DOI: https://doi.org/10.46354/i3m.2019.dhss.006

MODELING REALISTIC 3D TREES USING MATERIALS FROM FIELD SURVEY FOR TERRAIN ANALYSIS OF TACTICAL TRAINING CENTER

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ABSTRACT
This paper elaborates processes of modeling 3D trees for the simulation of the Army's Tactical Training Center. The ultimate objective is to develop the 3D model database for inclusion to a game engine library. The adopted methodology includes collecting a forestry inventory for later 3D tree modeling in a Unity's 3D Tree Modeler. Leaves and trunks were closely modeled using the data collected from the real site in the package SpeedTree modeler. Three tree types were sampled to demonstrate how close and realistic the adopted processes were to produce result 3D models for inclusion to the simulation of the tactical center. Visual comparison was made to show the final models. 3D scenes generated from the inclusion of the models were illustrated in comparison to the photo taken from the site. Further studies to adopt surface modeling data from UAV terrain mapping for tree canopies were recommended to verify photorealism of the processed 3D models.

Keywords: 3D tree model, forest inventory, tactical training

1. INTRODUCTION

This paper forms part of the report of the project 3D Simulation of the Army's Tactical Training Center of the Royal Thai Army. The most important objective of the project is to develop the 3D model of the training center in support of decisive and judgmental military trainings. The terrain of the 2 x 0.5 km2 study area is sparsely vegetated and needs 3D tree modeling to construct the realistic 3D model for such purpose of terrain analysis. The Army embraced the proposed 3D modeling of the study area for terrain analysis as part of OCOKA (Observation and Fields of Fire, Cover and Concealment, Obstacles (man-made and natural), Key or Decisive Terrain, Avenues of Approach. This current work is extended from that of Robert et al (2018) who attributed the realism of the modelled and visualized virtual world mainly to the detailed field survey together with UAV and GIS data modelling. The modelled terrain and geo-database were incorporated into military planning processes for tactical planning.

Kumsap et al (2005) addressed a rough survey of approaches to the generation of vegetation models. Continuous developments were witnessed and found in Sun et al (2009), Pratihast (2010), Pirk et al (2012), Xie et al (2015) and Wang et al (2018). Models grown by L-Systems and models from commercial libraries are dominant with growth parameters being determined and interpolated to create convincing animations. Wang et al (2018) proposed an algorithm for generating novel 3D tree model variations from existing ones via geometric and structural blending. Thus, the proposed framework only considered the tree branches and ignored the tree leaves in order to ensure the smooth change of foliage structures along blending paths. However, the methodology in this current work adopted SpeedTree® Modeler's combination of a home-grown procedural algorithm and hand drawing, which is more artistic an approach and fitted with the heterogeneously vegetated nature of the study area. This paper addresses the manipulation of data collection for a forestry inventory by modeling sampled trees in a Unity's SpeedTree® Modeler rather than attempting to investigate an algorithm to append photos of tree's leaves and barks to the 3D tree model. Furthermore, the validation of modeled outcomes that is deemed significant to complete the simulation process is left for further study and publication.

2. FOREST INVENTORY

In this section, the details of field survey and quantitative forest characteristics of tactical training field are explained as seen in section 2.1 and 2.2, respectively.

2.1. Field survey

Forest inventory has been carried out in environmental and ecological monitoring and management (Fischer, C., Kleinn, C., Fehrmann, L., Fuchs, H., and Panferov, O., 2011; Metsaranta, J. M., Shaw, C.H., Kurz, W. A., Boisvenue, C., and Morken, S., 2017). Studies describe investigations of forestry inventory in biomass carbon estimation (Brown, S. and Gaston, G., 1995; Mateos, E., Garrido, F., and Ormaetxea, L., 2016; Athanassiadis, D., and Nordfjell, T., 2017; Young B.D., Yarie J., Verbyla D., Huettmann F., Stuart Chapin F., 2018). To make it spatial related, geo-referencing of forest inventory data must be included. As such, we performed forest inventory by modeling in a geographic information system (GIS) prior to transferred into 3D tree modeling in a Unity's 3D Tree Modeler.

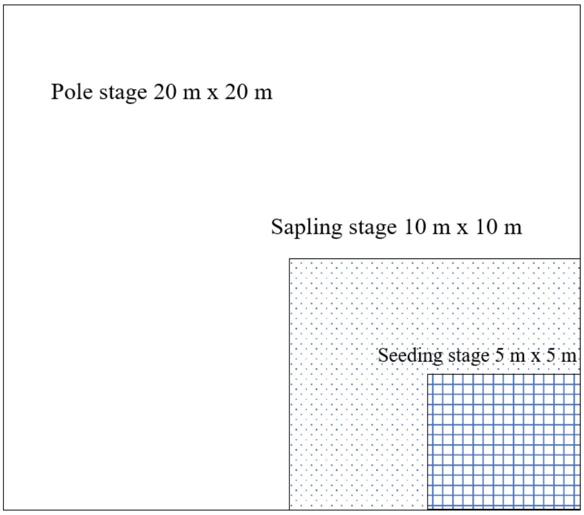

Figure 1: A platform of sample plot

Table 1: Example of tree characteristics retrieved from pole stage sample plot

Species	GBH[a]	Ht[b]	X[c]	Y[c]	X_1[d]	X_2[d]	Y_1[d]	Y_2[d]
Diospyros ebenum	0.41	7.67	20351	82698	2.50	2.33	2.83	1.83
Diospyros mollis	0.39	6.75	20349	82701	1.75	2.13	1.63	1.50
Leucaena leucocephala	0.38	7.17	20355	82700	2.67	2.00	1.17	2.33

[a]*Girth at breast height 1.30 meter > 0.30 meter,* [b]*Tree height in meter,* [c]*X and* [c]*Y coordinate referenced in military grid system (47P QS),* [d]*Tree canopy*

In this research, field survey using sample plots was implemented to acquire forest inventory. Our study area is one of military training fields of the Royal Thai Army Training Command, covering 2.0 kilometer x 0.5 kilometer. Six sample plots of 20 meter x 20 meter were carried out. Extrapolation was also included using Unmanned Aerial Vehicle (UAV) mapping so as to fulfil additional spatial information needed (Tomppo, E., Olsson, H., Ståhl, G., Nilsson, M., Hagner, O., and Katila, M., 2008; Haywood, A., Mellor, A., and Stone, C., 2016). Figure 1 displays a platform of sample plot. There are three sections in each platform, which are 20 meter x 20 meter, 10 meter x 10 meter and 5 meter x 5 meter. These different sections are designed to acquire characteristics of tree stages including pole, sapling and seeding stage, respectively. The characteristics of trees in pole and sapling stage retrieved from one platform are shown in Table 1 and 2. The vegetation species discovered in pole and sapling stage were geo-located in military gird referencing (MGR) format. Considerably, we sampled merely species and counts of seeding trees.

Table 2: Example of tree characteristics retrieved from sapling stage sample plot

Species	Count	Ht[a]	X[b]	Y[b]
Diospyros ebenum	1	2.0	20359	82690
Diospyros ebenum	1	2.5	20345	82701
Afzelia xylocarpa	1	4.0	20347	82699

[a]*Girth at breast height 1.30 meter < 0.30 meter,* [b]*X and Y coordinate referenced in military grid system (47P QS)*

The plant information received from sample plots were further used to investigate quantitative forest characteristics of tactical training field. The forest characteristics were quantitated by number of sample plots found, frequency percentage, counts, and frequency class in order to study forest homogeneity of this tactical training field. The results of quantitative forest characteristics are explained in section 2.2.

2.2. Quantitative forest characteristics of tactical training field

Table 3 illustrates quantitative forest characteristics of tactical training field. Trees in pole and sapling stage were sorted in descending order. The percentage of tree frequency was used to describe forest homogeneity, which was categorized into five classes (From class A to class E). The frequency percentage of Class A to Class B is 1-20, 21-40, 41-60, 61-80, and 81-100, respectively. Forest homogeneity is referred as to $\frac{Class\ E+Class\ D}{\text{Class B+Class C}}$. It shows strong homogeneity when homogeneity value is more than one. As illustrated in Table 3, this tactical training field is homogenous with homogeneity value 1.5.

Table 3: Quantitative forest characteristics of tactical training field

Order	Species	Number of sample plots found	Frequency (%)	Count[a]	Class[b]
1	*Diospyros ebenum*	5	83.3	15	E
2	*Holarrhena pubescens Wall. ex G.Don*	5	83.3	4	E
3	*Millettia kangensis*	5	83.3	7	E
4	*Diospyros mollis*	5	83.3	12	E
5	*Lagerstroemia calyculata Kurz*	4	50.0	3	D
6	*Spondias pinnata (L. f.) Kurz*	4	50.0	6	D
7	*Bridelia ovata Decne*	3	50.0	3	C
8	*Hopea ferrea*	3	50.0	3	C
9	*Leucaena leucocepphala (Lam.) de Wit*	3	50.0	4	C
10	*Combretum quadrangulare Kurz*	3	50.0	3	C

[a]*Number of trees found,* [b]*homogeneity class*

In can be concluded that those trees in pole and sapling stage as seen in table 3 represent majority of tree species found in the tactical training field. The forest inventory collected from the field survey was later transferred into 3D tree modeling in a Unity's 3D Tree, elaborated in next section.

3. 3D TREE MODELING FOR UNITY'S SPEEDTREE® MODELER

The conceptual methodology is threefold as illustrated in figure 2. First is the implementation of forest inventory in order to prepare geo-database of vegetation characteristics. Second is the modeling 3D Trees in Unity's SpeedTree® Modeler using actual materials of barks and leaves. Thirdly, it is the approach of visualization of 3D Tree Models based on different levels of details prior to include in Unity game engine library. The elaboration of this conceptual methodology is explained below.

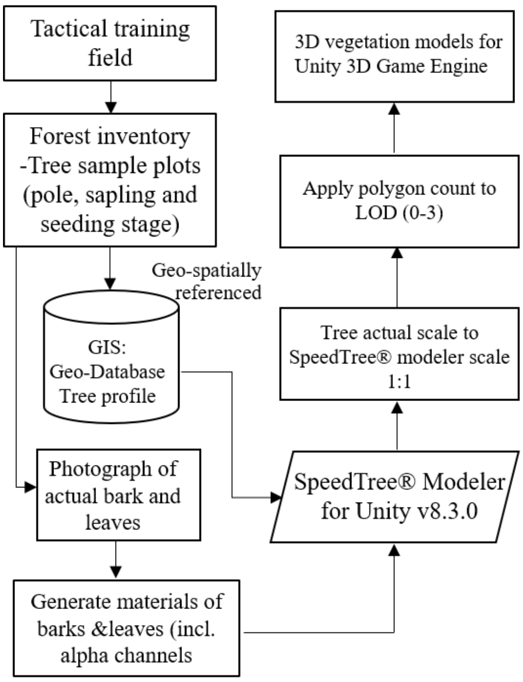

Figure 2: A process of modeling 3D trees in SpeedTree® Modeler

3.1. Modeling 3D Trees in Unity's SpeedTree® Modeler

With the final goal to develop the 3D model database for inclusion to the Unity game engine library, the process of modeling 3D trees in SpeedTree® Modeler was developed as shown in Figure 2. The training field of 2 x 0.5 square kilometer in which the research team performed tree sample plotting for the forest inventory selected and outlined by the Royal Thai Army Tactical Training Center. Fine resolution imagery from UAV was used to obtain geo-referenced tree footprints while field survey photos were source of site-specific barks and leaves. These materials from the site along with the tree profiling data of the geo-database were input to the SpeedTree® Modeler and scaled to replicate actual height as indicated by tree profiles. For example, *Diospyros ebenum* was 7.67-meter-high (see table 1). The height of this tree was modeled from actual scale to SpeedTree® modeler scale as seen in Figure 3 (Left image).

Prior to export 3D trees from SpeedTree® Modeler to Unity 3D game engine, levels of details (LOD) were taken into consideration. Polygon count limits spatial resolution displayed in game engine. Since our study was aimed to develop tactical training field in troop level, we limited polygon count of LOD at 10,000. The number of LOD 0-LOD 3 polygons were pre-computed to avoid lengthy rendering time during 3D scene computation with appropriate level of detail in relation to viewing distance (Kumsap et al, 2005). Four LOD for three 3D tree models (see Figure 3-5) were then added to the library. Figure 3 displays *Diospyros ebenum* in LOD 0, and Figure 4-5 shows LOD 2 of *Diospyros mollis* and *Leucaena leucocephala,* respectively.

Figure 3: A visual comparison between a computer-generated image (left) and real photo (right) of *Diospyros ebenum* (Ebony)

Figure 4: A visual comparison between a computer-generated image (left) and real photo (right) of *Diospyros mollis* (Ebony tree)

The nature is literally impossible to model and simulate using a scientifically and technologically complete and flawless manner. An individual tree is modeled with the addition of photographical materials from the field to enhance the sense of geo-specific simulation to provide an accumulative geo-typical simulation product. The accumulation of individually modeled object contributes to tactical training in a way that trainees stay connected to the actual site of training. Therefore, the modeler outcomes will be further validated in an accumulative approach, which was planned to study the visual comparison of the tree profile from the actual site and the terrain modeling and visualization from the result 3D tree models. This emerging notion deserves effort, resource and time to further investigate, thus beyond the scope of this actual material tree modeling methodology.

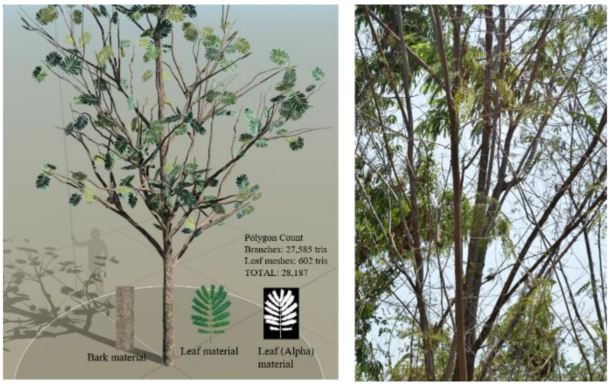

Figure 5: A visual comparison between a computer-generated image (left) and real photo (right) of *Leucaena leucocephala* (White popinac)

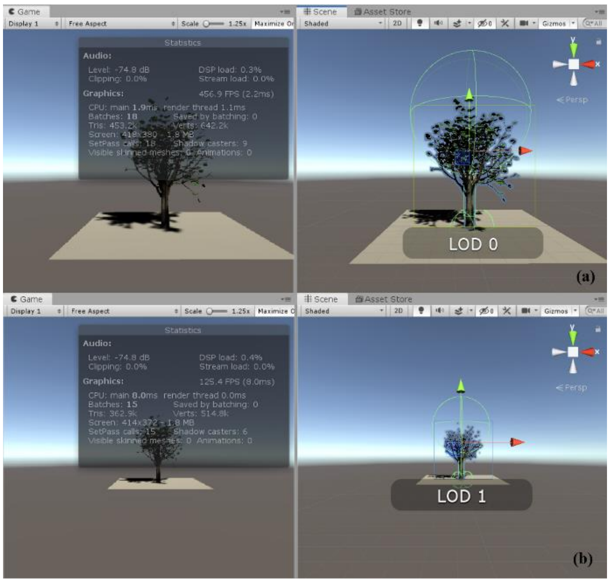

Figure 6: *Diospyros ebenum* tree plotted in Unity 3D game engine (a) in LOD 0 and (b) in LOD 1

3.2. Visualization of 3D Tree Models

The result of 3D tree modeling was illustrated in Figure 3 – 5 with photos taken from the site displayed alongside. The foliage density of the model was manually edited to reflect that of the real tree. Mesh materials from the site were added to branches and trunk to obtain quite a resembling 3D model from visualization. Modeling the foliage density and length demanded lengthier time than expected, thus excluded from this report and could have resulted in close resemblance with the actual trees. However, adding more detail of leaves, branches and trunk to the model could lead to a lengthier rendering time and unnecessary extra details being rendered without being actually viewed (Kumsap et al, 2005). Therefore, the LOD 0 – LOD 3 were generated for inclusion to the database of Unity game engine for proper rendering and visualization purpose.

Figure 6 showcases statistics of rendering *Diospyros ebenum* tree models at LOD 0 and LOD 1. The number of polygons to construct LOD 0 at 453.2k of polygons and LOD1 with 362.9k polygons. The LOD in SpeedTree® Modeler is dynamic for smooth changes as the distance to the tree changes, hiding any geometry unnecessary to render.

3.3. Vegetated Terrain Modeling for Terrain Analysis

To construct 3D scene shown in Figure 7, the geo-database and tree profile were incorporated to produce a rather photorealistic view of the study area. Tree footprints collected in Section 2.1 yielded tree density and heterogeneity, main factors to converge visualization and first-hand experience of terrain viewers. The first-person view was well welcome for the terrain analysis of the Royal Thai Army's Tactical Training Center. However, statistical results of the acceptance of the proposed methodology were out of the scope of this study and recommended for further investigation.


Figure 7: 3D trees plotted on Terrain of the study area.

4. CONCLUSION AND FUTURE WORK

Our work was aimed to transfer modelled 3D trees into Unity 3D game engine to further develop a virtual world tactical training simulator for infantry company commander and infantry platoon leader which is not existing in the Royal Thai Army. In virtual world military training, plants characteristics affect the perspective and ability of trainees. Key terrain analysis must be included in intelligence preparation of the battlefield called OCOKA. Vegetation characteristics are necessary to be observed in individual virtual training; for example, an avenue of tank movement, height, diameter, and canopy of trees must be considered. The realism of trees and terrain enhance the success of intelligence preparation of the battlefield. The proposed modeling approach enhances the realism of the modelled and visualized virtual world tactical training system, which the performance of trainees would be improved. Thus, we denied using ready-made trees. The adopted methodology manipulated the data collection for the forestry inventory and attempted to model the sampled trees in the Unity's SpeedTree® Modeler rather than to investigate a modeling algorithm for 3D tree modeling. The forest inventory was modeled in a GIS prior to transferring into 3D tree modeling in the Unity's 3D Tree Modeler. The barks and leaves of each vegetation species were photographed during field survey and used as mesh for actual materials of barks and leaves. The alpha channel was enabled for leaf material generation, thus allowing opacity among leaf space. Since the study was aimed for the tactical training field at troop level, the LOD polygon count was limited to 10,000. In addition, the number of LOD0-LOD3 polygons were pre-computed to accelerate the 3D scene computation, and the rendering of each LOD was illustrated to reveal gradual changes of modeling details. The visual comparison was illustrated for the visualization of mesh materials added to the branches and trunk at sufficient resemblance to the actual trees. However, the complete rendering of the 2 x 0.5 km^2 study as well as the result of incorporating 3D scene computation results with OCOKA terrain analysis are in current investigation and worthy of further discussions. UAV terrain modeling can be a reliable and quick source for collecting tree canopies and highly recommended to verify photorealism of the processed 3D models. In addition, the modeler outcomes needed further validation, which was planned to study the visual comparison of the tree profile from the actual site and the terrain modeling and visualization from the result 3D tree models.

ACKNOWLEDGMENTS

This research was funded by the Office of the Higher Education Commission, Thailand and Army Research Development Office, Royal Thai Army. The Authors would like to extend our appreciation to Royal Thai Army Training Command and Tactical Training Center for their constructive suggestions.

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