INTISARI

Dalam era digital, penggunaan teknologi *Terrestrial Laser Scanner* (TLS) sebagai salah satu teknik penyedia data spasial mengalami perkembangan sangat pesat. Hal ini, didorong oleh kemampuan TLS dalam menghasilkan data spasial 3D suatu objek secara cepat, akurat, dan detail, sehingga sangat efisien untuk berbagai kebutuhan pemetaan berbasis spasial. Dalam kegiatan pemetaan suatu area, TLS tidak dapat dilakukan hanya dari satu posisi berdiri alat (*scan station*), sehingga diperlukan prosedur registrasi *point clouds* untuk menggabungkan data *scan world* hasil pengukuran TLS. Registrasi *point clouds* memegang peranan krusial dalam menghasilkan *point clouds* dengan kualitas geometrik yang baik dan akurat. Terdapat beberapa teknik registrasi yang bisa dilakukan yaitu teknik *target to target*, teknik *cloud to cloud*, dan teknik *control point based*. Penelitian ini bertujuan untuk menganalisis ketelitian hasil registrasi *point clouds* antara teknik *cloud to cloud* dan teknik *control point based* pada data TLS serta melakukan uji signifikansi. Algoritma teknik registrasi *cloud to cloud* yang dikaji pada penelitian adalah algoritma *Iterative Closest Point* (ICP) dan *Normal Distribution Transformation* (NDT), sedangkan teknik *control point based* yang dikaji memanfaatkan sejumlah titik kontrol sebagai input koordinat *scan station*.

Penelitian ini dilakukan pada Gedung *Smart Green Learning Center* (SGLC) Fakultas Teknik Universitas Gadjah Mada. Data *point clouds* dihasilkan dari pengukuran menggunakan alat TLS *Topcon GLS-2000* yang diolah menggunakan perangkat lunak *Magnet Collage* untuk teknik *control point based*, *Maptek* untuk teknik *cloud to cloud* algoritma ICP dan *Visual Studio Code* untuk teknik *cloud to cloud* algoritma NDT. Selama proses akuisisi, pemindaian dilakukan dari beberapa *scan station* dengan mempertimbangkan cakupan area dan saling tumpang tindih antar *scan world* untuk mempermudah proses registrasi. Proses registrasi dilakukan secara bertahap, dimulai dari penyusunan urutan *scan*, identifikasi titik referensi, hingga penerapan algoritma penyelarasan sesuai teknik masing-masing. Analisis hasil registrasi dilakukan dengan membandingkan ketelitian hasil registrasi dari ketiga teknik menggunakan 30 sampel uji. Uji yang dilakukan adalah dengan uji perbandingan ukuran jarak *point clouds* dengan ukuran jarak di lapangan menggunakan disto meter untuk jarak sisi dan *total station* untuk data ketinggian serta melakukan uji signifikansi ketiga teknik tersebut.

Berdasarkan hasil uji validasi, teknik *cloud to cloud* menunjukkan tingkat ketelitian dan kualitas data registrasi yang lebih baik dibandingkan dengan teknik *control point based*. Hal ini, terlihat dari nilai RMSE teknik *cloud to cloud* algoritma ICP sebesar 9 mm, dan algoritma NDT sebesar 10 mm, sedangkan teknik *control point based* menghasilkan nilai RMSE sebesar 21 mm. Hal ini, disebabkan karena titik kontrol diukur menggunakan teknik RTK-NTRIP yang memiliki ketelitian rendah sehingga mempengaruhi hasil registrasi teknik *control point based*. Hasil uji t menunjukkan bahwa tidak terdapat perbedaan ketelitian yang signifikan antar ketiga teknik registrasi *point clouds,* ketiga teknik memberikan hasil yang setara, sehingga pemilihan teknik registrasi dapat disesuaikan secara kompleksitas objek, atau ketersediaan data kontrol.

Kata kunci : *Terrestrial Laser Scanner*, Metode *Cloud to Cloud*, Teknik *Control point based*

ABSTRACT

In the digital era, the use of Terrestrial Laser Scanner (TLS) technology as one of the techniques for providing spatial data has experienced rapid development. This is driven by TLS's ability to generate 3D spatial data of an object quickly, accurately, and in detail, making it highly efficient for various spatial mapping needs. In mapping an area, TLS cannot be executed from only one instrument standing position (scan station); therefore, point cloud registration procedures are necessary to combine the world scan data obtained from TLS measurements. Point cloud registration plays a crucial role in producing point clouds with good and accurate geometric quality. There are several registration techniques that can be employed, namely target-to-target technique, cloud-to-cloud technique, and control point-based technique. This research aims to analyze the accuracy of point cloud registration results between the cloud-to-cloud technique and the control point-based technique using TLS data, as well as to conduct a significance test. The algorithms examined in this study for the cloud-to-cloud registration technique are the Iterative Closest Point (ICP) and Normal Distribution Transformation (NDT) algorithms, while the control point-based technique analyzed utilizes several control points as input for scan station coordinates.

This research was conducted at the Smart Green Learning Center (SGLC) of the Faculty of Engineering, Gadjah Mada University. Point cloud data were generated from measurements using the TLS Topcon GLS-2000 instrument, processed using Magnet Collage software for the control point-based technique, Maptek for the cloud-to-cloud technique utilizing the ICP algorithm, and Visual Studio Code for the cloud-to-cloud technique utilizing the NDT algorithm. During the acquisition process, scanning was performed from several scan stations, considering area coverage and the overlap between scan worlds to facilitate the registration process. The registration process was carried out in stages, starting with organizing the scan sequence, identifying reference points, and applying alignment algorithms according to each technique. The analysis of the registration results was conducted by comparing the accuracy of the registration results from the three techniques using 30 test samples. The test conducted is a comparison of the distance measurements of point clouds with the actual distances in the field using a disto meter for side distances and a total station for elevation data, as well as performing a significance test for the three technique.

Based on the results of the validation test, the cloud-to-cloud technique demonstrates a higher level of accuracy and quality of registration data compared to the control point-based technique. This is evident from the RMSE values of the cloud-to-cloud technique using the ICP algorithm at 9 mm, and the NDT algorithm at 10 mm, while the control point-based technique resulted in an RMSE value of 21 mm. This is attributed to the control points being measured using the RTK-NTRIP technique, which has low accuracy, thereby affecting the registration results of the control point-based technique. The results of the t-test indicate that there are no significant differences in accuracy among the three point cloud registration techniques; all three techniques yield comparable results, thus allowing the choice of a registration technique to be tailored to the complexity of the object or the availability of control data.
Keywords : Terrestrial Laser Scanner, Cloud to Cloud Method, Traverse Method