

Doctoral Thesis

**A Novel Methodology for the Determination of Optimal
Locations for the Establishment and Performance Assessment
of Integrated GNSS CORS and SAR Corner Reflector Networks
in the Advent of GGOS**

Dimitris Kakoullis

Limassol, April 2024

CYPRUS UNIVERSITY OF TECHNOLOGY
FACULTY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF CIVIL ENGINEERING AND GEOMATICS

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Approval Form

Doctoral Thesis

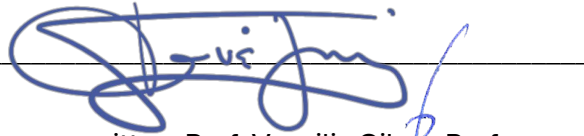
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Presented by

Dimitris Kakoullis

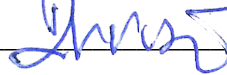
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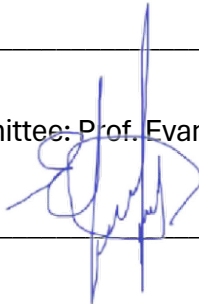
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The approval of the thesis by the Department of Civil Engineering and Geomatics does not necessarily imply the approval by the Department of the writer's views.

ACKNOWLEDGMENTS

This study was conducted as part of the PhD program in the Department of Civil Engineering and Geomatics at the Cyprus University of Technology, associated with the CyCLOPS (RIF/INFRASTRUCTURES/1216/0050) project. This project received funding from the European Regional Development Fund and the Republic of Cyprus through the Research and Innovation Foundation under the RESTART 2016-2020 program.

Additionally, aspects of the research outlined in this dissertation were carried out under the auspices of the "CyCLOPS+" (RIF/SMALL SCALE INFRASTRUCTURES/1222/0082) project, also supported by the European Regional Development Fund and the Republic of Cyprus through the Research and Innovation Foundation.

First, I would like to express my deepest gratitude and appreciation to Dr. Chris Danezis, my PhD supervisor, Associate Professor, Department Chair, Head of CUT Laboratory of Geodesy, and Coordinator of CyCLOPS, for his invaluable support, insights, and encouragement throughout this journey. His guidance has been instrumental in shaping this study, for which I am deeply thankful.

I would also like to thank my advisory committee members, Prof. Diofantos Hadjimitsis, manage director of the ERATOSTHENES Centre of Excellence, and Dr. Nicholas Kyriakides, Assistant Professor, for their advice and support during my PhD.

My heartfelt appreciation extends to Kyriaki Fotiou and Marina Pekri, whose insightful exchanges of scientific ideas have greatly enriched my PhD journey. Their contributions and thoughtful feedback on various journal and conference publications have been invaluable. I am profoundly grateful for the collaborative spirit and enduring support they have provided throughout our years of research together.

Finally, my deepest gratitude is reserved for my family, and most especially to my wife, whose steadfast support and encouragement have been my guiding light during my PhD journey. Their belief in me has been a wellspring of motivation, providing me with the strength and resilience to navigate the challenges of this academic voyage.

To my beloved wife Christy...

ABSTRACT

This doctoral thesis is intrinsically linked to the Cyprus Continuously Operating Natural Hazards Monitoring and Prevention System, abbreviated CyCLOPS, a national strategic research infrastructure devoted to systematically studying geohazards in Cyprus and the EMMENA region. To date, the permanent segment of CyCLOPS is comprised by six permanent sites, each housing a Tier-1 GNSS continuously operating reference stations (CORS) co-located with two calibration-grade corner reflectors (CRs). The latter are strategically positioned to account for both the ascending and descending tracks of SAR satellite missions, including ESA's Sentinel-1.

The goal of CyCLOPS is to establish a reliable permanent station network across Cyprus, featuring co-located GNSS and SAR CR configurations that continuous monitoring geohazards. To fulfil this goal, it is essential to determine the most suitable sites for the permanent installation of equipment, which guarantees the best performance of each device that utilizes associated space-based technologies. Thus, a comprehensive literature review was conducted to analyze such infrastructures, the required instruments according to international standards, installation procedures, and the optimal spatial distribution of stations to create an integrated nationwide network capable of providing combined data of the two advanced space-based technologies, with maximum performance and minimal error. Nonetheless, the review identified fragmented guidelines regarding the co-location of SAR and GNSS permanent infrastructures. Furthermore, no guidelines exist for the determination of the most suitable locations using a holistic approach, in terms of criteria and required data.

Therefore, to address this gap in literature, the objective of this PhD thesis is twofold. First, to propose a semi-automatic suitability analysis for selecting sites for the permanent installation and co-location of GNSS CORS and a pair of SAR triangular trihedral CRs, considering crucial factors that influence both their individual localization and their interspatial interrelation. Second, to propose a standardized comprehensive workflow for the assessment of the performance of integrated GNSS-SAR permanent stations, which also serves as an evaluation tool for the proposed suitability analysis.

All necessary parameters and criteria were collected, and a semi-automated suitability analysis of determining the optimal positions was created for the installation of the abovementioned permanent co-located sensors.

The signal response and the position of CRs were evaluated in terms of radiometric characteristics and geolocation accuracy, through Point Target Analysis derived from Sentinel-1A SAR data. Moreover, the position stability of the GNSS CORS was evaluated through the analysis of signals received from GNSS receivers.

The results indicate a consistent performance with the expectations for an adequately installed high-quality integrated GNSS and CR network. After 2.5 years of operational experience and excellence, these findings advance SAR product quality understanding, and CyCLOPS infrastructure effectiveness and reliability.

Keywords: Multi-Criteria Decision Analysis; Visibility Analysis; Point Target Analysis; Corner Reflectors; Quality Control; GNSS CORS; Infrastructures; CYCLOPS