# ADVANCED STUDY OF NON-PRISM LASER RANGER AND IT'S IMAGING

(Low-Cost 3D Imaging and Range Imaging Using Non-Prism Laser-Ranger)

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Commission V, Working group 2

KEY WORDS: Engineering,Application,Sensor,Aerial

ABSTRACT:

In recent years non-prism Laser-Ranger equipment is becoming more common,and methods of surveying and of measurements are changes dramatically. They are extremely useful instruments which constantlymeasure the distance between the subjects with the use of a sensor.They will also measure the distance between stationary and moving objects if measurement levels are speeded up.It was with this in mind that research was begun on the concept that the shape of the ground could be measured from the sky with the use of the non-prism Laser-Ranger.In order to attain this objective,work was started on examining non-prism Laser-Ranger available on the open market to basically veryfy their characteristics,the meaning of the information they obtain and their limits of detection.Experiments were initiated in various stages including desk-top testing,laboratory testing,field testing and airborne testing.This report explains the results and basic outcome of these experiments.

## 1.Research Objectives

Easy-to-use methods of continually,economy and safely obtaining ground surface information including tree lines without the use of image data,such as photographs or videos,were established.In other words,we attempted to establish methods of measuring the height of the ground surface and other objects with a Laser-Ranger directly from an aerial platform,and not with the indirect method of measuring the height of the ground surface and other objects with the use of stereopair from photographic or video images (with the use of a parallax). The levels of measurement accuracy aimed at for these experiments was set at within a 1m error ratio for ground measurement at a height of 100m to 150m. The target for the first stage was to obtain a line profile from an aerial location,and the target for the second stage was to obtain a scanning profile.

## 2. Research Method and Experiment Results

### 2-1. Desk-Top Testing

The Laser-Ranger to be used as the sensor was selected. Conditions for selection were:

*Large numbers of measurements (as current equipment carries out few measurements,a unit for which technological advancement could be relied up on the future).
*A unit which would enable all measurement data to be loaded into a personal computer.
*A unit with high resolution.
*A unit with a measurement distance of within 200m.
*A unit with a measurement accuracy of ±20mm.
*A unit which is safe,economy and easy to use.

A non-prism infrared laser-ranger manufactured by a certain company was selected as satisfying all of the above conditions.

2-2. **Laboratory Testing and Results**

Laboratory tests were carried out to determine the basic characteristics of the non-prism infrared laser-ranger selected. The experients implemented and the results attained are as follows:

[Distance Measurement and Error Characteristics]
A variety of distances within the laboratory were obtained,and a total of 100 measurements for each naural object targeted (cardboad) were taken from the same position in the set mode (continual and single ) and precision mode (±3,±5,±10,±20mm). An example of the distribution (dispersal) of the measurement values is indicated in Fig.1. These are at a distance of 8.1m in the continual mode with a precision level of 20mm. The laboratory tests provided us with information on:

*The subject measurement error of the natural object can be contained within a range of approximately 2.5 times the catalog value in each mode.
*Measurement accuracy relies on the number of pulse shots,but does not depend greatly on measurement distance.

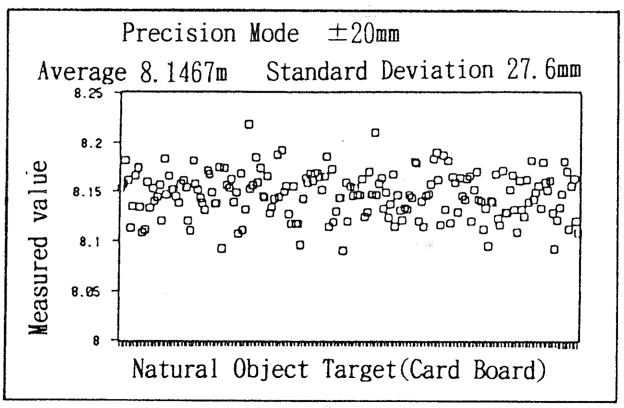


**Figure 1. An Example of the Distribution of The Measurement Values**

2-3. **Field Test and Results**

As the laboratory tests were restricted to a measurement distance of approximately 10m,outdoor tests were carried out in order to secure a measurement distance of about 200m. The test were implemented over variable distances betweem approximately 40m and 260m, and 100 measurements over each distance was the target. Accuracy verification results are indicated in Table.1.

Table 1. Accuracy Verification Results

| Approximate Distance(m) | Average(m) | Standard Deviation(mm) |
|---|---|---|
| 47m | 46.5341 | 21.3 |
| 69m | 68.8399 | 20.9 |
| 106m | 105.9953 | 23.8 |
| 262m | 262.3227 | 27.3 |

These results are in the continual mode with an precision level of 20mm. The field tests provided us with information on:

*Although the measurement distance was alternated at variable distances between 40m and 200m, the measurement error levels did not experience large changes.
*Although a variety of natural outdoor objects with differing reflection qualities were used (wood,grass,rocks,etc) there were no discrepancies in the measurement vallues.

2-4. **Identifying Precision**

Objects with a large surface area were used for the rests on distance accuracy measurements as described in 2-2,and 3. Tests were then carried out to determine if smaller objects could be identified. One problem here was the fact that the beam of the non-prism infrared laser-ranger used had a diameter of 20cm from a distance of 100m. Dowels with differing diameters (10,19,25mm) were used as the subjects during the identifying precision tests, and the measurement distance was alternated at variable distances between 60m and 120m . With the fact that the beam has a diameter of 20cm at a distance of 100m as a basis, we obtained the relationship between varying distances and the ratio of the beam (surface area ratio) on the surface of the dowels. The results of these tests are indicated in Fig.2.

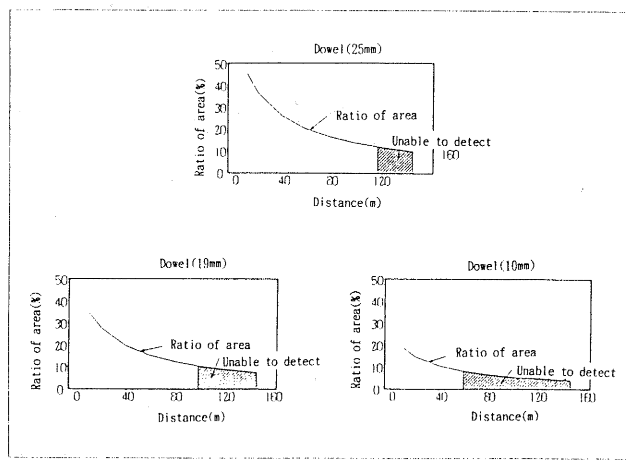


Figure 2. Relationship Between Varying Distance and The Ratio of The Beam on The Surface of The Dowels

2-5. **Summary of Test Results**

We confirmed that measurement values taken with a non-prism laser-ranger did not change even though the types of the objects measured differed and the measurement distances were alternated in laboratory and field tests. This led us to believe that we could rely on the measurement values obtained in the following stage by measuring the ground surface with a non-prism laser-ranger from a helicopter. In further detail, this meant that we could measure distances with an accuracy level of ±50mm from an aerial position 100m and 150m up in the continual mode with precision levels set at ±20mm. We also discovered that we could measure all objects with a size of 10% or more of the beam's surface area (approximately 31.4cm² at 100m– a circle with a diameter of 3.2cm or an object of the same area). Having obtained these results, we prepared a bridge over a pond and continually measured the distance between the parapet and the ground surface. The conditions below the bridge are indicated in Fig.3., and the cross-sectional profile we obtained is indicated in Fig.4. The plants on the slope of the pond and the railings of the scenic path were clearly captured.

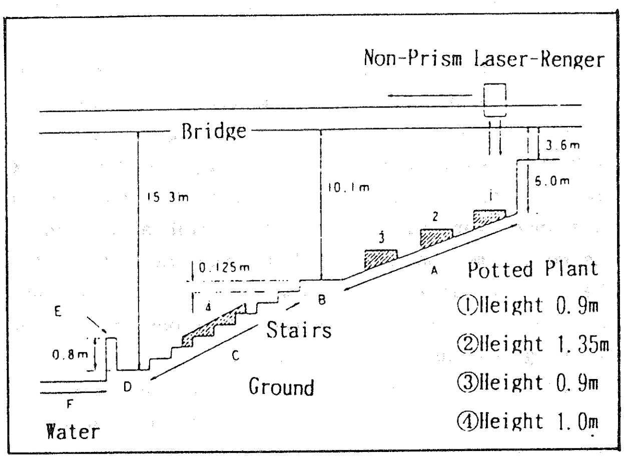


Figure 3. The Conditions Below The Bridge

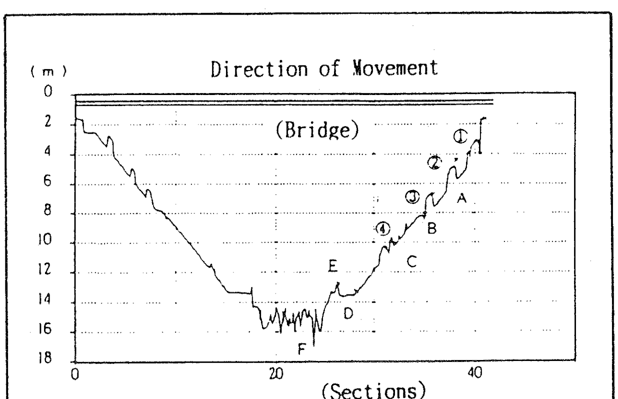


Figure 4. The Cross-Sectional Profile Below The Bridge

3. **Aerial Tests and Results**

We carried out laboratory and fields tests as mentioned in 2. to determine the characteristics of the non-prism laser-ranger we could use as a sensor. We then mounted this equipment onto a helicopter for the next stage and carried out tests to determine if a line profile of the ground could be obtained from the air. Before carrying out the tests, we investigated such aspect as electricity, oscillation, maintenance equipment, cables, wiring and noise, etc., and installed what was necessary. After carrying out various tests, we implemented aerial experiments with the equipment configuration indicated in Fig.5. We used the video camera in the illustration to verify position for the objects being measured. The helicopter flew at a fixed speed and altitude, and the non-prism laser-ranger used as a sensor measured the distance between the helicopter and the ground continually at a frequecy rate of 3.3 times per second. The ground surface line profile obtained with the aerial tests is indicated in Fig.6.

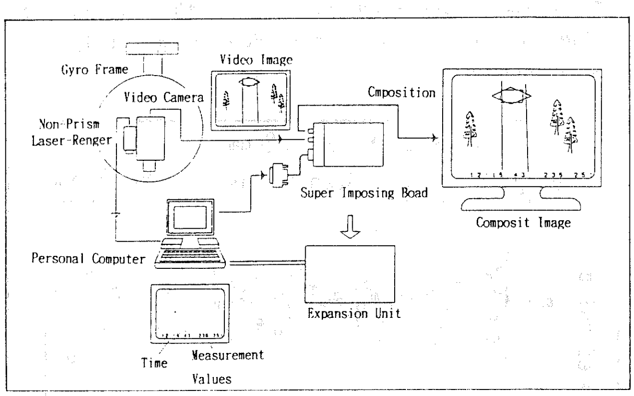


Figure 5. The Equipment Configuration

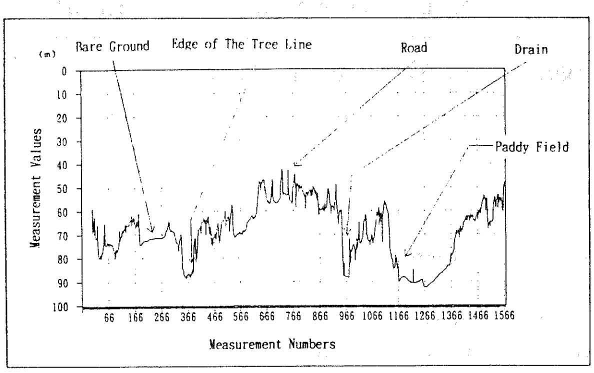


Figure 6. An Example of The Ground Surface Line Profile

## 4. Summary

We implemented a wide range of experiments though many stages in order to establish a non-image, inexpensive and easy to use method of measureing cross-sections of the ground. We were able to grasp a good understanding of the problems that became clear during each stage as well as certain characteristics of the sensor which were not previously known. The result of this is the fact that we were able to review our opinion of the suitability of non-prism laser-ranger as sensors for obtaining information on ground surface cross-sections. In other words, the points which have been made clear as the characteristics of the non-prism (prism not required ) laser-ranger are:

*Measurement discrepancies are not on the distance.
*During practical application, the measurement error of the natural object can be contained within a range of approximately 2.5times the catalog value. (can be used as ±50mm if the catalog value is ±20mm.)
*There is no effect on measurement accuracy even if the object being measured is a natural object.
*Identifying precision is approximately 30cm$^2$ at a measurement distance of 100m (circle with a diameter of approximately 3.2cm or a rectangele with an area of 5.5cm). We have therefore been able to determine that it is suitable for use as a "Profiler"sensor,which was the aim of this research.

## 5. Problems and Future Conciderations

### 5-1. Probrem of the Platform

The result of a wide range of experiments induced us to determine that the non-prism laser-ranger is the most suitable for use as an "easy to use, inexpensive and safe profiler" sensor, which was the aim of this research. However, there remains an unsolved problem with the helicopter upon which the sensor is mounted for use as a platform. If the sensor is set to measure the distance between the helicopter and the ground with a precision level of ±50mm, the movement of the helicopter itself renders the measurement values meaningless. The fact of the matter is that it is impossible to request a helicopter pilot to fly with a precision level of 1m, let alone 50mm. The most expedient way to avoid this is to use INS or GPS system. We will design and do it in the next.

### 5-2. Working Toward a Scanning Profile

There is currently a wide variety of non-prism (prism not required) laser-ranger on the open market. However, most of these have basically been designed to measure fixed points and fixed point quantities, which places restrictions upon them for use in the research of a profiler in their present form. Also,as consideration is being given to extending this research in order to obtain ground surface cross-sectional information,it will be necessary to have a per-second measurement rate (pulse rate) of several kHz at the very minimum. The measurement rate of the non-prism laser-ranger used in this research was only 3.3Hz per second in the highest-speed mode. If this was changed to a scanner sensor which emitted continuous beams at ±20degrees,total 40degrees,each scan would need 100seconds.
At the present time (March,1996), we have a plan to get a new and optional 2kHz laser-ranger for the sensor in early this April,1996.We have great expectations of putting to use it.

## 6. References


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