様式Ｆ－１９

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研究課題名（和文）　森林管理のための知能的画像処理システムの開発

研究課題名（英文）　Development of An Intelligent Photogrammetric Tree Measurement System for Forest Management

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研究成果の概要（和文）：地球温暖化対策として二酸化炭素を減らすために森林の持つ機能への期待が高まっている。本研究の成果は、フィールドで得られた木の画像と衛星画像を組み合わせ、ホログラフィックニューラルネットワークで学習することによって狭い範囲の２次元画像から森林全体の３次元のＣＡＤモデルを構築したことである。これによって、フィールドの計測時間が短縮され、現行の森林管理システムの計画を促進することができた。

研究成果の概要（英文）：As the countermeasure against global warming, a high expectation is accorded to the function of forest to reduce the carbon dioxide. This research succeeded in constructing the full 3D CAD image based on the combination of satellite images with tree images acquired on the small field by training a newly proposed Holographic Neural Network. Key-technologies introduced in the system reduce field measurement time and facilitate the planning in current forest management systems.

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キーワード：Image processing / image recognition/ Forest Management and Planning

１．研究開始当初の背景

Knowledge of canopy vertical structure is particularly important in assessing the potential value of forest resources for the production of private (water quality/quantity, recreation, fisheries and wildlife habitat, carbon sequestration) and public (wood, fiber, nontimber forest products) goods. For more demanding investigations and analyses, canopy vertical structure is typically measured using some combination of in situ and remotely sensed data. Among several possibilities of remotely sensed data sources, only digital photogrammetry and LiDAR (Light Detection And Ranging) data are both (1) widely available commercially, and (2) suitable for forest structural analyses at the scale of management, which is the stand unit on which silvicultural prescriptions (establishment, fertilization, thinning, release, and harvest) are made. Of these two data sources, LiDAR data has become the most common. LIDAR is an optical means of measuring reflected light from distant objects to determine range, and from this information, to determine position. Because of high per hectare costs, LiDAR data are only being utilized by a subset of forest landowners and land managers at present. As such, recent research is focused on using imaging data as strip samples for large-scale inventories and forest resource evaluation.

２．研究の目的

It has become an urgent issue to establish measurement technologies for the forests. So, this research aims the "Development of An Intelligent Photogrammetric Tree Measurement System for Forest Management".

３．研究の方法

A new method for forest measurement has been developed based on the combination of satellite images with images acquired on the field. Using the developed method a 3D model of the forest was obtained from the acquired 2D images. First, using a satellite imaginary, the approximate position of each tree is computed from the segmentation of the satellite image. Interactive segmentation based on polygonal representations [1] was used for satellite images and fast line-based image segmentation [2] was applied for the images acquired in the field.

Then, in order to do the field measurement, the optimal route is computed using the approximate position of each tree. The proposed optimization approach [9] generates a plan composed of a series of sensor viewpoints and a shortest path that traverses each viewpoint exactly once. The plan guarantees that the total number of images needed to be taken is minimum and the travel distance of the path is the shortest while our plan satisfies the constraint that each tree appears in at least one image without being blocked by any other trees.

Among several parameters, the diameter at breath height (DBH) is one of the most widely used parameters to assess the potential value of the forests. The 3D model is created from the 2D images and the results of the DBH measurements in the field. The height of each tree in the 3D model was computed from a correlation curve between tree height and DBH. The measurement of a wide area was predicted to construct the full 3D CAD model of the area by training a newly proposed Holographic Neural Network with the tree measurements in a small sample plot.

４．研究成果

In coordination with the government of Ehime Prefecture and Ishizuchi Forestry Association, an area of 225m^2 (15m x 15m) was selected to measure the DBH of 45 trees from January 18 to 21, 2012. Figure 1 shows some results of the current proposed system. We employed a GPS device to mark the exact position of the trees in the field in order to combine the measurements with the IKONOS satellite image from the Japan Space Imaging (JSI) Company (Fig 1a). We measured the DBH using the traditional method and compared the results with measurements made by the Microsoft Kinect sensor (Fig.1b). As result, we achieved an average error of 26% between the two DBH measurements (the maximum error was 63%). We showed that it is possible to reduce the time of field measurements by 37% if "flying robots" are used to take pictures in the field moving through the optimal proposed path [11].
The 3D model of the small measured area (shown in Figure 2) was created using the

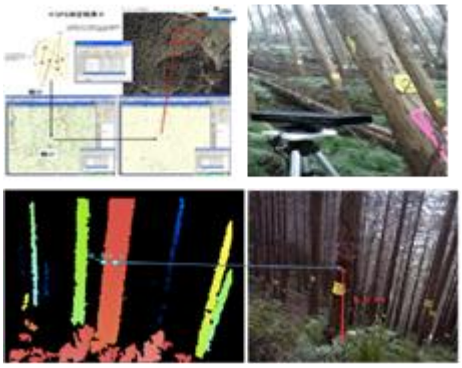

Figure 1 Results of current proposed system: (a) GPS device, (b)Kinect sensor, (c) Depth image, (d) RGB image

depths and RGB images in Figure 1c)-d). However, it was necessary to decrease the average error below 20% to meet the requirements of forest managers. To meet this demand, we identified 4 fundamental problems (P1-P4) in the previous measurement method (P1- The previous method was too sensitive to changes in depth, P2- The previous method was not developed to measure in steep terrains, P3-

It was necessary to recognize the baseline of the tree from the picture in order to measure DBH at a height of 1.5m, P4- It was necessary to recognize already measured trees in different pictures). To solve above problems (P1 and P2) the formula for measurement was adjusted for working on slopes and the sensitivity of the method to changes in depth was eliminated. To solve the problems P3 and P4, fast segmentation algorithms [1-2] were applied to recognize the trees in real time. A new in-painting method [11] was also applied to remove the grass, recognizing the floor to measure the DBH at a height of 1.5m.

Accuracy of the measuring method: The solution of the tree recognition problem (P4) was the most complicated because it has to deal with different lighting conditions and different types of trees. However, we developed a measuring method for a compact sawmill machine at Kyowa Kikai Ltd Co that achieved a high accuracy and was adapted for tree measuring on the field. The sawmill machine application includes more stringent requirements of accuracy for the 3D logs reconstruction. In the sawmill machine, it was necessary to determine the shape of the log to make an optimal cut. In the current system a laser device is used to get the 3D information of each log but the machine is too big (12m are used for measurement) and the accuracy is strongly affected by the lighting conditions. After

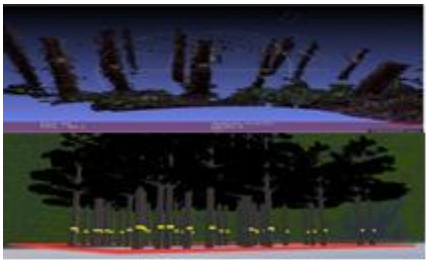

Figure 2 - 3D model of the measured area: Point clouds (up) and 3D rendering (down)

doing experiments during November 21-22, 2011, February 11-12, 2012 and July 27-28, 2012 at Kyowa Kikai Ltd Co in Kanazawa, the main problems were solved. The main results after measuring 3 logs with different size and shape are shown in Figure 3. The results obtained with a laser device are shown in red and the results obtained with proposed method are shown in white. As the results are almost the same, the machine space could be reduced in 33% while maintaining high accuracy in the 3D information by using the proposed imaging technology (AVT cameras). The proposed correction method for shadows in the face [4] was adopted to solve the problems with different lighting conditions. Paralel algorithms based on graphic processors (GPU) were also developed to speedup the simulations with natural atmospheric phenomena in the forest [4-5]

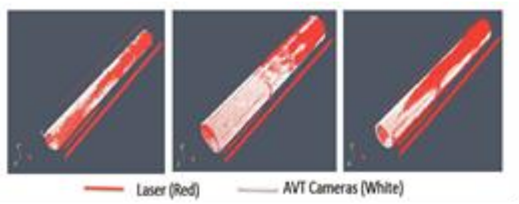

Figure 3 – Accuracy of 3D logs reconstruction

Conclusions and Future Works:

"An Intelligent Photogrammetric Tree Measurement System for Forest Management" has been developed. Key-technologies introduced in the system reduce field measurement time and facilitate the planning in current forest management systems. In order to validate the results of the predicted 3D model, we plan to use "flying robots" to take pictures in the field moving through the optimal proposed path [9].

５．主な発表論文等
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