the simulation of DEM
- High data accuracy: Unlike traditional aerial photography, the accuracy of LiDAR data is very high due to the principle of laser echo detection. Moreover, the laser has (GPS+IMU) system, which achieves high positioning accuracy without ground control points
- Vegetation penetration capacity: Because the laser detection has multiple echo characteristics, it can return the elevation of the crown, branches, and ground. It effectively overcome the influence of vegetation, and is more accurate in detecting ground

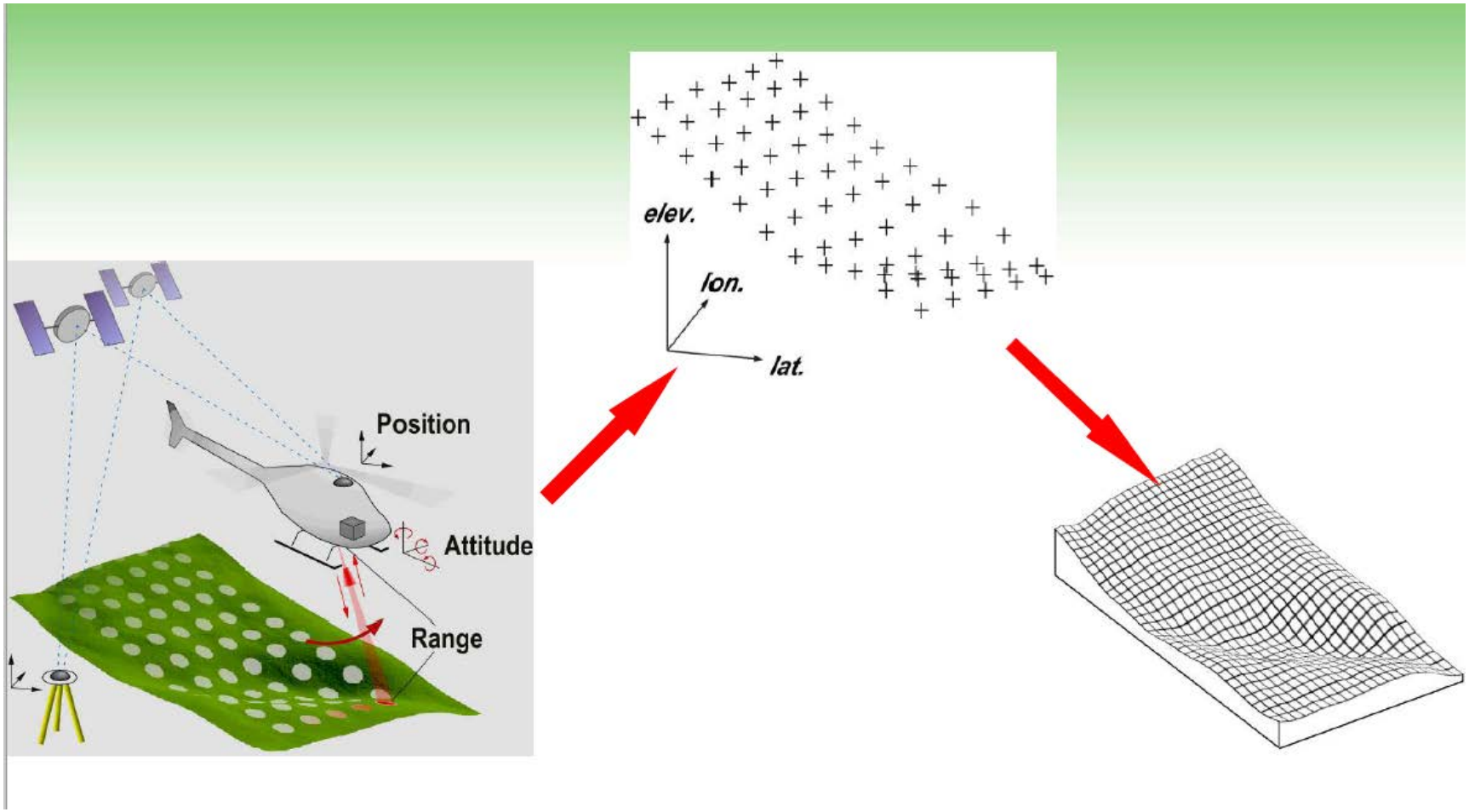
Feature

- Unaffected by shadows and solar heights: The method of laser ranging is not dependent on natural light for active measurement
- Fast access to data: Each laser point is collected directly with real 3d coordinate, and it does not need a lot of ground work, so it can greatly reduce the field workload.
- Abundant product: Using the high density and high-precision 3D point cloud and image data, it provides diversified products: digital surface model DSM, digital elevation model DEM, digital line drawing DLG and digital orthophotomap DOM.

Comparisons

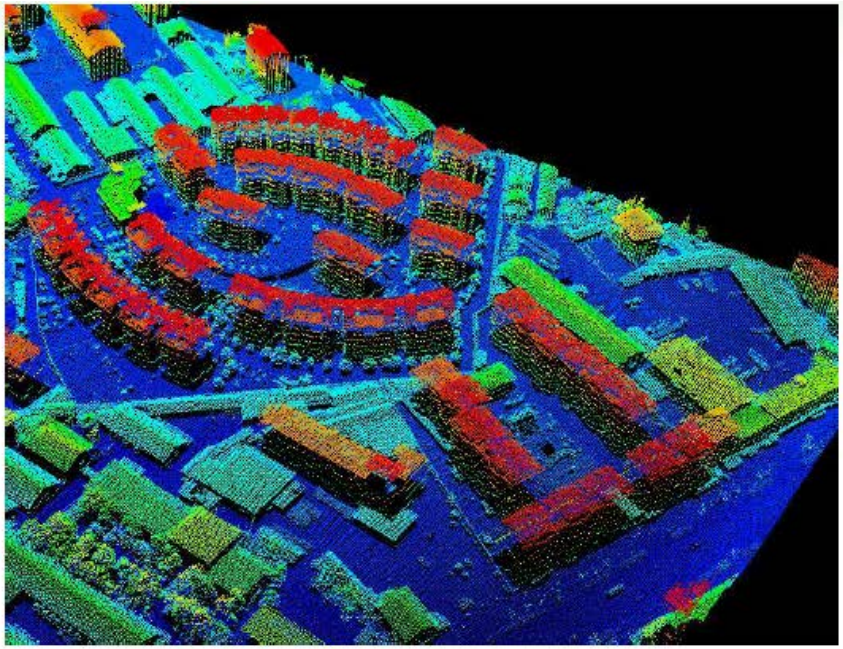
传统航摄	机载LiDAR
被动式测量 ——被动接收地物反射，依赖自然光	**主动式测量** ——主动发射激光，不受太阳高度角限制
面状二维采样 ——只有二维影像数据 ——影像质量高，平面精度优于高程精度	**点、面采样相结合** ——激光逐点高密度采样得到三维点云数据，数码相机面状采集二维影像数据 ——高程精度优于传统航摄
无法剔除植被影响 ——植被密集区域不能获取地面数据	**植被穿透能力较强** ——利用激光多回波技术，可以探测树下真实地形，精确建立真实地面高程模型
间接获取地面三维坐标 ——经过较大量外控和内业处理，传统方法获取地面三维信息	**直接获取地面三维坐标** ——利用集成的机载POS定位定姿系统直接记录三维坐标信息
外业工作量大 ——布设大量地面控制点，无法在地形复杂地区大量作业	**外业工作量小** ——仅布设少量地面基站，供后期差分处理 ——进行国家/地方坐标转换，需测量部分坐标转换控制点

Fast DEM construction



3D coordination

- The laser point cloud data itself is 3D data. The traditional aerial photogrammetry is 2D.

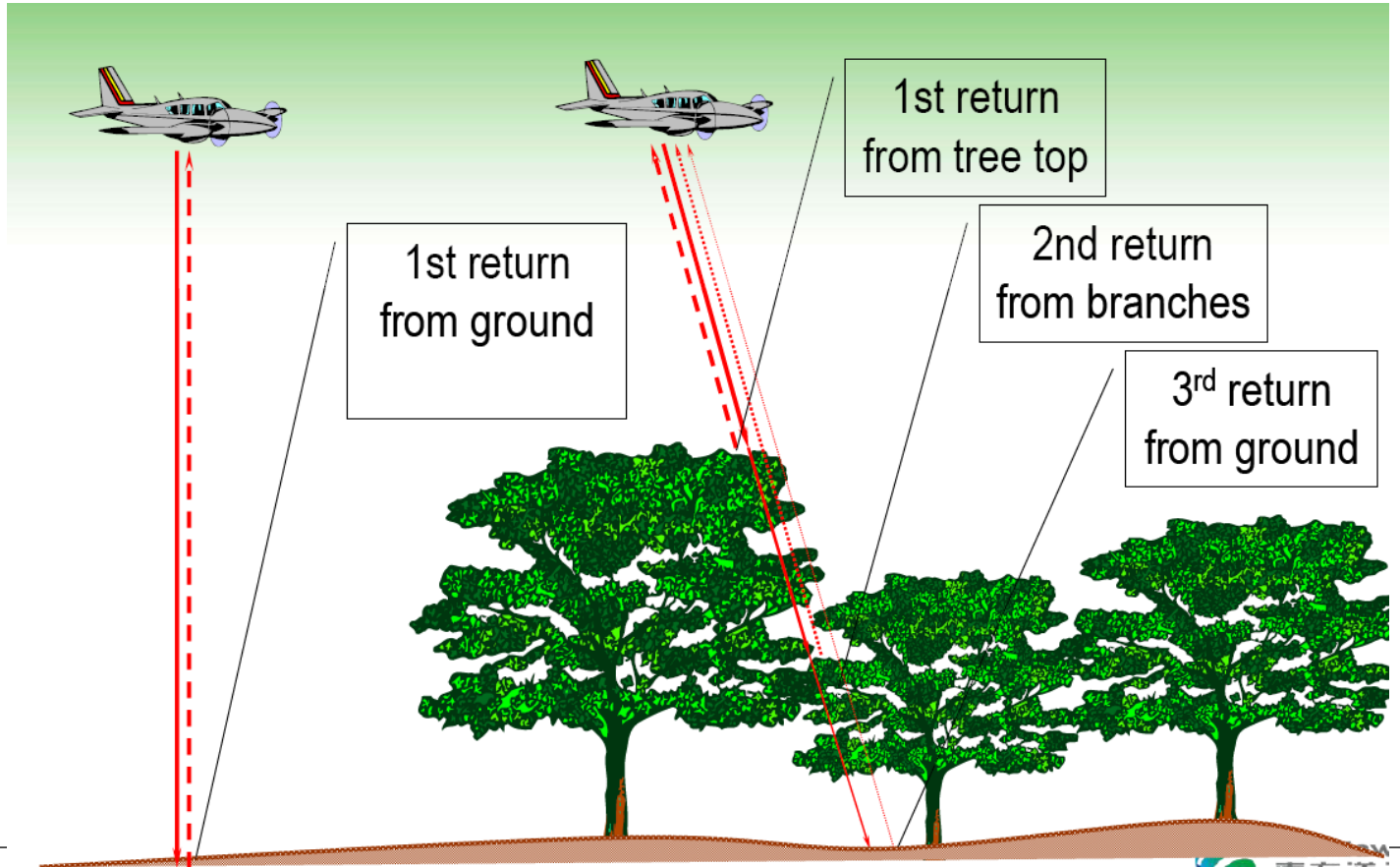


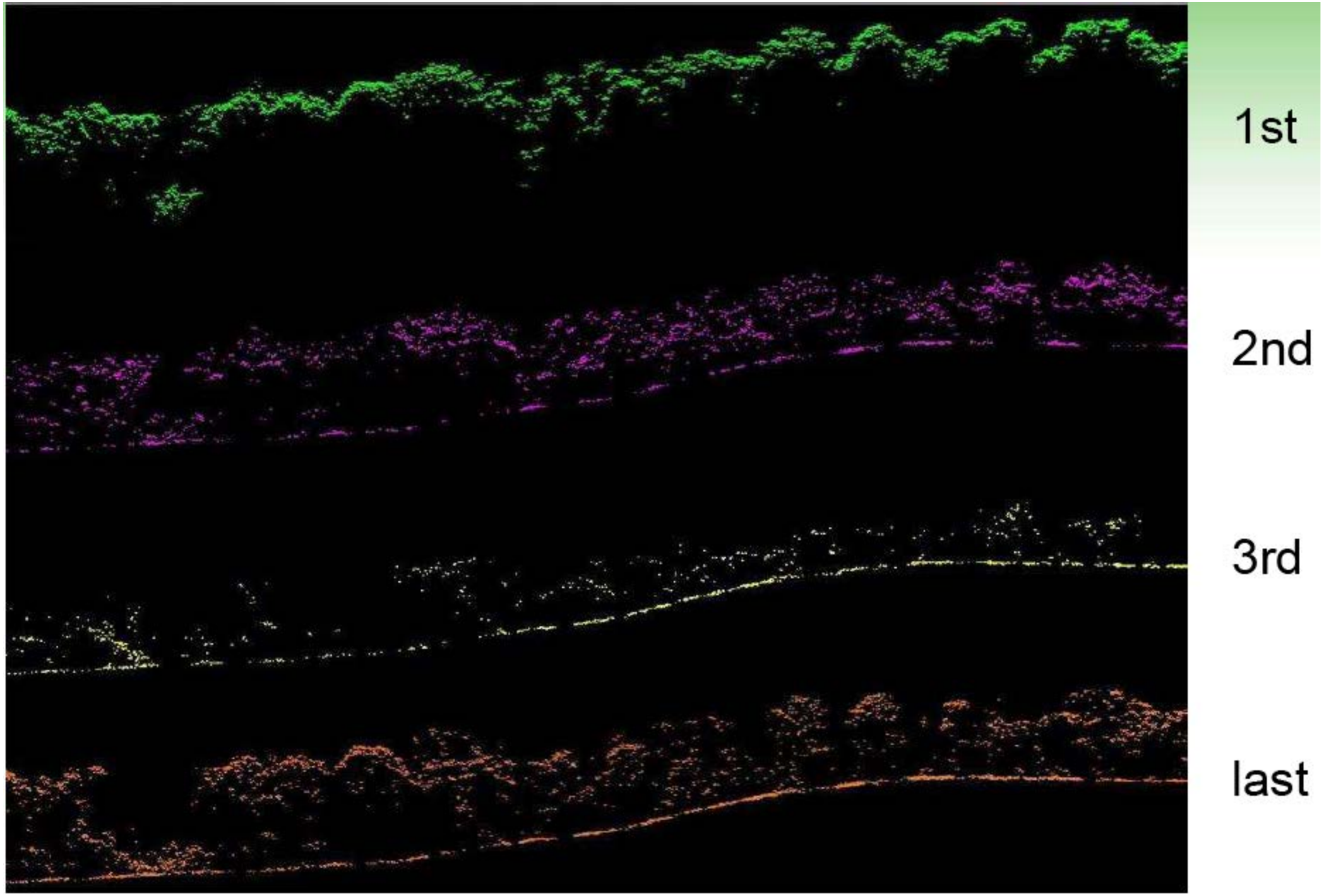
3d data cloud

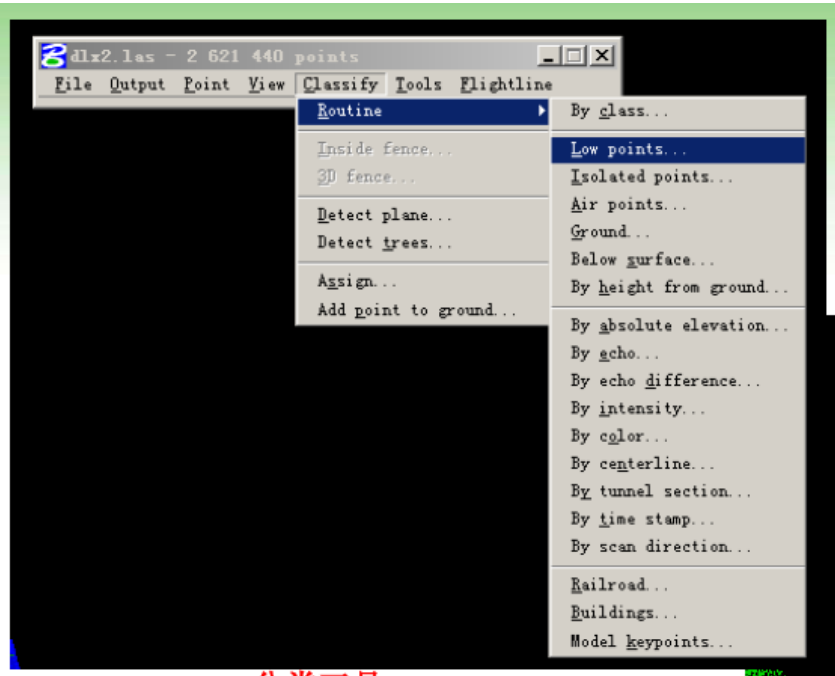
aerial photogrammetry

Vegetation penetration

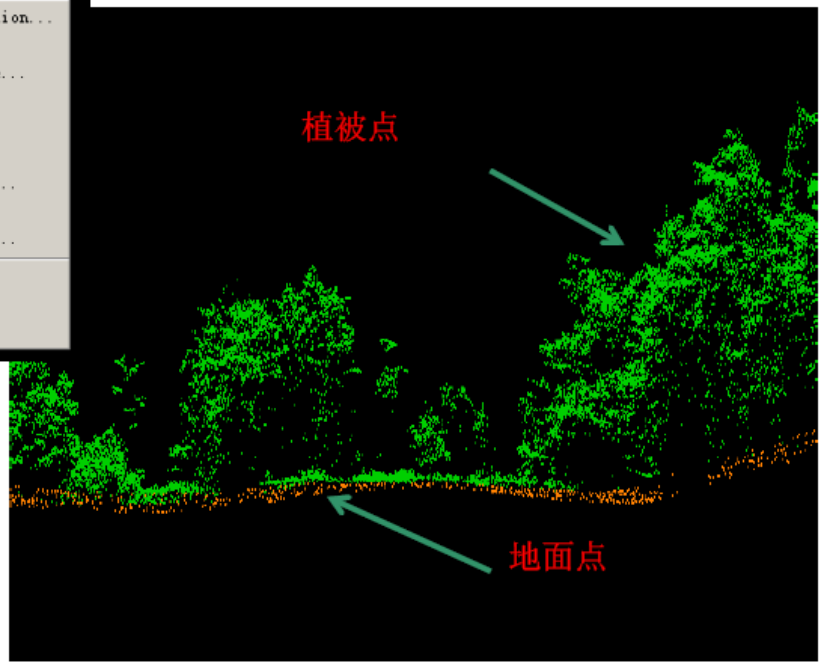
- Multiple echo detection technique
  - This feature can effectively detect the height of trees and the acquisition of 3D information under trees

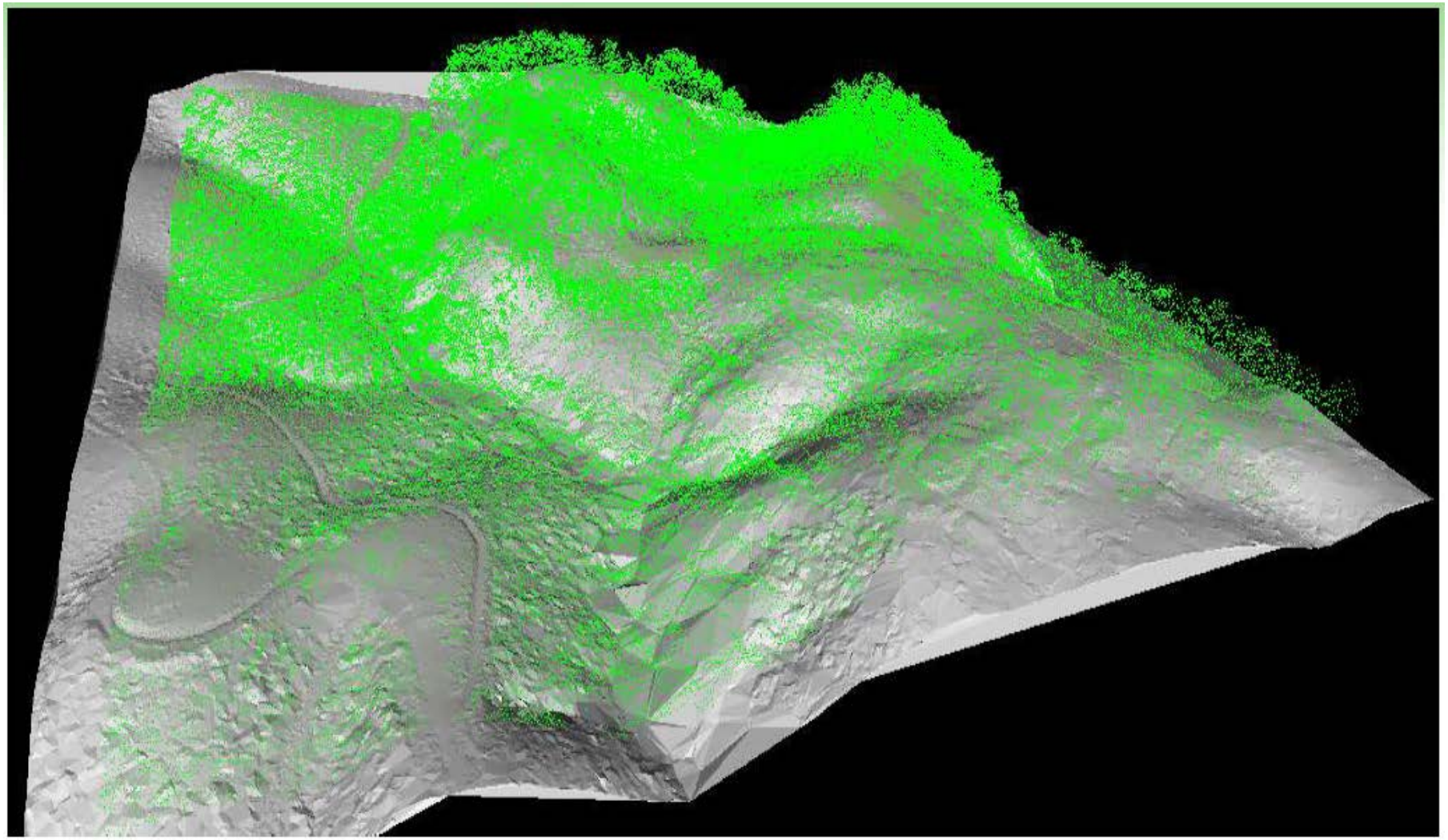



1st
2nd
3rd
last

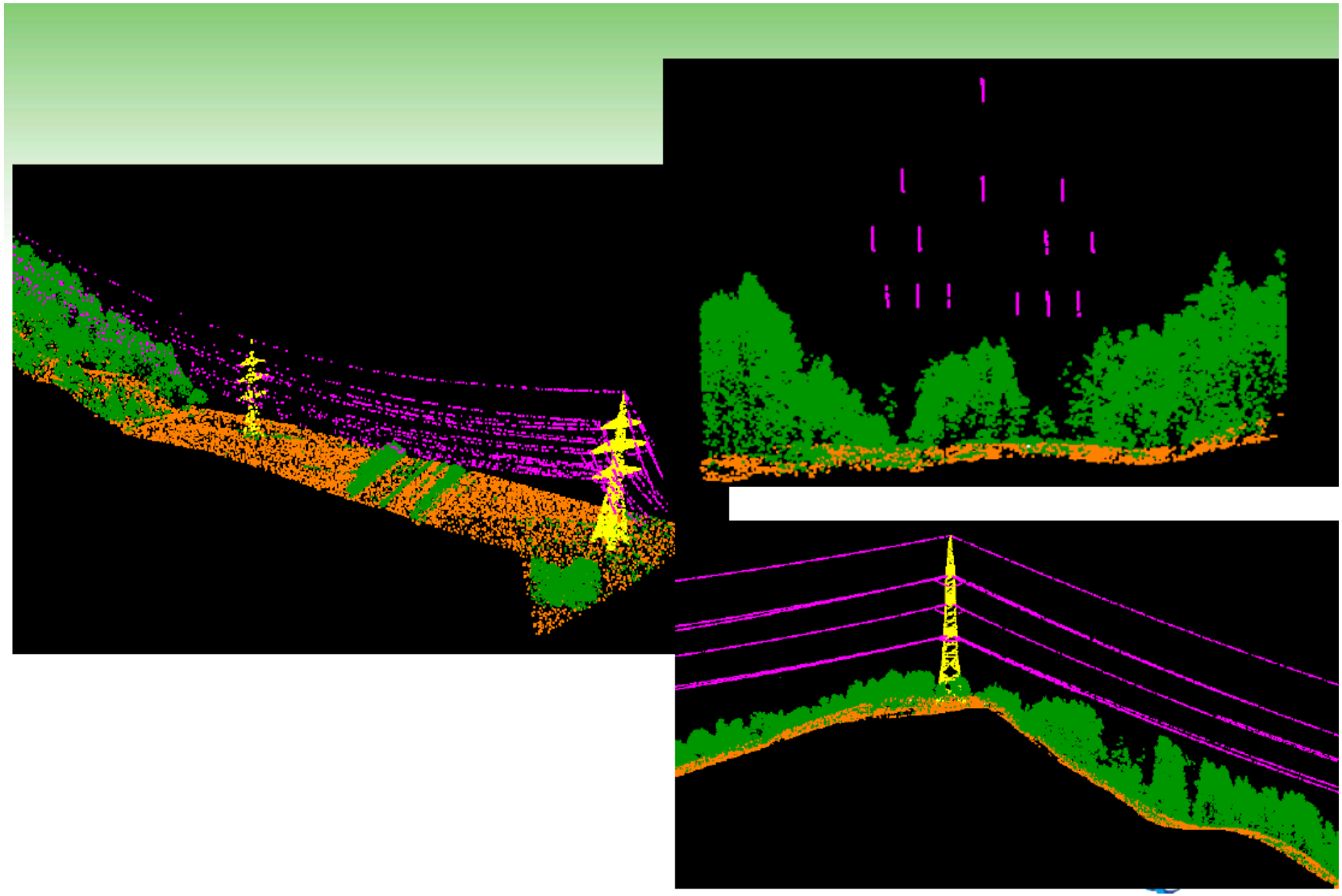

dlx2.las - 2 621 440 points
File Output Point View Classify Tools Flightline
Routine
Inside fence...
3D fence...
Detect plane...
Detect trees...
Assign...
Add point to ground...
By class...
Low points...
Isolated points...
Air points...
Ground...
Below surface...
By height from ground...
By absolute elevation...
By echo...
By echo difference...
By intensity...
By color...
By centerline...
By tunnel section...
By time stamp...
By scan direction...
Railroad...
Buildings...
Model keypoints...

分类工具


植被点
地面点



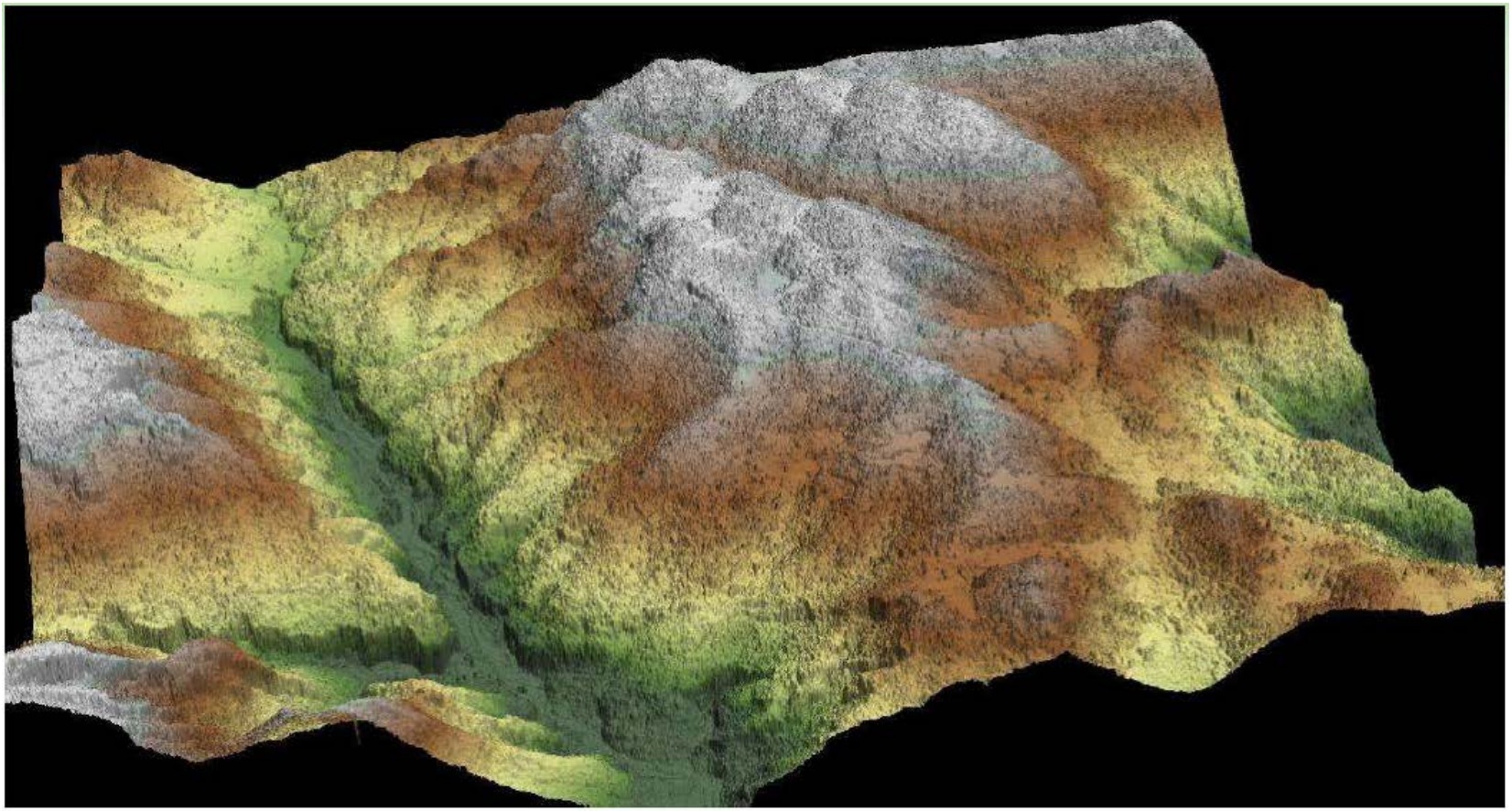
Products-Raw data cloud



DSM

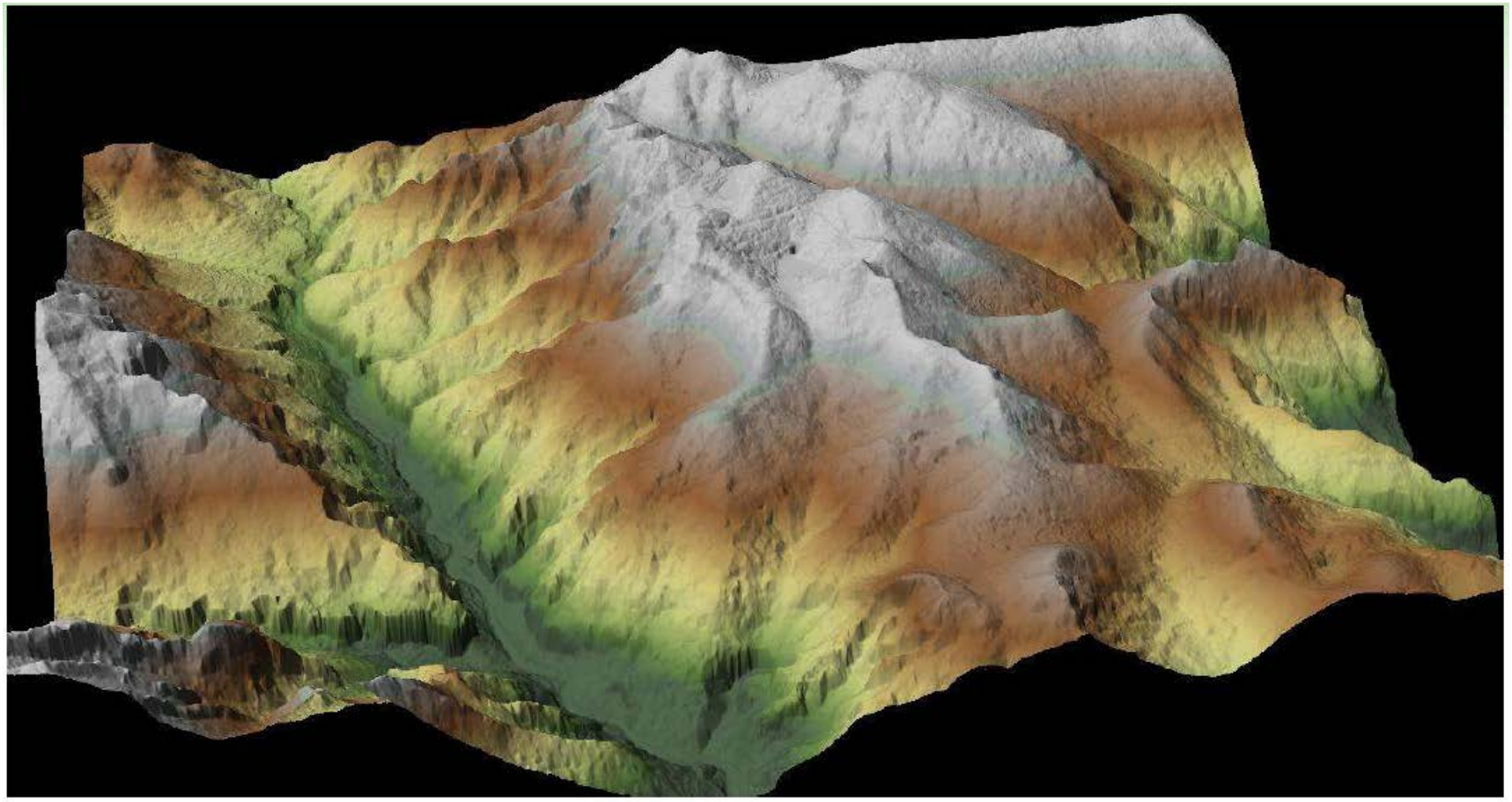
Urban area— grid gap 0.5m

DSM

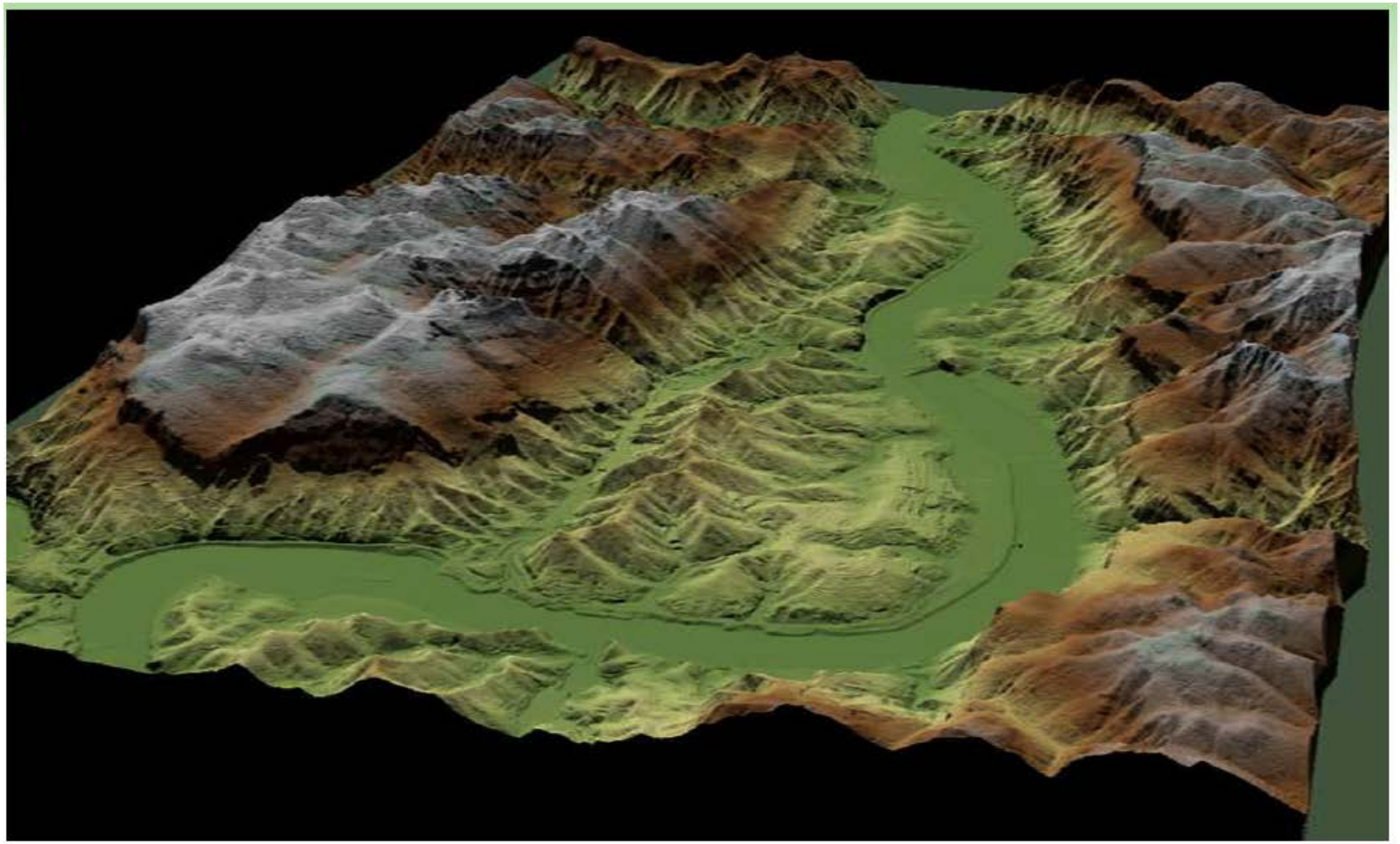


Mountain zone- grid gap 1m

DEM

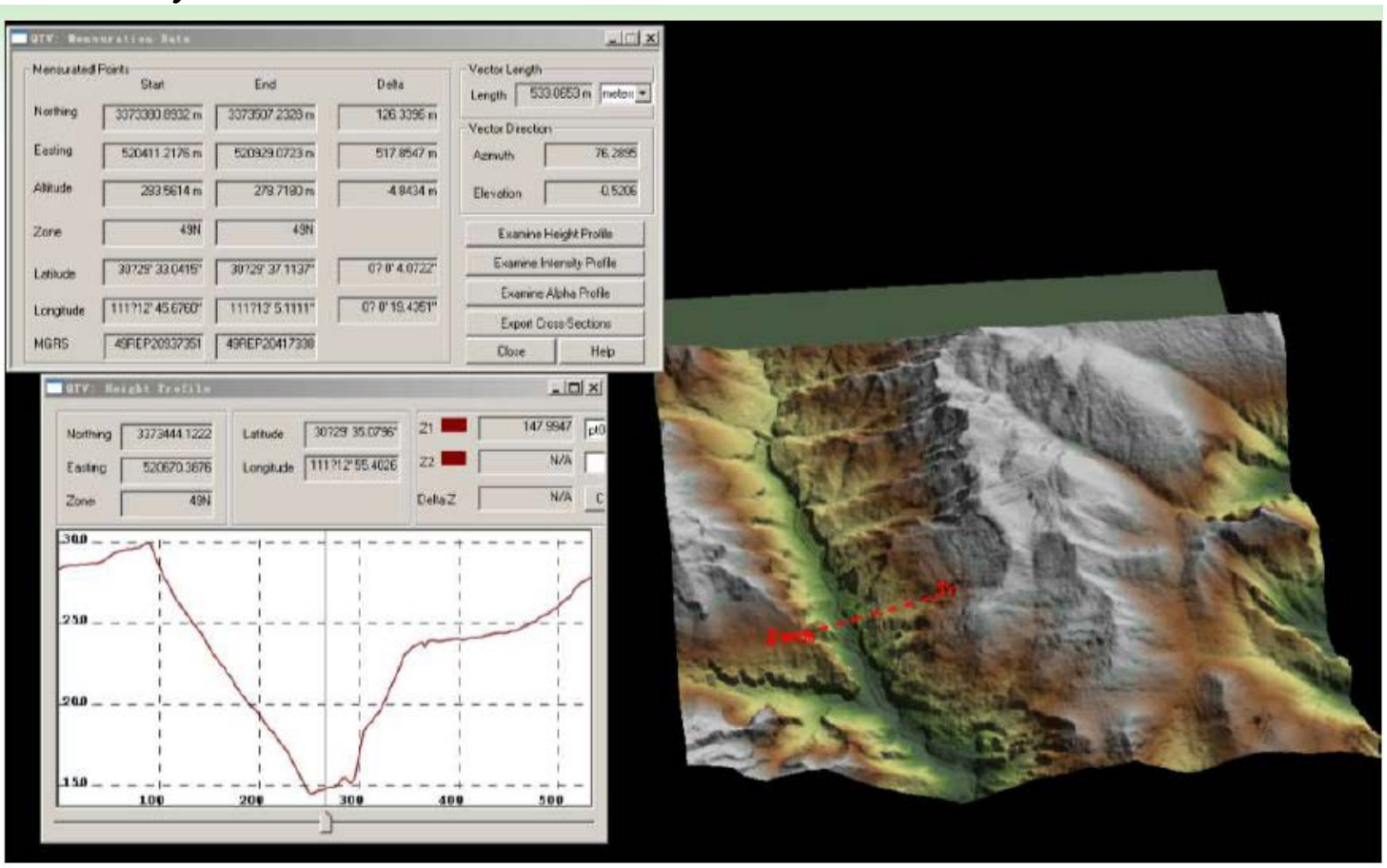


DEM



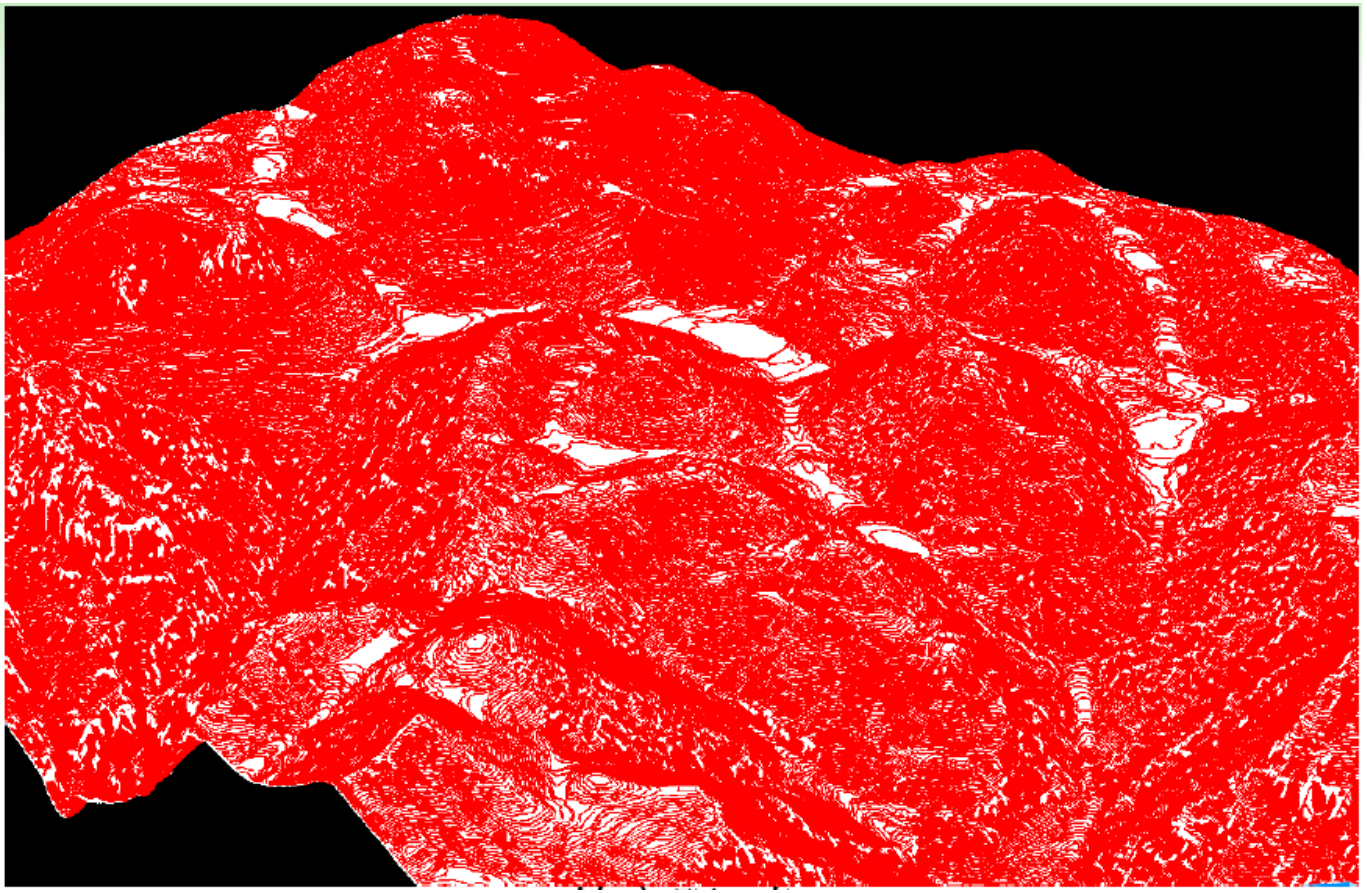
DEM and cross sectional profile

- Using 3D DEM data, the engineering data can be measured directly



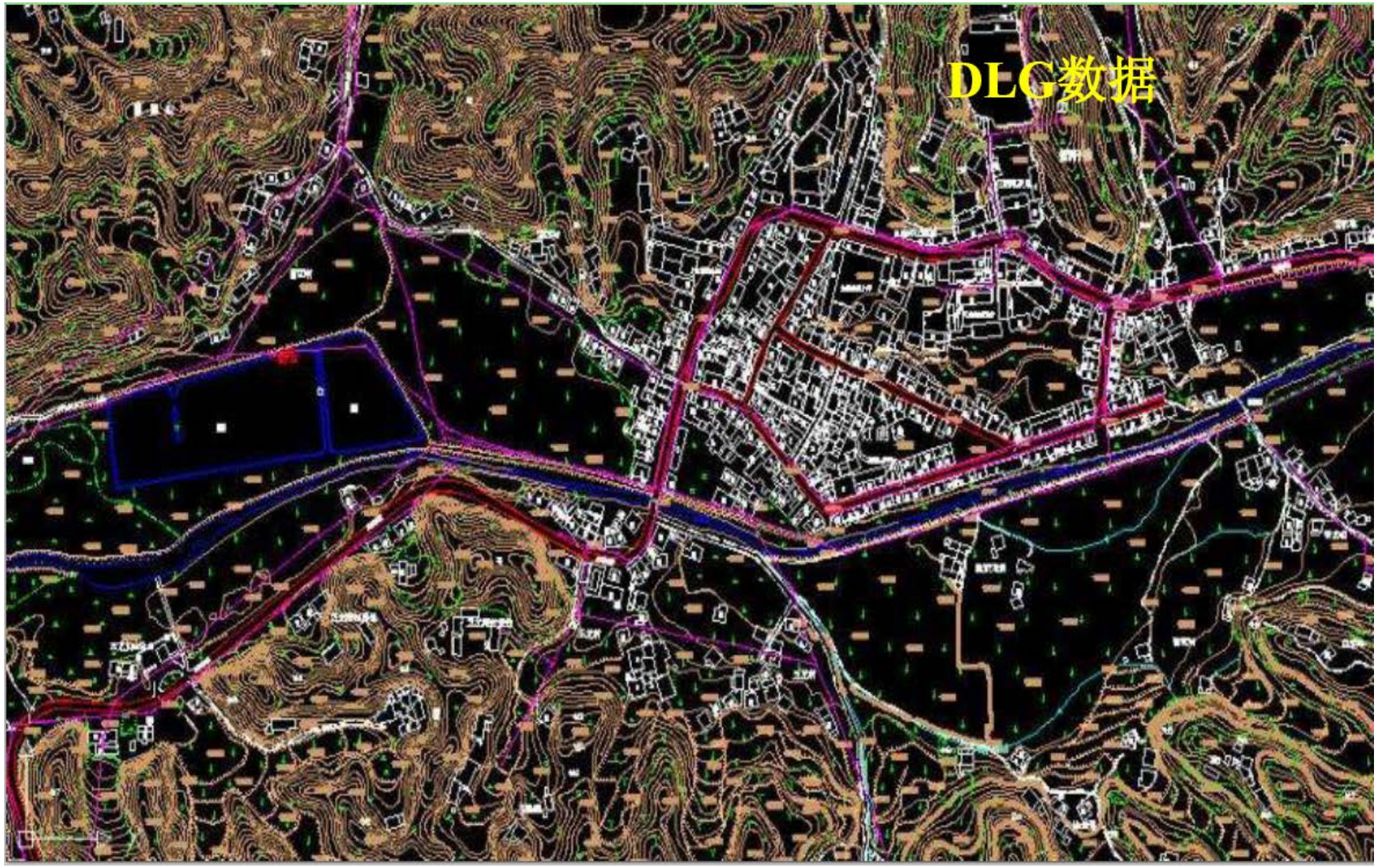
Contour vector data

- Generating high precision contour lines by DEM data



The interval is 1 meter

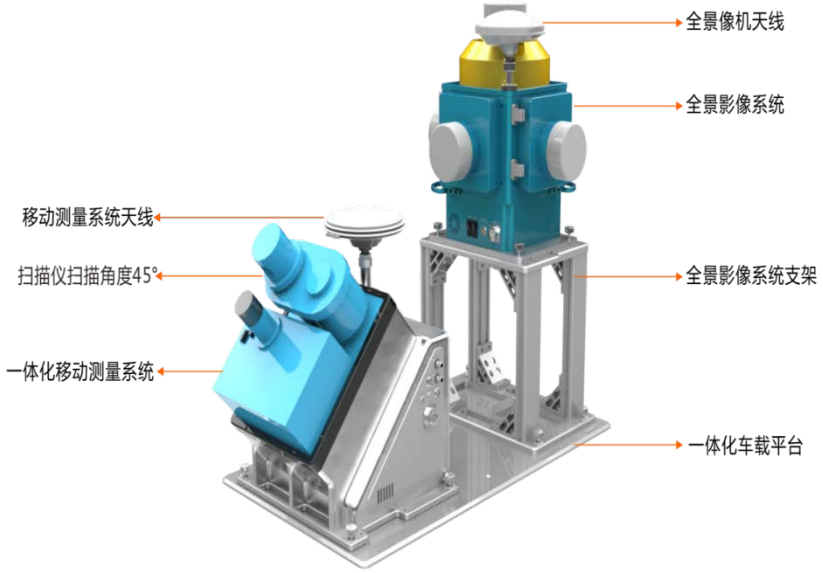
DLG



Digital orthophoto map

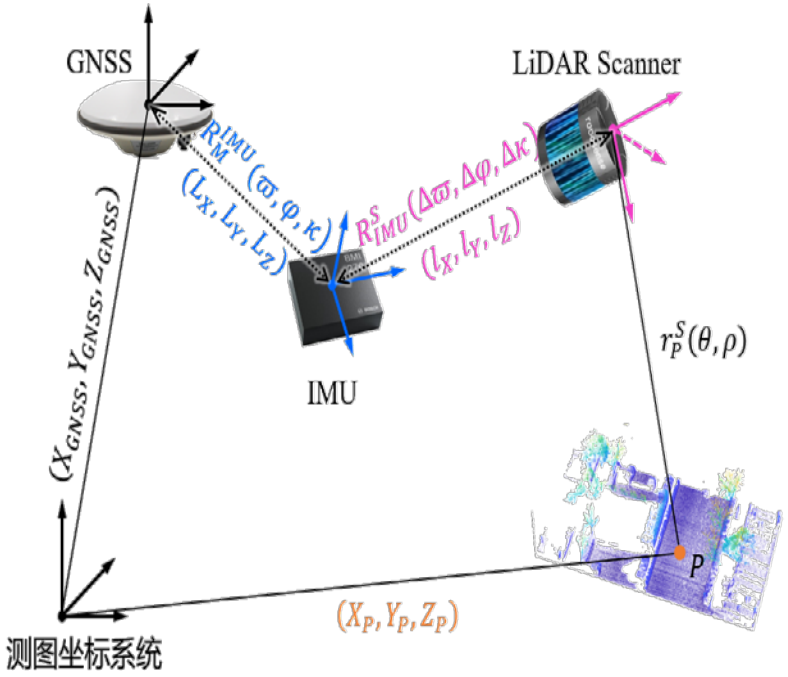
➢ 车载激光雷达（Mobile LiDAR)

By driving on the road, high-precision 3D point cloud data can be collected to accurately describe the road environment.

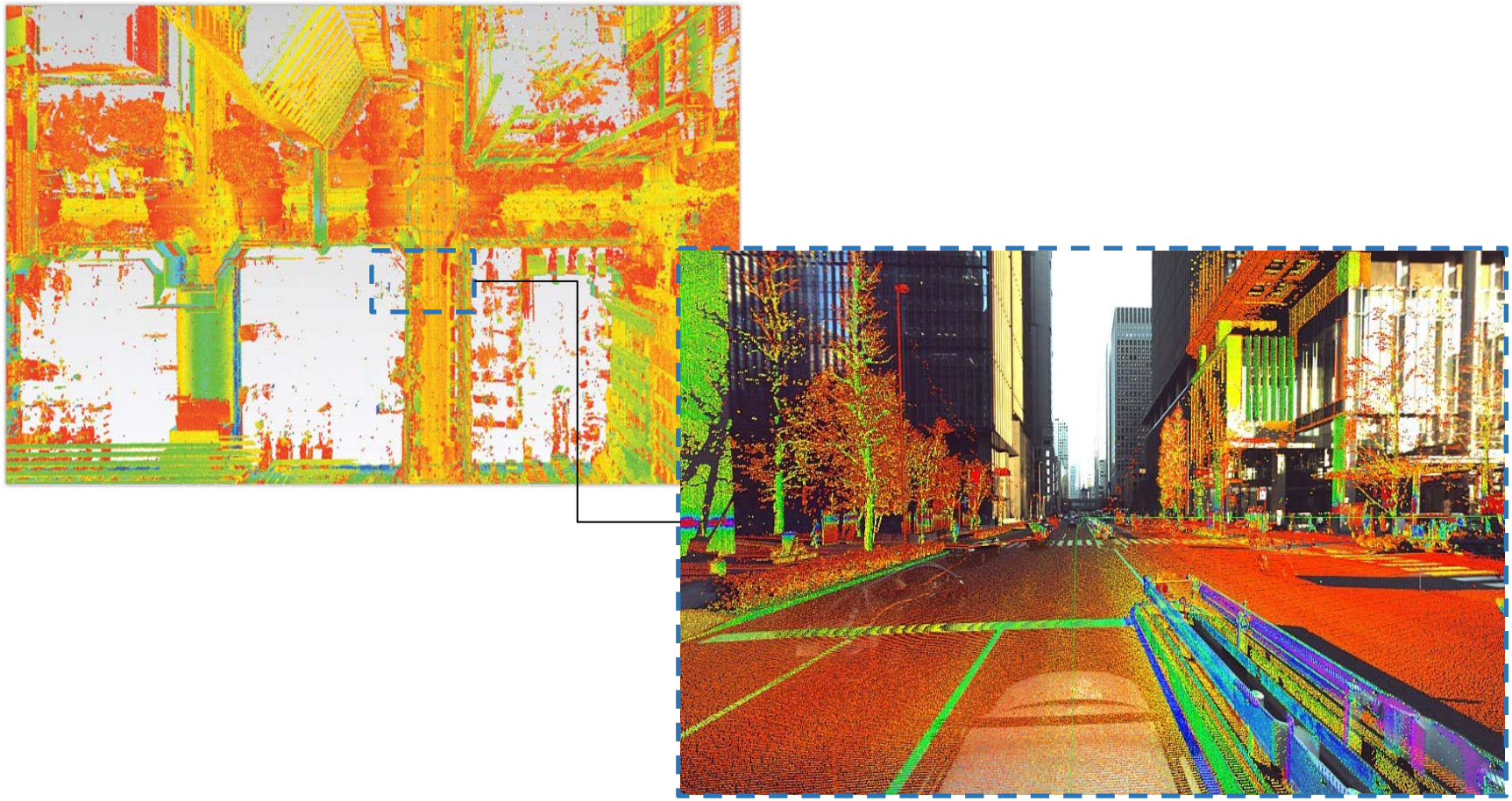


➢ 车载激光雷达（Mobile LiDAR)

Lidar scanner rotates at high speed. When it encounters an object, the distance between lidar and scanner is calculated by laser pulse parameters, and the scanning angle is recorded by the scanner. Then, according to the transformation of lidar coordinate system, IMU coordinate system and GNSS receiver coordinate system, the three-dimensional coordinates of the point are obtained。



➢ achievement

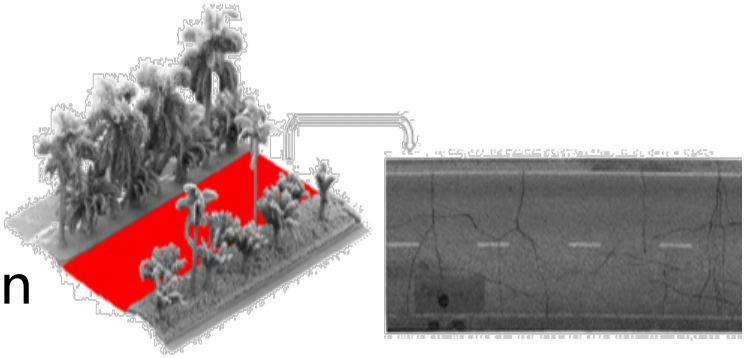


Color represents reflection intensity

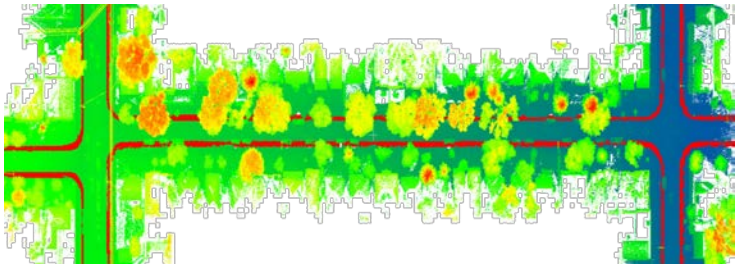
➢ **Multi dimensional road facility information extraction**

In road information extraction

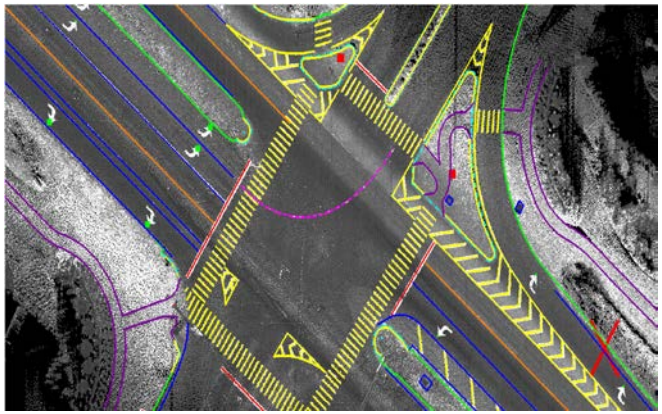
(a) surface & boundary extraction



(b) Markings



(a)



(b)

(c) Geometric parameter extaction

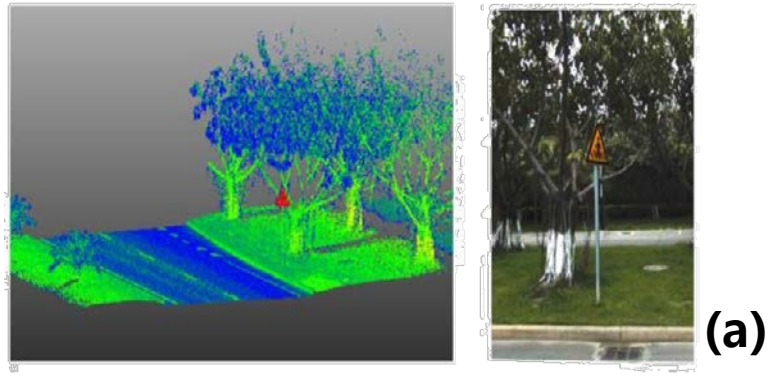
(c)

➢ Multi dimensional road facility information extraction

Outside road information extraction

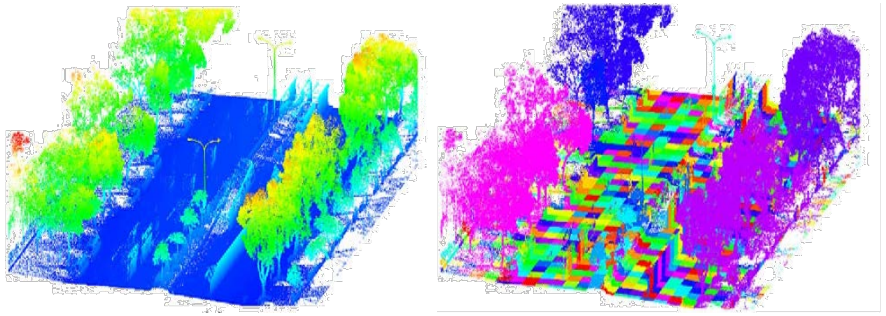
(a) traffic signs and signal facilities

(b) Greenbelt

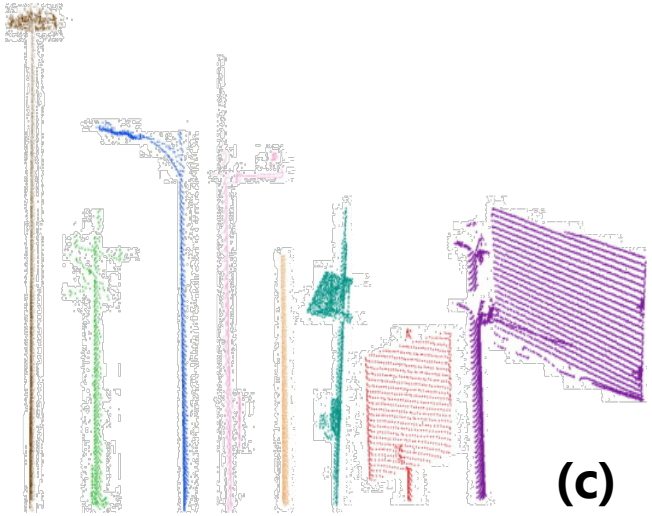


(a)

(c) Others



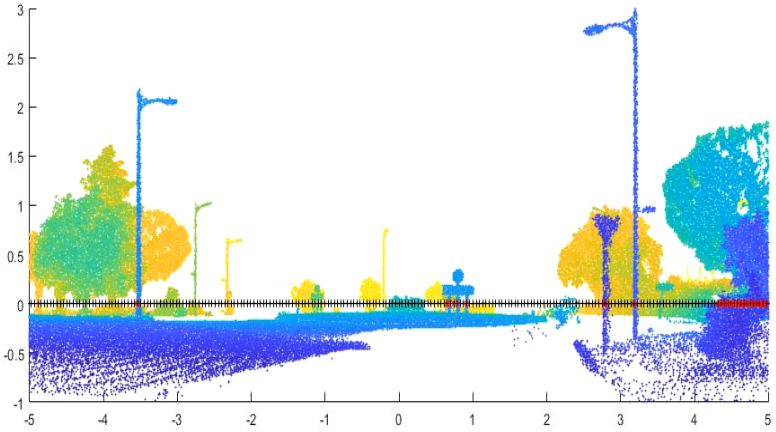
(b)



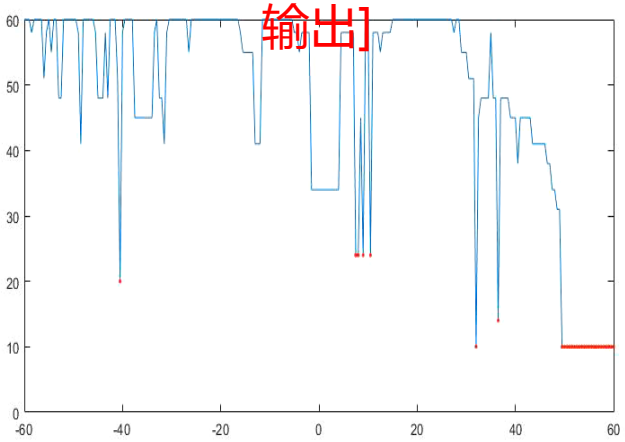
(c)

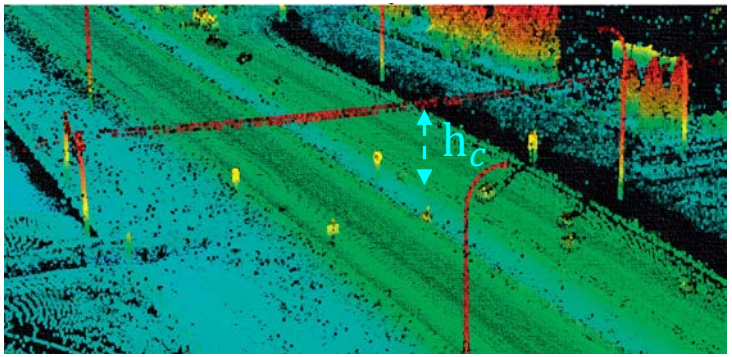
➢ Applications

One time collection, multiple information services



[视频-动态可视性输出]





(a)

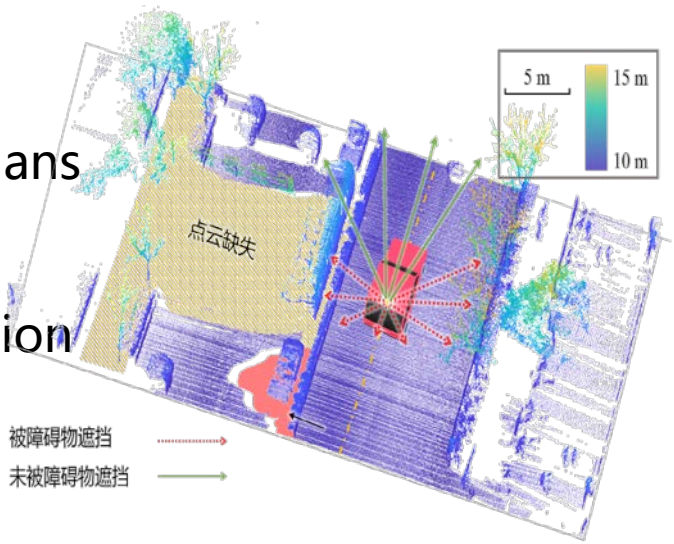
(b)

- Automatic driving path generation
- Accessibility analysis of urban pedestrian facilities
- Safety analysis of intersections
- Extraction of some pavement state information……

➢ Lidar

Shortcomings

- The amount of data is too large
- noises such as moving vehicles and pedestrians resulting in the lack of point cloud
- no perfect algorithm for information extraction of some categories



Development trend

- Important support of Digital City
- Methods to apply AI technology to improve the efficiency of algorithm

Question?

- Please discuss the advantages and disadvantages of the afore-mentioned methods and their application conditions?