Development of a Methodology to Estimate Biomass from Tree Height Using Airborne Digital Image

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Abstract Globally biomass is becoming imperative for function such as climate change, combined heat and power generation. The biomass energy is gaining significance as a source of clean heat for domestic heating and community heating applications. Regarding climatic change and global warming, the biomass is being estimated in various ways. By including three dimensions (i.e.) height of a tree or stand height of trees in forest will greatly help in estimation biomass more accurately. Traditionally close range Photogrammetry is used to determine volume and biomass of the tree. However, this method of volume/height of a tree is not feasible in large scale applications and time consuming. Globally researchers are working to estimate this by using either airborne/space borne data. In this project, a methodology to measure tree height in case of single tree or stand height (mean tree height) of an area is developed using airborne digital camera. The height of the tree was first estimated from the airborne digital camera image data. The image taken from Airborne UltraCamD has been used. This image is 23cm X 15cm image size and 20cm resolution. Aerial Triangulation was done using Leica LPS Software. The position and altitude has taken from the GPS/IMU system. After bundle adjustments, mass points will be generated with pre-determined grid spacing. Generally airborne or space-borne data provides digital surface model (DSM) which includes surface features like trees, buildings etc., along with terrain. A filter is designed to separate surface features and terrain using height and crown width was obtained from stereo data using automated classification algorithm. The height derived from automatic method is validated with height derived from manual process i.e. photogrammetric method and measured from stereo measurements. From the obtained parameters the DBH and Biomass will be estimated; from this we can know the bio resource of the particular area.

Keywords Aero Triangulation, Above Ground Biomass, Allometry Equation, ERDAS, Leica-LPS, Tree Height
1. Introduction

Global climate change is widely considerable that led to the organizing of the UN Framework on Climate Change at the 1992 UN conference on Environment and Development. The keen focusing on national greenhouse gas emission inventories, use, transform in the cover, management of forest, create sources and sinks of carbon dioxide to and from the biosphere [13]. In order to estimate the magnitude of the basis and sinks requires dependable estimates of the biomass density of the forest undergoing variation [1].

Biomass is a renewable energy resource resultant from the carbonaceous squander of different human and natural actions. It is derived from the timber industry, raw material from the forest, major element of household waste, agricultural crops and forest wood. Biomass not have the action of adding carbon dioxide in to the environment as it absorbs the similar quantity of carbon in growing as it discharge when consumed as a fuel [2]. Biomass is significant source of energy and the most imperative fuel worldwide after coal, oil and natural gas.

Scientists are trying to discover the advantages of biomass energy as an alternative energy basis as it is renewable and free from CO₂ emissions, and is richly obtainable on earth in the form of agricultural rest, metropolis garbage, livestock dung, firewood, etc. Bio-energy, in the structure of biogas, which is consequent from biomass, is predictable to become one of the key energy resources for global sustainable growth [3].

Allometry is the study about the relative size or mass of a part of an organism. In this work we are applying the tree allometry, which narrows the Allometry definition as it is the study about the tree measurements according to their species and the characters. This allometry relation is applied to find the tree menstruation such as volume, height, crown width, mass and so on. The use of allometry is widely spread in the study of forest ecology [4].

The general allometric equation for mathematics and science is

\[ Y = b_0 + b_1 X \]  

eq (1)

The following allometry equation is used to estimate the biomass,

\[ AGBM = b + aH_{est}^2 \]  

eq (2)

2. Study Area

In India forests cover 67.83 million hectares of area in India which symbolize 20.64% of the nation’s geographical territory [14], unreliable from the arid zone forests to Himalayan temperate forests. In this the forest in Godavari river basin (between 36°59’N and 96°43’E) which is covering of approximately 131km² of area in Andhra Pradesh state; is the study area of this project is shown in Figure 1.
Among this, study area is of 250.37 km² with a scale of 18°35′45″N to 18°24′45″N and 80°15′00″E to 80°24′22.5000″E and it is on the bay of river Godavari. Among the total area 204.24 km² is high dense vegetation area.

### 3. Methodology

The data downloaded from High Resolution Airborne Digital Image and the Geo-registrations are done. To estimation the height of the tree from the Digital Stereo Model was generated by using following technique. The stereo model was generated from the Leica LPS system then each tree were measured physically the top of the tree and the bottom of the tree; are measured manually by scrolling to the top and the bottom of the tree. From the manually collected tree top and tree bottom, the difference was calculated. Thus by the difference between the tree top and tree bottom, tree height was calculated. The following Figure 2 represents work flow of the project.

#### 3.1. Extraction of DSM

After pre-processing of the aerial images and production of the image pyramids, result matches three kinds of features, i.e. feature points, grid points and edges, on the aerial images are finally found gradually starting from the low-density features on the images with the low resolution. Since all the matching procedures are based on the concept of multi-image matching guided from the object space, any number of images could be processed simultaneously [5]. TIN from DSM is reconstructed from the matched features on each level of the pyramid using the embarrassed Delaunay triangulation method [15], which instead is used in the consequent pyramid level for the approximations and adaptively addition of the matching parameters. Finally least squares matching methods are used to achieve more defined matches for all the features and identify some artificial matches [6]. Therefore, such design is more flexible so that the refined matching module can be an option for DSM generation. The Figure 3 shows the extracted DSM.
3.2. Extraction of DTM

The DSM was generated by using the DEM extraction tool in ERDAS 2011 [16–18], which is in Itf format. This Itf data format was converted las format which is the point data; the following flow chart represents the process of DTM extraction in ground level. The point cloud generated was 3m X 3m [7]. The Figure 4 shows the Extraction of DTM.

**Figure 2: Work Flow of the Project**

**Figure 3: Extraction of DSM**
3.2.1. **Filtering the Terrain** Filters are built from combinations of different elements. Therefore, to comprehend or envisage the performance and output of a filter the way in which elements are united has to be tacit. Every filter makes an assumption about the structure of Bare Earth points in a local neighborhood. This forms the concept of the filter [8].

3.2.2. **Point-to-Point** In these algorithms two points are compared at a time. The categorize purpose is based on the positions of the two points. If the output of the categorize purpose is above a certain threshold then one of the points is assumed to belong to an entity, automatically only one point can be classified at a time [9]. The Table 1 shows the Filtering class.

3.2.3. **Slope based Filtering** This algorithm used to find slope or height difference between two points. If the slope is on top of a certain threshold then the uppermost point is assumed to belong to an object. The assumption is based on the rational that the steepest slopes in a landscape fit in to objects [10]. The Figure 5 shows the slope based filtering model.
Table 1: Filtering Class

<table>
<thead>
<tr>
<th>Item</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landscape</td>
<td>The topography: A scene consisting of the earth and any other features (buildings, trees, power lines, etc.) residing on it.</td>
</tr>
<tr>
<td>Bare Earth</td>
<td>Topsoil or any thin layering (asphalt, pavement, etc.) covering it. Hauschild and Heutling (2001) define Bare Earth as the continuous and smooth surface that has nothing visible below it. However, this definition is for the purpose of implementation of a filter and because of that it is restrictive.</td>
</tr>
<tr>
<td>Object</td>
<td>Vegetation and other artificial features that have been added by human hand.</td>
</tr>
<tr>
<td>Detached Object</td>
<td>Objects that rise vertically (on all sides) above the Bare Earth or other Objects.</td>
</tr>
<tr>
<td>Attached Object</td>
<td>Objects that rise vertically above the Bare Earth only on some sides but not all (e.g., bridges, gangways, ramps, etc.).</td>
</tr>
<tr>
<td>Point-cloud</td>
<td>A collection of points (acquired by ALS) in a 3D Cartesian co-ordinate system.</td>
</tr>
<tr>
<td>Filtering</td>
<td>Abstraction of the Bare Earth from an ALS point-cloud.</td>
</tr>
<tr>
<td>Outlier</td>
<td>Points in a point-cloud that are not off the landscape (e.g., birds, gross errors from the ALS system, etc.).</td>
</tr>
</tbody>
</table>

This filter based on morphological filter developed by Vosselman (2000, 2001). In this algorithm the data set is initially gridded, to carry a database structure, outliers are noticed and discarded. The slopes were calculated with the help of local linear regression method [11]. In the linear regression every point should compared to the lowest point in the local operator neighborhood. The height and distance dissimilarity from the near to the ground points are weighted and used as observations in the linear regression. The threshold used in formative the class of a point is based on the underlying slope in the initial DEM [12]. The following Figures 6 and 7 explain how the DEM is classified from the cloud points. The Figure 8 shows the extracted DTM.

Figure 6: Reference data for filtering
Automatic tree heights are taken using MICROSTATION (TERA SCAN) the DSM was generated in ERDAS and imported to MICROSTATION as point data (las format) [19]. The grid points were generated in 3m X 3m. The sampled locations are overlaid in the point data and the DSM of the samples was taken. The Slope Based Filtering was applied to filter the ground value from the point data in Terra Scan tool with various conditions. They are Building Size with 60m, Terrain Angle with 88m, Iteration Angle with 6° and Iteration Distance with 1.4m.

### 4.1. Manually Measured Tree Heights

The tree heights are measured visually from the Stereo View generated by the ERDAS IMAGINE [20]. The values are accomplished by getting the coordinates (x, y, z) value where, x is Longitude; y is Latitude; z is Height. The following Figures 9, 10 and 11 show the comparison of the tree height values.
The above ground biomass was estimated by using the allometry equation as represented in equation (3), (4) and (5).

\[ \text{AGBM} = b + a \times H^2_{\text{est}} \]  
\text{eq (3)}

\[ \text{AGBM} = 22.66 + 0.154 \times H^2_{\text{est}} \]  
\text{eq (4)}

Which is 85 Mg/Ha for automatically generated height.

\[ \text{AGBM} = 22.50 + 0.168 \times H^2_{\text{est}} \]  
\text{eq (5)}

Which is 88.75 Mg/Ha for manually measured tree height. Therefore the total high denser vegetation area among the study area is 204.24km^2 and the above ground biomass of the vegetated area is 1756145.013Mg which estimated from the manually measured tree height and for the automatically measured tree height the biomass is 1812485.935Mg.
5. Conclusion

Biomass is the natural source which acts as one of the major resource of a country. Biomass also takes major part in global warming, climate changes and modeling. The bio substance can be used as an alternative for some of the resources like petrol, LPG and so on which can be replaced as Bio Fuel. In this research work the above Ground Biomass was estimated from a parameter which is height of the tree. To identify the tree height the data captured by the high resolution camera UltraD cam is used as the source. The height is estimated by developing a stereo model which the tree heights are measured manually and the heights are also estimated from the DSM by applying the slope based filtering. The difference between the DTM and DSM gives the tree height. The manually measured and automatically derived height may be, (+/-) 0.20m differences.

The derived height is applied to the Allometry Equation to estimate the above Ground Biomass. Since the allometry which is used in this study is Universal Equation that is applicable for all kind of species. But to get the actual value, the allometry differs according to the species. The built area of this research contains 75% of Mangroves and 25% other species and hence the actual value of the biomass was not able to estimate without the field survey. Even though the field survey is not taken the approximate value generated might introduce an error of about (+/-) 2 mg/m$^2$.

This developed methodology proves that the Biomass can be estimated for large area in short period.
And it also determined that the Biomass or the tree height can be estimated without the field data, but by using the High Resolution Airborne Digital Image.

References


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