Introduction of next generation Visual Positioning technology brought by Hi-Target

Key words: surveying;GNSS;RTK;visual; 3D reconstruction; real-time image processing;

SUMMARY

Visual measurement technology is the leading technology in the industry, users have been eager to see a more convenient way to achieve measurement for a long time, and into the era of computer technology is so developed, AR, UAV and other sensing technology has been widely concerned in society, mapping industry as a high-tech technology industry, can be combined with visual measurement must be a great joy in the industry. Thankfully, this is no longer a dream, Hi-Target's visual measurement RTK products can easily achieve non-contact high-precision measurement for you. This article will take you deeper into the current development of the industry and the development of vision technology, and share with you the new Hi-Target vision measurement RTK that can unlock more application scenarios and make measurement less of a hassle.

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1. RTK Product Trends

1.1 Tilt measurement RTK

In the early days, the tilt measurement RTK receiver is a product that allows users to measure the target point in the state of the tilt receiver, the initial generation of tilt measurement mostly using magnetometer tilt measurement must be tilt correction (about three minutes), each measurement of a point only three seconds, but because the tilt measurement technology at that time mainly relies on the geomagnetic solution, it is easy to be affected by the magnetic field, the use of the scene is very limited, the measurement The results are not controllable, and the users are not fully satisfied with the results. However, tilt measurement is a very urgent and practical need in mapping operations, which can greatly reduce the work intensity of field surveyors and improve their operational efficiency.

1.2 Satellite-based RTK

RTK with satellite-based enhancement services, for marine measurement, no network signal land measurement has obvious advantages, the past two years, with several major domestic manufacturers of system construction to promote, satellite-based PPP Service is already an important technical indicator of RTK products.

1.3 Multi-system RTK

The four global satellite systems together have more than 120 satellites, for urban measurement, mountain measurement and other half of the sky, a line of scenarios can also be fixed properly, so Beidou three, Galileo brought a comprehensive upgrade of RTK products.

1.4 Software RTK

Now the computing power of mobile ddevice is getting more and more powerful, the development of software receivers (Software GNSS Receiver) from the technical point of view has the conditions, from the mass market demand, low-cost, simple software RTK has begun to usher in the development.

1.5 RTK with IMU

As we know, the combination of INS and GPS usually has three modes: loose combination, tight combination and deep combination. Among them, the deep combination (super tight combination) can use INS measurements, acceleration, velocity and other information on the receiver signal tracking assistance, is the signal processing level of the underlying fusion, for high dynamic, complex environment receiver performance improvement is helpful, has been only in the military, scientific research and other fields of application. With the cost of MEMS IMU down and performance improvement, the combination of future inertial guidance and RTK will not only be used to complete attitude correction (tilt measurement), a short period of

continuous measurement of satellite out-of-lock, more valuable is the spring of RTK receivers by deep combination to bring better signal, more stable and higher accuracy.

1.6 Visual RTK

With the popularity of automated vehicles like the Unmanned Vehicle in the air and on the ground, the integration of RTK and vision positioning technology has become a trend. Vision enhanced RTK takes advantage of the mutual independence and exclusivity of GNSS and vision system (e.g. camera) data in the error source, and deeply integrates high-precision GNSS positioning and computer vision technology, and allows the two to correct each other at the data layer, thus ensuring centimeter-level positioning in various complex scenes (woods or electromagnetic interference environment). precision positioning in various complex scenes (woods or electromagnetic interference environment).

At present, the popular RTK receiver products on the market is basically the first five types, due to a combination of technical, cost and other factors, the development of visual RTK is still relatively niche, not yet widely popular, but because the current GNSS receiver products are limited to the applicable scenarios need to be measured at the target point, the objective environmental conditions of the target object to the measurement caused by a certain degree of difficulty. In this situation, visual measurement technology still has a very large development space, through the visual area to achieve non-direct contact measurement, will open another door to the future GNSS receiver products.

2. Vision Surveying Applications

With the development of visual measurement and computer technology, 3D reconstruction has been widely used in digital cities, smart cities, cultural relics and archaeology, and high precision measurement combined with 3D reconstruction of images will also become a cross-natured progress in mapping operations. The integrity and refinement of 3D models are also increasingly required. For high-precision measurement, visual measurement needs to build a refined model that can retain the integrity of large scenes and highlight local details, while maintaining a high level of accuracy of the location information of the measured features.

Images and high-precision measurement can establish a 3D spatial coordinate system through image matching to obtain the precise location of specific feature points from a large number of image elements. The position of a point can be reconstructed from images that are positioned and oriented in a local coordinate system. The position of an object point can be determined from intersecting image ray beams. The coordinates of the image points conducting the image film with internal and external orientation elements and ground coordinates can be computationally interconverted.

The commonly used beam method *Block Aero-triangulation By Bundle* is to solve for the coordinates of the exterior orientation elements of the image and the encrypted points, which are calculated by using the common equation and the basic condition that the image point, the ground point and the projection center point are co-linear, and the corresponding two error

formulas are obtained based on the common points of the image and the external control points as data, and then solved in accordance with the minimum and the criterion of parity. By solving, we can get 6 exterior orientation elements and 3 individual orientation parameters, and finally get the coordinates of encrypted points.[1,2]

The space resection is used to solve the exterior orientation elements of the image, which is calculated from the elements of interior and exterior orientation of the image and the coordinates of the three ground points. The location information of the feature points is obtained by transferring from the photogrammetric coordinate system to the ground survey coordinate system, and the transition between the two is made by the ground photogrammetric coordinate system, which conforms to the right-hand rule, with the origin being the control point of the ground in the survey area, and the X-axis corresponding to the ground survey coordinate system is used to get the same direction, and the Z-axis is the plumb line over the origin, which is positive upward. The common line equation is the core formula of photogrammetry, which can represent the image point, object point and projection center in the same line, which is the inverse transformation of image space coordinate system and image space auxiliary coordinate system. After acquiring the image, the same feature point in a large number of images is called the same name feature point, the same feature point is the same point corresponding to the final model, such as the corner of the building, etc., to build a three-dimensional model will acquire the image through forward intersection to orient the image, which points are needed before this can be forward intersection, the extraction of feature points becomes the key technology for image matching.

In the process of 3D reconstruction, the advantages of nap-of-the-object photogrammetry, close-range photogrammetry and oblique photogrammetry are integrated to build a 3D model that can retain the integrity of the large scene and highlight local details by combining multiple photographic methods. We also designed a scheme to improve the efficiency of image control point field measurement and eliminate the invalid and redundant information. For the new product form brought by the obtained refined 3D model, the field of high-precision measurement services can be greatly expanded, and the combination of high-precision measurement technology and image modeling makes the application in the field of surveying and mapping go further, improving the efficiency of photogrammetry, guiding production efficiently, minimizing user intervention and reducing workload.[3]

3.Project Background of VRTK

There are eight major deserts in China, including the Taklamakan Desert south of the Tianshan Mountains in Xinjiang and the Gurbantunggut Desert north of the Tianshan Mountains, which are the two largest of the eight deserts from the current situation due to three mountains plus two basins and the blockage of high mountains in the west. Global satellite navigation system, as a more maturely developed location service system, can solve most of the relevant problems in outdoor situations, but due to the complex terrain conditions in China resulting in serious signal blocking, complex channel conditions, multi-path effects and other factors, the existing

outdoor positioning methods cannot achieve good results, and some areas are not yet suitable for human entry surveys due to the harsh environment, which causes on-site measurements certain difficulties.

And in the traditional surveying scenario, the current mapping users also still face more bottleneck scenarios are not easy to measure. What are the challenges when using traditional GNSS sensors for surveying? Currently, a general GNSS receiver needs to search for satellite signals in an open environment in order to achieve high accuracy measurements, and the location of the point can only be measured if the GNSS RTK receiver has access to the open sky and the rod tip can actually touch the point. Otherwise, many different auxiliary methods are needed to measure the exact position.

For example:
1. using additional equipment for the receiver and tools to achieve the measurement, but this method is time consuming and difficult to guarantee accuracy.
2. Using a total station as a backup tool for measurement. When the receiver measurement conditions are not met, the use of total station will be measured out of individual locations, the use of this alternative method will also be time-consuming, and requires the user to have more familiar with the skills of the use of the total station, is not an optimal way.
3. When there are many details to be measured, users will face higher measurement difficulties. This is because measuring each point with a rod tip requires a lot of time in the field. There is also a risk that some points are missed and the site needs to be re-surveyed, resulting in additional costs.
4. scenes that are not convenient for direct measurement in dangerous areas in the field such as mountain ravines, slopes and desert locations may pose safety risks, and the time consuming operation will increase significantly due to the harsh environment.

3.1 Hi-Target's exploration of visual measurement technology

Hi-Target, as the industry leader, has long been aware of the drawbacks of user measurement use, the past in 2016 has opened the research of visual RTK and launched CNOOC's first visual GNSS receiver combination type products, including receiver + professional-grade camera + tablet for 3D image processing, compared with the traditional RTK, total station, point, line, area measurement, the High efficiency, no need to check if there are missing points. Visual RTK technology uses the UAV oblique photogrammetry, can achieve a full range of image processing, but compared with the UAV image measurement, visual surveying RTK can be measured at ground level more ground details that can not be measured by the UAV, free from the UAV flight height restrictions at the same time to maintain the accuracy of the measurement, measurement of more details, and Realize fine management.

However, although this product can provide customers with better measurement results, the complex product combination form is not widely accepted in terms of portability and cost performance level. Subsequently, a new GNSS product combining image, GNSS receiver and IMU inertial guidance was launched in the market, which successfully solved the problem of portability of high-precision visual measurement and achieved the world with one pole.

The process and technology of such innovative products smoothly solved the painful problem that customers need to carry heavy hardware when using visual measurement, which makes people shine, but the high price brought by brand value + new technology is also the reason that many users are discouraged. Therefore, Hi -Target's R&D team has been working hard for years

to find a way to manufacture GNSS products that can highly integrate compact IMU, camera and GNSS to solve users' needs for high precision measurement, compactness, convenience and cost effectiveness of GNSS receivers.

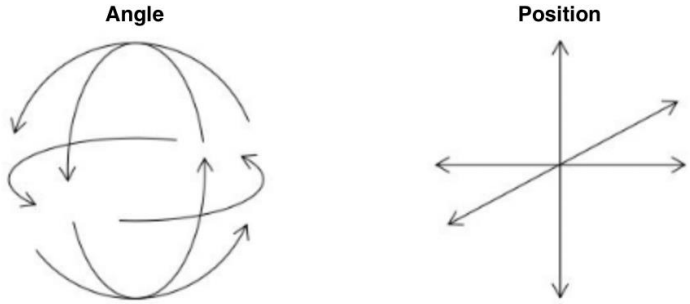
Task Requirement:

- Measure target points without direct contact
- Maintain a high level of measurement accuracy

Challenges:

- No mature technology and products in local products for reference
- Difficult to maintain high accuracy when distance changes
- Cost-effectiveness with high quality experience and efficient measurement results

At present, highly integrated GNSS receiver products have become mainstream products, and the technology of combining IMU sensor and GNSS is quite mature. Hi-Target hopes that the 6DoF sensing solution will allow customers to maintain sensitive camera posture capture while moving as freely as possible, combined with close-range photogrammetry to produce more accurate results. The development of 3D modeling technology has also made post-processing of image measurement data from GNSS products a reality, and a successful visual measurement RTK product combined with third-party 3D modeling software for post-processing is the icing on the cake.



3.2 VRTK, the solution for high precision measurements without direct contact

3.2.1 VRTK

Hi-Target image RTK products, a hit product that has been prepared carefully over many years, is a high-precision measuring solution that realizes long-distance non-direct contact and guarantees the safety of personnel and data accuracy during surveying operations.

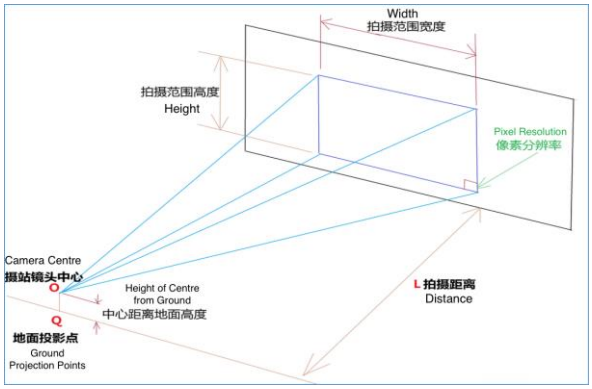
VRTK is Hi-Target's 2022 RTK receiver that supports vision measurement, a new portable GNSS product with highly integrated hardware and software. It can measure points in images

from a certain distance using visual positioning technology, and successfully integrates GNSS sensors with IMU and camera to achieve high precision image positioning. Due to its most accurate sensor fusion, it can immediately measure the inaccessible points in the image in the field, and after acquiring the data, it can be compatible with the third-party post-processing 3D modeling software to realize the non-contact, remote, online operation mode, and fully improve the efficiency and accuracy of information acquisition.

Combined with the new IMU module, the integration of GNSS, IMU (Inertial Measurement Unit) Module and camera eliminates the need to use other time-consuming methods or additional equipment when measuring. Measured from images by the visual positioning technology in VRTK has obvious convenience for points with obscured skies and other inaccessible points, and in-process measurements of image measurements allow users to capture with measurement-level accuracy in the open environment closest to the target point.

In addition, the current market vision RTK photography pixels of 120MP, VRTK use higher pixel than similar products in the market dual camera, through the 500MP rear camera and 200MP lower side camera to achieve the 3D survey of groundsill side and AR real-world release, in the intuitive picture scene easily access to achieve high-precision positioning information, in the 2-15 meters within the measurement accuracy of 2 ~ 4cm.

The introduction of VRTK, based on accurate geo-referencing of images, provides a variety of possibilities for measurement work, on the one hand, capturing a large number of points in a short period of time, increasing productivity and saving time and money costs; on the other hand, in areas previously defined as unreachable for measurement, it can guarantee safety while opening up more measurement scenarios and responding flexibly to measurement content.



3.2.2 How to obtain accurate position information from images

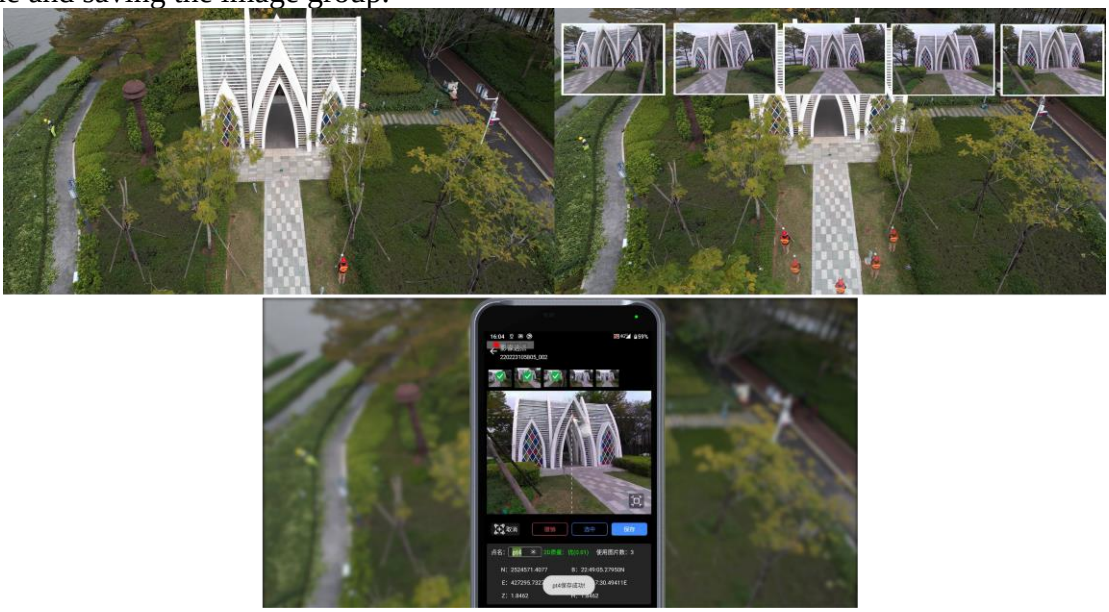
Hi-Target sets up a measurement method for the user that improves accuracy and is attached to the software interface to guide the user. When using VRTK for the 3D survey, images are automatically captured at 2 Hz. The receiver position is the integration of the GNSS/INS coordinates determined by the camera in the following way.

Afterwards, the extracted features and the estimate of the initial camera position are used for bundle adjustment to optimize the camera position determination. After the capture stops, the software automatically calculates the position and orientation of the image in the global coordinate system by combining the data from GNSS and IMU with the features identified in the image and tracking from one image to the next. After confirming the selection of a rearview camera capture image group, the Hi-survey Road software can immediately process the VRTK data and calculate the position and orientation of each image.

When a point is selected, the bottom information bar does not display the calculated coordinates. When two or more photos are selected, the bottom information bar automatically displays the measured coordinates, 2D quality, and the number of photos used; where 2D quality is indicated by red-green for quality. The bottom information is updated automatically every time a point is

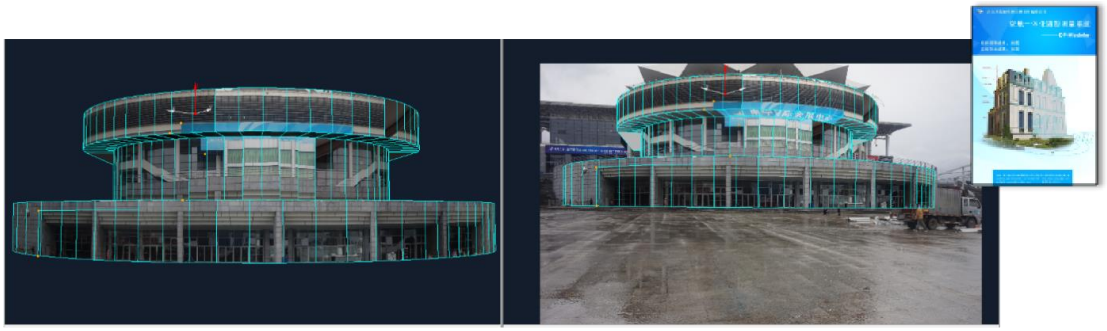
selected. Save the current calculated points to the image point library, the information in the point library is the same as the information displayed at the bottom when you click Save. The user selects the object photographed at different angles and selects one of the feature points, the 3D point coordinates have been calculated in the global coordinate system, with Block Aero-triangulation By Bundle,it can successfully solves and processes 100 photos in less than 4min.

If the user needs to increase the image content after the completion of the object camera, Hi-survey Road software certainly supports make-up shots, and finally enter the image group information confirmation interface, displaying the image group schematic, the default name of the image group (default YYMMDDHHMMSS_NNN, can be modified), image size, image quantity, image quality and other information, the number of photos including the initial shot and subsequent The number of photos includes the total number of valid photos taken for the first time and all subsequent replacement photos, and also supports modifying the image group name and saving the image group.



Can the data measured by images also run in third-party software?

Yes, the images taken with VRTK are also compatible with the third-party industry's mainstream modeling software, point cloud and 3D modeling in one step, generating 3D landscape models in modeling software such as ETOP, CC, Smart3D, etc.



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AR real-time scene takeout is another highlight feature of Hi-survey Road software, the use of iHand55 controller on Hi-Survey Road software fully supports VRTK equipment, Hi-Survey Road will automatically process, locate and orient the captured image, thus ensuring quality control of the scene. Previously, the release process, because the controller software screen and the actual scene viewed can not quickly reflect and slow down the release time, the latest version of Hi-Survey Road software and VRTK receivers can be realized in the user within a distance of 1m, the software screen converted to the lower side of the receiver camera view, the process of the controller 360 degree AR release and the host seamlessly switch between real-world release, so that The release sample is fast

and accurate, and the accuracy is better than 2cm.

What is the difference between VRTK and V200?

The VRTK is the new flagship of the GNSS receiver portfolio under the Hi-Target brand. while the V200 is the new pocket RTK product on the market with a high-performance IMU inertial guidance module and highly configurable motherboard hardware, the VRTK has all the premium features of the V200 and the added value of visual positioning technology, including a new motherboard and a new IMU inertial guidance. Like any other GNSS sensor from Hi-Target, the VRTK can use RTK corrections from all GNSS correction services.

The comparison test shows that the VRTK outperforms the V200 by about 5s in fixation time; about 28% in fixation subrate; and the VRTK is comparable to the V200 in plane and elevation accuracy under the same high-rise + shade test environment with repeated initialization.

Device	Fix Rate（%）	Fix Time（s）	Elevation(m) -2σ~2σ(95.5%)	horizontal plane(m) -2σ~2σ(95.5%)
VRTK	72%	86	0.087	0.049
V200	44%	91	0.083	0.042

3.2.3 Where can VRTK be used?

The visual measurement that VRTK can do enables many scenarios that previous GNSS receiver products could not work, and allows for better measurement results.

Measuring scenes that contain a lot of detail.
Measuring off-the-beaten-path points, such as areas of desert, cliffs, ravines, etc.
Measuring dangerous scene areas such as through busy streets, behind gates or in hazardous areas (e.g. risk of dog attack, dangerous utilities, edge of roofs).
Measuring target points in areas with GNSS signal obstructions such as on roofs, balconies or under trees.
Measuring target points on building facades such as the corners of windows and the height of roofs.
Measuring other points without having to revisit the site.
Measuring discreet scenes such as traffic accident scenes.
3D modeling of cities through surveying.
Application to integrated surveying projects for premises.
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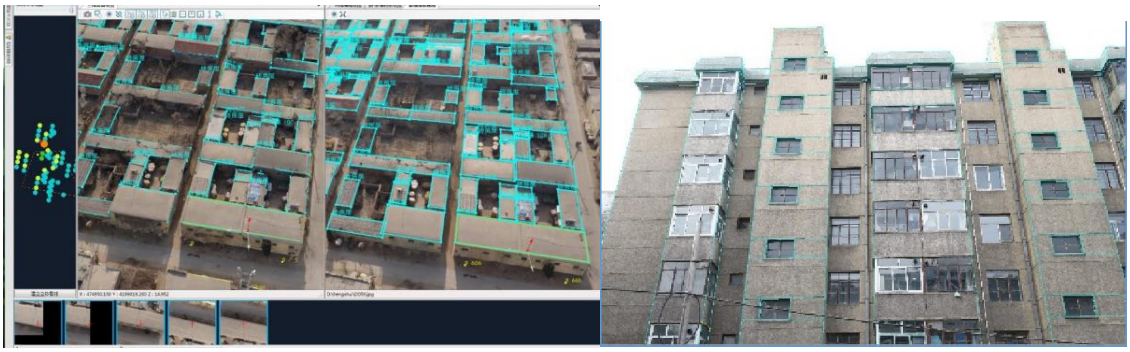
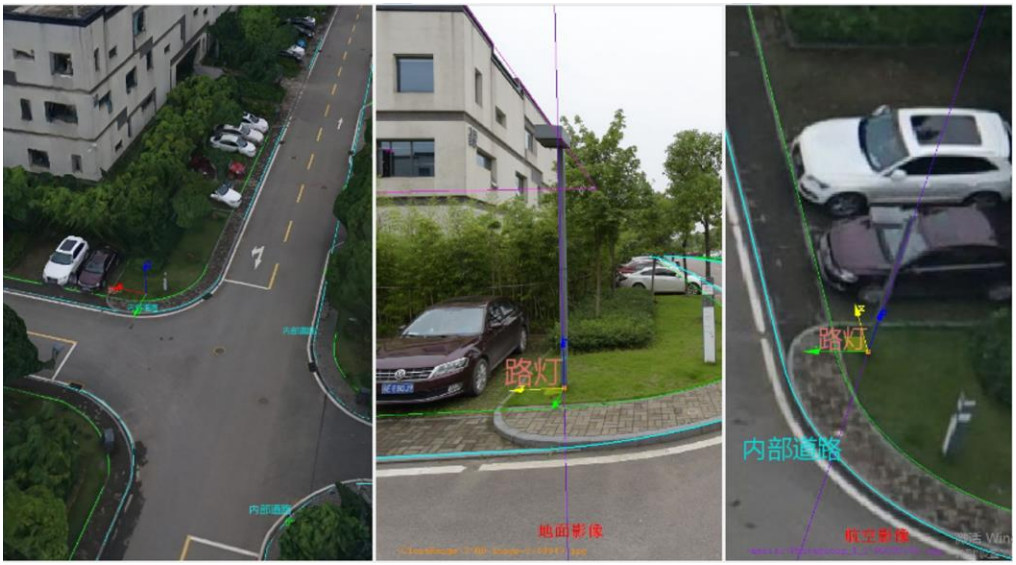
For the domestic situation, some government department projects on cadastral measurement will be the key platform for image RTK to play its advantages. With the promotion of our government's integrated rural premises measurement project, carrying out integrated rural premises measurement is an important element of real estate surveying and mapping at this stage. UAV oblique photogrammetry technology provides a new means and method for integrated rural premises measurement, which has the advantages of high efficiency, low field workload and low cost compared with traditional cadastral and property measurement methods.[?]



VRTK is designed for users who need to easily measure target points that are difficult to reach with traditional GNSS RTK Rover. VRTK is sure to be a great tool for users to collect large amounts of data in the field, and users can think about which points to measure in image measurement level accuracy while on camera. However, when users use VRTK to achieve visual measurement, they should also consider some usage considerations to achieve the best results.

1. Maintain a normal satellite tracking process and successfully search for satellites, otherwise it will not be able to continue capturing images.
2. Please take care to try to measure the target object at the right angle and avoid using it in dark conditions or when directly facing the sun to keep is to identify the object.
3. please use it in the range of 2-15m to maintain the best measurement accuracy.



With the help of the VRTK, The measurement results and user experience will be taken to a higher level, which is a dramatically improvement comparing to the traditional way.

4.CONCLUSION

VRTK is a highly integrated and innovative GNSS receiver product that can help people complete projects safely and quickly, and is suitable for non-direct contact measurements in various dangerous and complex environments. The integration of camera, GNSS and IMU sensorless inertial guidance will greatly enhance the user experience and open up more usage scenarios, so that measurements will no longer hit a wall everywhere and what you see is what you get.

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