INTISARI

Penentuan posisi teliti di Indonesia bersumber dari infrastruktur penentuan posisi berupa *Indonesia Continously Operating Reference Station* (INACORS), Jaring Kontrol Horizontal Nasional (JKHN), Jaring Kontrol Vertikal Nasional (JKVN), dan model geoid nasional (INAGEOID). Namun demikian, hingga saat ini distribusi INACORS, JKHN, dan JKVN di Indonesia belum merata, sedangkan verifikasi INAGEOID belum dilakukan pada beberapa wilayah timur Indonesia. Evaluasi kualitas infrastruktur SRGI tersebut belum pernah dilakukan secara komprehensif. Disparitas infrastruktur penentuan posisi tersebut memiliki konsekuensi pada kebutuhan ekstensifikasi/densifikasi titik kontrol untuk area yang jauh dari infrastruktur. Metode PPP memiliki potensi untuk mengkomplemen metode GNSS diferensial dalam penentuan posisi mengacu ke SRGI 2013, karena penentuan posisinya tidak perlu mengacu infrastruktur terdekat. Secara teoritis dan empirik, metode PPP mengacu langsung ke *International Reference Frame* (ITRF) yang kompatibel ke sistem referensi nasional. Namun demikian, informasi ketelitian dan kompatibilitas koordinat hasil PPP terhadap SRGI 2013 belum diketahui. Agar koordinat 3D hasil metode PPP dapat dipadukan dengan GNSS diferensial dalam satu sistem referensi SRGI 2013, hal tersebut perlu dirumuskan dalam sebuah rancangan perekomendasi. Penelitian ini bertujuan merancang perekomendasi dan mengimplementasikannya dalam sistem perekomendasi yang dapat mendiseminasikan perpaduan metode PPP dan GNSS diferensial dengan mempertimbangkan kualitas infrastruktur sesuai lokasi pengguna.

Data untuk analisis kualitas infrastruktur penentuan posisi secara multi kriteria terdiri atas distribusi INACORS, ketersediaan layanan INACORS, distribusi JKHN dan JKVN, serta ketelitian penentuan tinggi INAGEOID. Data untuk analisis ketelitian dan kompatibilitas PPP terhadap SRGI 2013 terdiri atas sampel data RINEX versi 2.11 dan koordinat tetap SRGI 2013 dari 42 sampel INACORS. Evaluasi kualitas infrastruktur dilakukan dengan *Multi Criteria Decision Making* (MCDM) dengan teknik *Outranking*. Ketelitian PPP dianalisis berdasarkan kepresisian dan uji signifikansi sampel berpasangan koordinat dari metode CSRS PPP dan PRIDE PPP-AR. Analisis kompatibilitas dilakukan dengan perbandingan koordinat hasil PPP tiap metode terhadap koordinat tetap sampel INACORS dalam SRGI 2013. Rancangan sistem perekomendasi disusun dalam bentuk model konseptual dan kerangka kerja perpaduan metode PPP dan GNSS diferensial dengan teknik *geofencing* berdasarkan data kualitas infrastruktur penentuan posisi sesuai lokasi pengguna. Rancangan perekomendasi tersebut diimplementasikan dalam sebuah sistem perekomendasi *hybrid* Android yang didukung *web service* pada sisi *backend.* Sistem perekomendasi dievaluasi dengan uji kinerja *Black Box* dan pemuatan aplikasi serta uji kegunaan dengan kuesioner yang melibatkan responden dengan latar belakang profesi bervariasi.

Hasil penelitian menunjukkan adanya disparitas kualitas infrastruktur di berbagai wilayah di Indonesia. Jawa merupakan wilayah dengan kualitas infrastruktur terbaik di mana 98,78% wilayahnya terdiri atas gabungan kualitas infrastruktur yang sangat baik dan baik. Kualitas infrastruktur di Maluku dan Papua merupakan merupakan wilayah yang perlu segera ditingkatkan karena kualitas infrastruktur kategori sangat tidak baik masih berkisar di angka 46,04% dan 88,15%. Simulasi MCDM menunjukkan penerapan perpaduan metode PPP dan GNSS diferensial dapat mengurangi wilayah dengan kualitas yang tidak baik pada wilayah tersebut. Metode PPP terbukti memiliki kepresisian pada level milimeter hingga sentimeter dan kompatibel terhadap SRGI dengan kesalahan rata-rata di bawah 10 cm. Rancangan yang disusun dapat secara teknis mengimplementasikan pemanfaatan data kualitas infrastruktur dalam sistem

perekomendasi. Uji kinerja dengan *black box testing* menunjukkan sistem perekomendasi dapat berfungsi sesuai desain yang ditetapkan. Uji kegunaan dari umpan balik kuesioner menunjukkan sistem perekomendasi dapat mendiseminasikan perpaduan metode PPP dan GNSS diferensial sesuai dengan kualitas infrastruktur penentuan posisi pada lokasi pengguna dengan cepat dan responsif.

Kata kunci: infrastruktur penentuan posisi, evaluasi multi kriteria, PPP, *geofencing*, sistem perekomendasi

ABSTRACT

Accurate positioning in Indonesia comes from positioning infrastructure in the form of the Indonesia Continuously Operating Reference Station (INACORS), the National Horizontal Control Net (JKHN), the National Vertical Control Net (JKVN), and the national geoid model (INAGEOID). However, until now, the distribution of INACORS, JKHN, and JKVN in Indonesia has not been evenly distributed, while INAGEOID verification has not been carried out in several eastern regions of Indonesia. Evaluation of the quality of the SRGI infrastructure has never been done comprehensively. The disparity in positioning infrastructure has consequences on the need to extend/densify control points for areas far from the infrastructure. The PPP method has the potential to complement the differential GNSS method of positioning in reference to SRGI 2013, as it does not need to refer to the nearest infrastructure. Theoretically and empirically, the PPP method refers directly to the ITRF, which is compatible with national reference systems. However, information on the accuracy and compatibility of PPP-generated coordinates with SRGI 2013 is unknown. For the 3D coordinates from the PPP method to be integrated with differential GNSS in the SRGI 2013 reference system, it needs to be formulated in a recommender design. This research aims to design a recommender and implement it in a recommender system that can disseminate a combination of PPP and differential GNSS methods by considering the quality of infrastructure according to the user's location.

Data for multi-criteria positioning infrastructure quality analysis consisted of INACORS distribution, INACORS service availability, JKHN and JKVN distribution, and INAGEOID height determination accuracy. Data for the analysis of accuracy and PPP compatibility with SRGI 2013 consisted of RINEX version 2.11 data samples and SRGI 2013 fixed coordinates from 42 INACORS samples. Infrastructure quality evaluation was conducted using MCDM with Outranking technique. The PPP solutions were analyzed based on precision and significance tests of paired sample coordinates from CSRS PPP and PRIDE PPP-AR methods. Compatibility analysis was conducted by comparing the PPP result coordinates of each method to the fixed coordinates of INACORS samples in SRGI 2013. The design of the recommender system is organized in the form of a conceptual model and framework for the combination of PPP and differential GNSS methods with geofencing techniques based on positioning infrastructure quality data according to the user's location. The recommender design was implemented in an Android hybrid recommender system supported by web services on the backend. The recommender system was evaluated with a Black Box performance test and application loading as well as a usability test using a questionnaire involving respondents with varied professional backgrounds.

The results show that there are disparities in infrastructure quality across regions in Indonesia. Java is the region with the best infrastructure quality with 98.78% of the region consisting of a combination of excellent and good infrastructure quality. The quality of infrastructure in Maluku and Papua is an area that needs to be improved immediately because the quality of infrastructure in the very poor category is still around 46.04% and 88.15%. MCDM simulations show that the application of a combination of PPP and differential GNSS methods can reduce areas with poor quality in the region. The PPP method is proven to have millimeter to centimeter-level precision and is compatible with SRGI with an average error below 10 cm. The design can technically implement the utilization of infrastructure quality data in the recommender system. Performance tests using black box testing showed that the recommender system could function as designed. Usability tests from questionnaire

feedback show the recommender system can disseminate a combination of PPP and differential GNSS methods according to the quality of the positioning infrastructure at the user's location quickly and responsively.

Keywords: positioning infrastructure, multi-criteria evaluation, PPP, *geofencing,* recommender system