Performance Evaluation of the New Control Center and Receiver Hardware for the CORS-TR System

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Abstract

A Continuously Operating Reference Stations (CORS) GNSS network is crucial for providing regional positioning services capable of delivering highly accurate, purpose-specific positioning. In CORS infrastructure, correction data is transmitted in real-time from the control center to the rover receiver (user side), enabling precise positioning of the rover in real-time (Singh and Kumar 2019). In the early 2000s, the engineering and scientific communities successfully incorporated Real-Time Kinematic (RTK) positioning into their CORS networks, which were initially passive and static (Bock et al, 2002; Rizos et al., 2003; Eren, 2005; Rizos, 2007; Grejner-Brzezinska et al., 2007). This development marked a significant breakthrough in the concept and efficiency of positioning technologies. These enhanced networks, now known as RTK CORS or CORS-Active, distinguish themselves from the older passive CORS systems (Rizos et al, 2003, Wubbena et al, 2001, Retscher, 2002). The TUSAGA-Aktif system, known internationally as the Continuously Operating Reference Station-Turkey (CORS-TR), is a wide-area GNSS network that provides continuous RTK services over the whole of Turkey and the Turkish Republic of Northern Cyprus (TRNC). Operational since 2008, it was developed through a public project supported by Turkish Scientific and Technical Research Agency (TUBITAK) and managed by the General Directorate of Land Registry and Cadastre (GDLRC). The aim of the project was to optimize system upgrades to acquired control center software and hardware are under rigorous testing, with preliminary results indicating accuracy comparable to the existing system while offering brand independence. This advancement has enabled the integration of additional GNSS stations, improving the coverage and reliability of the network. By expanding access to multiple satellite systems and achieving cost efficiencies, the upgraded system promises a more robust and efficient service that will effectively meet user needs. This paper presents a comparative analysis of the newly acquired control center software and hardware with the existing control center. The analysis emphasizes the advantages of the new system, particularly in terms of its flexibility and independence, while also identifying certain limitations. In the subsequent sections, the paper provides comprehensive information regarding the integration of the new software for TUSAGA-Aktif users and outlines how they can effectively utilize its features. These insights are intended to streamline the transition process and ensure that users can fully capitalize on the innovations introduced by the upgraded system.

1. Introduction

Continuously Operating Reference Stations (CORS) are systems introduced by the National Geodetic Survey (NGS) to conduct GPS code and carrier phase measurements, enabling the determination of a point’s 3D coordinates (Tekdal et al., 2006). A standard CORS setup typically includes a dual-frequency GPS receiver and antenna capable of supporting both carrier phase and code range measurements. While traditional setups often use choke-ring antennas designed to minimize multipath effects, recent developments have introduced smaller, high-tech antennas that effectively reduce such interference. Other essential components include an uninterruptible power supply to ensure continuous operation of the GPS receiver, data storage, and communication devices such as radio modems to transmit data and corrections (e.g. Figure 1).

Figure 1. Pillar and Antenna (left), Solar panel for power supply (middle) and Reference station cabinet (right).

The term CORS, used by many countries, has become part of the international literature in this sense. In a CORS system, GNSS observations from reference stations with known coordinates covering the entire country are transmitted to a control center. (Figure 2) At the control center, atmospheric and other errors are modeled and RTK/DGPS corrections are computed in real time and sent to mobile GNSS receivers in RTCM format via GPRS/EDGE. Servers at the control center use data from all stations to perform atmospheric modeling and calculate DGPS/RTK correction data, which is then sent to mobile receivers in NTRIP format, enabling sub-meter accuracy with DGPS or centimeter accuracy with network RTK corrections.

The TUSAGA-Aktif system, developed as part of a public project supported by TUBITAK, is a wide-area GNSS network providing continuous RTK services throughout Turkey and the Turkish Republic of Northern Cyprus (TRNC). (e.g. Figure 3) Known internationally as CORS-TR, the project was launched on May 8, 2006, under the leadership of Istanbul Kültür University, in cooperation with the General Directorate of Land Registry and Cadastre (GDLRC) and the Directorate General of Mapping (DGM), and became operational in December 2008. It is managed by the General Directorate of Land Registry and Cadastre under a 2010 cooperation protocol.

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Figure 2. Control Center of TUSAGA-Aktif system located in Ankara, Turkey.

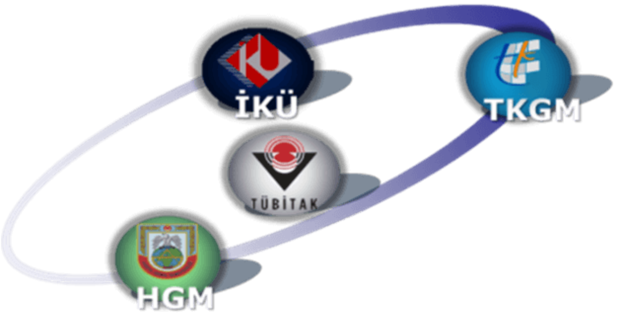

Figure 3. TUSAGA-Aktif project partners.

To build on the success of the CORS-TR system and increase its impact, we have identified the need for new software and hardware at a cost of one tenth of the current expenditure. The goal of this initiative is to improve system performance, enhance user value and satisfaction, and diversify the offering. These updates will strengthen the system's sustainability and ensure its continued effectiveness in meeting user needs.

2. Current System's Limitations and Challenges

The TUSAGA-Aktif system provides accurate GNSS positioning services throughout Turkey and Northern Cyprus. However, it faces certain limitations and challenges. A key issue is its reliance on a stable communication infrastructure such as GPRS/EDGE for real-time transmission of correction data, which can be disrupted in areas with poor network coverage, especially in the southern part of Turkey. (e.g. Figure 4) In addition, the accuracy of the system can be affected by environmental factors such as multipath and ionospheric interference. The cost of maintaining and operating a wide-area GNSS network is also a financial challenge. Addressing these issues is critical to ensure long-term sustainability, reliability, and efficiency of the system. To explain them more specifically for Turkey; due to geopolitical location, jamming is widespread, causing communication problems at the fixed stations of the CORS-TR network. These problems have a direct impact on positioning. Although the current system supports two different satellite positioning systems (GPS and GLONASS), both are also affected by jamming. As a result, when fixed stations experience signal loss, it becomes nearly impossible to provide accurate correction signals to users.

Another challenge is licensing issues related to the brands of receivers used in the control center software. To improve the performance of the CORS-TR system, our aim is to increase the number of stations and improve the baseline lengths. (e.g. Figure 5) We also plan to expand the network by integrating local networks. However, the brand-specific licensing of the current system makes it difficult to add new stations to the GNSS network. A network system serving nearly 27,000 users underscores the critical importance of station densification.

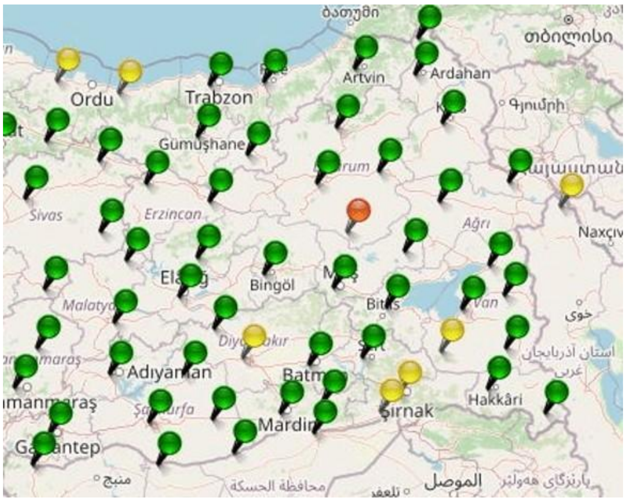

Figure 4. Stations experiencing signal loss due to jamming in the southern region of Turkey.

Figure 5. Need for network densification to reduce baseline length.

In addition, the most significant issue facing us is the rising cost of the current system. This increasing financial burden poses challenges to the sustainability and scalability of the network. Addressing this issue requires the adoption of more cost-effective solutions and optimization of system resources without compromising performance.

3. Benefits of Double Software and Hardware

As part of the system upgrade, a second set of control center software and 100 advanced receivers were procured at approximately one-tenth the previous cost, representing a significant reduction in financial expenditure. These state-of-the-art receivers not only support GPS and GLONASS, but also include compatibility with the Galileo and Beidou satellite positioning systems. This multi-constellation capability gives users access to a greater number of satellites, improving the accuracy, reliability and availability of positioning data, especially in challenging environments such as urban canyons or areas with limited satellite visibility. (e.g. Figure 6).

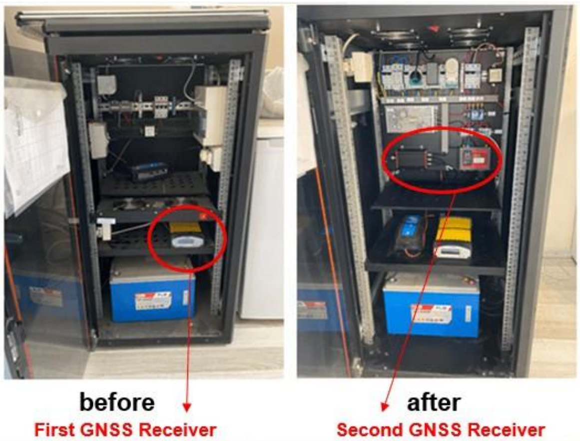

Figure 6. Reference station cabinet with two different GNSS receivers.

These receivers have also been strategically deployed in regions particularly vulnerable to signal jamming and interference, such as along our southeastern border. Our goal is to mitigate the impact of such disruptions and ensure the continuity and reliability of the system's services under adverse conditions.

In addition to technical improvements, the new system has solved long-standing operational issues, including those related to brand-specific licensing. Previously, the integration of receivers from different local networks was a major challenge due to compatibility restrictions. The new system has enabled us to overcome these obstacles and seamlessly integrate different receivers into the network. This has allowed us to efficiently increase station density, provide more comprehensive coverage, and improve the overall robustness of the GNSS network. These improvements not only strengthen the performance of the system, but also demonstrate our commitment to providing cost-effective, reliable, state-of-the-art services to users across the country.

4. Field Study

One of the biggest challenges with the existing system was that our fixed GNSS stations became inoperable under the influence of jamming, which immediately prevented users in the affected areas to work in the fields. The solution to this problem was the purchase of 100 new receivers and the prioritization of their installation on the southeastern border of Turkey, which is the most problematic area, and the extension of the coverage area to the Aegean Sea. The installation of 95 of the receivers has been completed by our staff and the plans for the installation of the remaining 5 receivers have been drawn up. (e.g. Figure 7)

Figure 7. Stations where the new receivers have been installed. The yellow color represents the stations planned for installation, while the green color indicates the stations where installation has been completed.

The field team (Figure 8) successfully installed the new receivers alongside the existing ones in the GNSS station cabinets, carefully ensuring the compatibility and efficient use of the existing infrastructure. This innovative setup allowed data from two different brands of receivers to be transmitted simultaneously to the control center, providing seamless integration while increasing system redundancy and reliability. By facilitating the parallel flow of data from two different receivers to two different control center software platforms through the same fixed station, this approach represents a significant advancement in the design of GNSS networks. Not only does it ensure operational continuity in the event of system failure, but also provides valuable data for cross-validation and performance benchmarking, making it one of the first implementations of its kind in the world and setting a new standard for similar systems worldwide.

Figure 8. Field team.

5. Performance Comparison of Two Systems

After completing the installation of the new system's receivers and ensuring that the new central station software was functioning properly, the GDLRC and DGM teams began field testing. The primary goal of these tests was to determine how closely the results of the new system matched those of the existing system.

First, as the GDLRC, we contacted employees in the regions where the installation had been completed. We asked them to take measurements with both the existing system and the new system. The process was straightforward. All they had to do was connect to the current CORS-TR system using their existing GPS receivers, and then switch to the new system by simply adjusting the port settings on their devices. While the method for changing the port settings varied slightly between receiver brands, the common denominator was that it was easy for the user to make the switch. The field teams successfully performed measurements on both systems and shared their results with us. When we analyzed the data, we found that the results from the two systems were very close. Differences in the X and Y coordinates were within 2 cm, while differences in the Z coordinate were up to 3-4 cm. In addition, some teams reported faster connection speeds at times with the new system.

Meanwhile, the Directorate General of Mapping (DGM) and its teams conducted test measurements at known coordinate points, the Turkish National Fundamental GNSS Network (TNFGNTUTGA), to further evaluate the accuracy of the new system. The evaluations based on the measurements at known coordinate points showed that both systems produced very similar results, with only minor differences in the millimeter range. In some areas, the new system provided even more accurate and consistent results than the existing system.

After thoroughly evaluating both systems based on field measurements, we extended our analysis to include the performance of the control center software during these measurements. The control center software of the current system has demonstrated exceptional reliability and functionality over the years. It provides detailed reports that enable us to efficiently monitor users in the field and respond swiftly to any issues they encounter, thereby ensuring a high level of service quality. Additionally, the software excels at monitoring fixed stations, promptly detecting potential problems, and facilitating proactive maintenance. This combination of features has made the existing control center software a cornerstone of the system's success, earning it a reputation as a dependable and well-optimized tool. On the other hand, the new central station software introduces a more modern and user-friendly web interface, featuring streamlined navigation that significantly improves the user experience. However, it currently lacks the depth of reporting detail provided by the existing system, which remains crucial for in-depth monitoring and problem-solving. Despite this limitation, the new software has been undergoing regular updates that are steadily enhancing its capabilities. These updates have already shown promising improvements, particularly in areas such as fixed station monitoring and user tracking, where it is beginning to match and, in some cases, surpass the functionality of the current system.

As ongoing enhancements continue to refine the new software, we anticipate it becoming an even more efficient tool, capable of addressing operational needs with greater agility and precision. With its potential to deliver advanced features and improved usability, the new control center software is positioned to play a pivotal role in the future development of our GNSS network, ensuring that we remain at the forefront of technological innovation while meeting the evolving demands of our users.

6. Conclusion

CORS-TR, one of the most significant projects undertaken by the General Directorate of Land Registry and Cadastre (GDLRC) and supported by TUBITAK's 1007 program, is designed to maximize the benefits of system upgrades to enhance development, improve user satisfaction, and promote continuous advancement. The newly developed control center software and hardware have undergone extensive and rigorous testing. The findings indicate that the new system achieves accuracy comparable to the existing system, with the additional advantage of being brand-independent. This feature has facilitated the integration of additional stations into the GNSS network, enhancing coverage, improving reliability, expanding access to multiple satellite systems, and achieving these advancements at a substantially reduced cost.

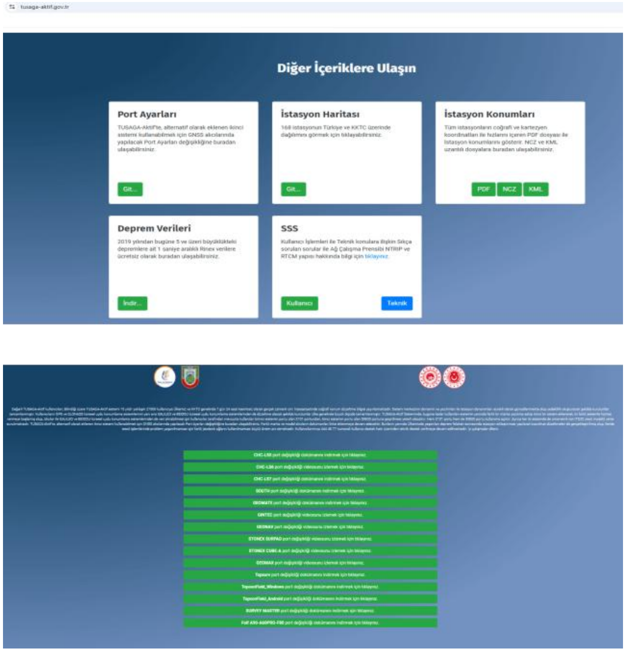

Figure 9. The port settings section of the TUSAGA-Aktif website.

In addition to maintaining the existing system, the new system has been made available to all TUSAGA-Aktif users. To ensure a smooth transition, detailed guidance on the required configuration changes is provided in the port settings section of the TUSAGA-Aktif website. (e.g. Figure 8) This section (see website: https://www.tusaga-aktif.gov.tr/) includes comprehensive information tailored to various GNSS receiver brands. Furthermore, updates to the system will continue as additional documents are received from equipment manufacturers. It is important to emphasize that the new system serves as an alternative option, and users may continue to access precise positioning information through the existing system.

The TUSAGA-Aktif system remains committed to adopting innovations that align with contemporary requirements, ensuring user satisfaction and maintaining its role as a leading GNSS network. By providing users with enhanced flexibility and access to cutting-edge technology, the system reinforces its mission to deliver accurate, reliable, and efficient positioning services.

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