Title	単一モータを用いた３次元メッシュ軌道走査機構の開発
Author(s)	中島，晨之介
Citation	
Issue Date	2016-03
Type	Thesis or Dissertation
Text version	author
URL	http://hdl.handle.net/10119/13620
Rights	
Description	Supervisor:丁 洛榮，情報科学研究科，修士

Development of 3D scanning machine with the mesh orbit driven by single motor

Shinnosuke Nakashima (1410032)
School of Information Science,
Japan Advanced Institute of Science and Technology

February 10, 2016

Kyewords: 3D scanning, mesh orbit, sensor positioner, single motor, external environment measurement, LIDAR

In this study, we propose new 3D scanning system that scans 3D space by a mesh orbit. This system is used for external environment recognition by mounting sensors on the system. External environment recognition using sensors is introduced into many systems, for example security systems, automobiles and robots. In almost cases, external environment recognition is implemented by data acquisition and data processing. Although various types of sensors are used to acquire data of external environment, there are some areas that can't be measured by sensors because a measurement range of sensors is limited. For that reason, the expansion of a measurement range is necessary.

In our lab, two systems that are driven by single motor were developed. These systems can be applied to all type of sensors. In these systems, expansion of a measurement range is implemented by changing direction of a sensor mechanically. Pan and tilt angles of sensor's direction are controlled by mechanism driven by single motor. As a result, the system scans 3D space by a spiral orbit and a measurement range is expanded into 3D space. Though this system is effective for expanding measurement range, there are some problems. Most critical problem is concentration of measurement points. Distribution of measurement points is depends on time interval of data acquisition, shape of scanning lines that is decided by mechanical structure and scanning speed controlled by single motor. In the spiral orbit, partial orbit becomes almost horizontal because variation of tilt angle is very small relative to variation of pan angle. Consequently, improvement of horizontal distribution density of measurement points is expected by controlling the motor, but vertical distribution density is not almost increased. In addition, because a vertical orbit interval is extended according to distance of the system and the orbit, distribution of measurement points becomes horizontal in case of long distance scanning. For that reason, the system that scans 3D space by a spiral orbit is advantageous to horizontal measurement, but it is unsuited to vertical measurement.

In order to solve the problem, it is required to nearly equalize the variation of the pan angle and the tilt angle. In this study, we propose a system that scans 3D space by new mesh orbit. Mesh orbit is constructed by some unit scanning orbit defined as equation including four parameters: r, θ_p, θ_t and θ_m.

Meaning of each parameter is as follows: r means distance from a center of a sphere to scanning line; θ_p means measurement range of pan angle; θ_t means measurement range of tilt angle; θ_m means maximum pan angle. The mesh orbit can realize equalization of variation of pan and tilt angles by selecting suitable parameter. Consequently, new system can disperse measurement points more than past systems.

First, in order to compare the mesh orbit and the spiral orbit, we have conducted some simulations. In the simulations, 1000 measurement points are set on each orbit. They are arranged equal angular interval about pan angle. We assume a sphere whose center is each measurement points. A radius of the sphere is given as r_p of parameter. Values of each parameter are as follows: r is 300[mm]; θ_p is 350[deg]; θ_t is 90[deg]; θ_m is 90[deg]. We conducted simulation by changing r_p: 10[mm], 50[mm] and 70[mm]. Detail of simulation conditions is described in my thesis. We simulated about number of measurement points in the sphere for each sphere. In this thesis, number of measurement points is referred to as N_i. In the beginning, we focused on relationship between N_i and z coordinates of a center of the sphere. In a range that z coordinates are between about 225 and 300, N_i increased quickly in proportion to z coordinates. This result shows that, measurement points concentrate in this region because distance from rotation axis of pan angle to scanning line shortens. Next, we focused on histogram of N_i. In the mesh orbit, about 10 ~ 20% of the spheres belonged in the ranks that N_i is relatively high, regardless of r_p. On the other hand, no sphere belonged in same ranks in the spiral orbit. This result means that, as for the concentration of measurement points, the mesh orbit is more remarkable than the spiral orbit. We conducted same simulation without measurement points whose z coordinates are larger than 275. In this simulation, number of measurement points decreased to 660 in the mesh orbit, 739 in the spiral orbit. By decreasing measurement points, no sphere belonged in the ranks that N_i is relatively high. This result suggests that, increasing of N_i is caused by concentration of measurement points in the area that z coordinates are larger than 275. In case of r_p is 10[mm], N_i of all spheres became 0 in the spiral orbit because distance of each measurement points is smaller than the radius of the sphere. This is bad influence of vertical interval of the scanning line. We conducted simulation about a standard deviation of distance between a center of the sphere and each measurement points in the sphere. In this thesis, this deviation is referred to as σ_i. First, we focused on relationship between σ_i and z coordinates of the sphere. In the mesh orbit, variation of σ_i was large in a range that z coordinates are between about 30 and 275. On the other hand, in the spiral orbit, σ_i changed gently and in stages in same range. This result shows that, distribution of measurement points in the sphere is very different for each orbit: dispersive and various in the mesh orbit; not dispersive and uniform in the spiral orbit. Through these simulations, we evaluate each orbit as follows: the mesh orbit is advantageous to measurement of outline; the spiral orbit is advantageous to detailed measurement of horizontal shape, but it is unsuited for measurement of vertical shape.

Second, we designed 3D scanning system that scans 3D space by a mesh orbit. The system is composed by three functional mechanisms: the rotation power generation mechanism; the rotation speed conversion mechanism; the reciprocating rotation motion generation mechanism. Main components of the rotation power generation mechanism are as follows: single motor and four gears. By driving the motor, rotation power is generated and transmitted to the rotation speed conversion mechanism. The rotation speed conversion mechanism is mainly composed of two gears. The rotation power is input to one gear, and it is transmitted to the reciprocating rotation motion generation mechanism through another gear. The rotation speed transmitted to the next mechanism is depends on tooth ratio of two gears. Main components of the reciprocating rotation motion generation mechanism are as follows: one cam, one rack, one pinion, one arm. The rotation power transmitted from prior mechanism is converted to linear motion of the rack by the cam. The rack is connected to the arm through the pinion. By mounting a sensor on the arm, the sensor is able to scan 3D space by the mesh orbit.

Finally, we concluded three experiments. First, we evaluated performance of the LIDAR used in this study. A panel was set in front of the sensor with constant distance and an angle. We acquired distance from the sensor to panel by the sensor. This experiment was conducted by changing the distance, the angle and color of the panel. Except black panel, stable value that is about 3.5~10cm larger than actual distance is acquired by the sensor. On the other hand, acquired value for black panel included some error because black tends to absorb light. Second, we measured shape of a cylinder using 3D scanning system developed in this study from inside of the cylinder. Error ratio between the actual angle and the computed angle of the arm was about 3~15%. Although the error ratio becomes high in specific area, it is confirmed that the 3D scanning system can implement the mesh orbit. Error ratio between the actual measurement point and computed measurement point without consideration of the result of prior experiment was about 3~35%. By assuming the distance acquired by the sensor is 8cm larger than actual range, maximum error ratio was about 15%. This result means that, by considering error of the sensor, we can get measurement points from which shape of objects is conjectured. Finally, we measured surrounding environment including stairs using two 3D scanning systems that scan by the mesh orbit and the spiral orbit. The systems are placed away 2m from the stairs. The measurement points acquired by the mesh orbit concentrated vertically in areas whose horizontal distance is about 215, 240, 270, 295, and 320. On the other hand, the measurement points acquired by the spiral orbit concentrated vertically in areas whose horizontal distance is about 250 and 270. Through these experiments, we were able to confirm as follows: developed system on which mounted a sensor can be used for 3D space scanning; as for vertical measurement, the mesh orbit is more remarkable than the spiral orbit.