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Procedia Computer Science 199 (2022) 174–181

Procedia Computer Science

www.elsevier.com/locate/procedia

The 8th International Conference on Information Technology and Quantitative Management (ITQM 2020 & 2021)

Design of a framework of military defense system for governance of geoinformation

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Abstract

A defense system for geoinformation governance must be able to manage geographic information related to national security. A Geographic Information System (GIS) is useful for the defense of the country, as in the case of monitoring the spread of COVID-19, enabling authorities to make decisions based on data (data-driven). The difficulty in developing a GIS for defense is that the system requires specific functionalities from military organizations and is fault-tolerant. A case study was conducted based on requirements engineering ISO/IEC/IEEE 29148:2018, to promote common understanding among all stakeholders, design a framework of GIS for defense, capable of isolating demands in a system developed in modules individualized. The system validation was demonstrated by obtaining the prototype of a tool of the defense system for geoinformation governance. The system framework is composed of input data, migrator, operational core, solver, output bus, geoportal, and external accessors. The application is under development and already has features such as tracing routes and identifying troop access.

Peer-review under responsibility of the scientific committee of the The 8th International Conference on Information Technology and Quantitative Management (ITQM 2020 & 2021)

Keywords: Defense Systems; Geographic Information System (GIS); Geoinformation; ISO/IEC/IEEE 29148:2018; Microservices

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1877-0509
Peer-review under responsibility of the scientific committee of the The 8th International Conference on Information Technology and Quantitative Management (ITQM 2020 & 2021)
10.1016/j.procs.2022.01.022

1. Introduction

Brazilian Armed Forces (FFAA) used geographic information (geoinformation) in various conflicts throughout its war history. Initially, the geoinformation used by commanders in military operations was in the form of paper maps. These maps had an important use for navigation, displacement and strategic positioning of troops. The first time that the use of digital geospatial data in military actions has been registered was in Granada in 1983 [1]. Since then, geoinformation has been subject of great interest in military operations around the world.

Each of the Brazilian FFAA, Navy (MB), Army (EB) and Air Force (FAB), has its culture, routine and patterns of use of geoinformation, whether in analog or digital form. However, from the establishment of the Defense Geoinformation System (SisGEODEF) project, joint operations planning will be made possible, in addition to having the strategic involvement of the Ministry of Defense (MD). Thus, the aim of this study is to define a framework that enables the integration of geoinformation from the FFAA and to perpetuate technological development in favor of the order and progress of other nations.

A Geographic Information System (GIS) is designed in order to capture, store, manipulate, analyze, manage and present geographic data [2]. Therefore, a framework was designed to enable the development of a system with special attention to the FFAA and the MD of Brazil. In the scope of this work, such a system will be called Defense GIS.

As mentioned by Fleming, Hendricks, and Brockhaus [3], "GIS technology is rapidly moving from its historic niche usage of installation inventory and monitoring within defense organizations to becoming a critical defense-wide infra-structure". Territorial monitoring can also be useful to identify outbreaks of local epidemics before they spread throughout the territory, such as COVID-19 [4].

A Defense GIS to support decision making is necessary to guarantee law and order [5]. In a state of crisis, as in the initial moments of an unknown epidemic, when its degree of contagion and fatality is not known, areas of outbreaks can be identified and monitored, allowing coordinated actions to be organized to contain the spread.

SisGIDE took into account security characteristics in accordance with the information security standards, inherent to the definition of requirements and their implementation (NBR ISO/IEC 17799, NBR ISO/IEC 27002 and ISO/IEC/IEEE 29148).

This system was designed to be fault tolerant, maintaining its execution even in the event of disruption of the operating structure. This need motivated the conception of the development of an architecture in modules, which is relevant, since the infrastructure system must provide fundamental security, resilience and stability requirements for operations.

2. Theoretical reference

Currently, Brazilian FFAA has invested in defense technologies that allow the increase in situational awareness [6] throughout the national territory and it has applied updated algorithms to the decision-making [7, 8].

Among various applications, this technological apparatus can assist in identifying the outbreak of epidemics, in monitoring the flow of people and in simulating scenarios, supporting high-level decisions, such as: positioning barriers, blocking or releasing transport, resource management and supply, distribution of foodstuffs and health supplies.

Therefore, the MD and the FFAA need systems that allow them to make fast, assertive and appropriate decisions in favor of security and national order. The use of historical data enables the creation of contamination predictive models [4]. The analysis of mobility data can be used to identify areas that are at high risk of infection in advance [9].

The standard "ISO/IEC/IEEE 29148:2018 - Systems and Software Engineering - Life Cycle Processes - Requirements Engineering" [11] specifies processes and products related to Requirements Engineering for systems, throughout their life cycle, by describing suitable attributes that the system should present. This standard provides additional guidance, both in the application of Requirements Engineering principles and in processes management for survey activities, analysis and specification of the solution to be developed. This standard was useful to guide the elaboration of the Concept of Operations (ConOps) and Operational Concept (OpsCon), on which the framework and requirements of SisGIDE were based.

The implementation of SisGIDE allowed the gathering of previously secreted geoinformation, allowing an increase in situational awareness by the MD, MB, EB and FAB, in addition to related departments. Situational awareness is widely used in areas that involve critical decision-making, such as emergency management [3].

This concept is related to the level of perception and understanding that an individual has about real events originated in complex circumstances. Operators base their decisions on understanding the event coupled with their previous knowledge and experience, which are valuable assets for military organizations. Decision theory aims to help decision makers both to systematize the problem of choice and to solve it, as highlighted by some studies on decision analysis in the military context [11].

With the scope of geoinformation and the spread of new technologies, it became possible to expand situational awareness through the improvement of technological tools, enabling the management of better coordinated operations using technological systems equipped with privileged information, such as SisGIDE. Thus, this system will allow the collection of data existing in the information-producing centers, crossing information that was not previously correlated and making reference data available to consumers.

As demonstrated by [12], geographic information applications are vast, as for the simulation and determination of the best distribution of 5G Internet base stations, which allows the evaluation of the performance of networks in a real scenario from the geographical information.

Dahmann and Baldwin [13] highlight the need to manage and design sets of systems to meet usability requirements in different military configurations. Therefore, there is the need to establish a framework within this context.

The FFAA are responsible for providing the geoinformation that underpins SisGEODEF to serve defense interests. A team of systems analysts was responsible for the development and implementation of data modeling, as well as the standardization and normalization of the databases.

For the management of Defense Geoinformation, the Technical Specification Standard for Structuring of Terrestrial Force Vector Geospatial Data (EDGV-Defense) establishes the pattern of the vector geospatial data structure in the sphere of the MD, which are the system's focus and, therefore, fundamental to the planning and execution of defense and national security actions. In this way, the EDGV-Defense data model, existing in that publication, enables the sharing, interoperability and rationalization of the use of the resources necessary for the production and use of geoinformation.

The data model currently used by EB is the EDGV 2.1.3, which is the standard for the vector reference geospatial data structures produced to compose cartographic bases. The data model followed by FAB cartography presents aeronautical information, air navigation and airspace procedures that are structured according to the international data exchange model named AIXM (Aeronautical Information Exchange Model), recommended by ICAO (International Civil Aviation Organization). The data model used by the MB, the S-57, defines hydrographic information as a combination of descriptive and spatial characteristics. In this model, feature sets are defined in terms of objects separated into a part as a resource and a part as a spatial one. The resource part of an object contains descriptive attributes without geometry, while the spatial part contains mainly vector-type geometry and can contain additional descriptive attributes.

In short, to deal with the inherent differences in data models used by the Brazilian FFAA, the EDGV-Defense model was the selected, which is compatible with: EDGV 2.1.3, from EB; S-57, from the Navy; and AIXM 5.1, from the FAB. And in order to be assimilated, these models demanded the creation of a system that would store the relationship between them and EDGV-Defense, causing the development of technology that allowed the storage of the geoinformation of these different models.

There are works related to the design of defense systems framework [14-16], but the differential of this work is to be a framework focused on geoinformation in microservice architecture. The development of SisGIDE followed the waterfall model and ISO/IEC/IEEE 29148, which facilitated the understanding between stakeholders and the specification of requirements, as described in [17].

3. Methodology

The elaboration of this software engineering case study methodology follows the guidelines of [18], which is set out below.

3.1. Case study design

This case study in software engineering aimed to establish the framework developed by the MD and the FFAA in order to develop a defense system for geoinformation governance.

The functioning of the SisGEODEF depends on SisGIDE, which is the technological component responsible for the integration and interoperability of the geoinformation of interest, produced within the scope of the FFAA, which serves the Strategic, Operational and Tactical purposes of Defense. This component is capable of processing the geoinformation of several producing or managing sources, integrating them and making them available in a standardized way to other specific systems of the MD and the FFAA, as well as through a viewer, directed to the qualified users. To unify geoinformation with heterogeneous characteristics of the different FFAA and their specific requirements, it was intended to develop a framework that reflected the needs of the reported context.

The lessons learned, the doctrinal update and the increase in interoperability among the FFAA, as a result of the evolution and consolidation of the planning and execution process of joint operations justified the need to use geospatial data and information from different sources and different complexities. However, this use requires the development of new solutions and the use of tools that can assist and optimize the production, sharing and efficient use of Defense Geoinformation, essential in joint operations, as well as in singular operations and subsidiary actions.

In this sense, it was up to the MD, as a centralizing element of Command and Control (C2) information at the political and strategic level, to establish a geoinformation pattern and guide the planning and execution of joint operations. Thus, technological systems of MD, MB, EB and FAB, which used geoinformation independently, will be able to supply and consume it in an integrated way through SisGIDE.

3.2. Preaparation for data collection

Face-to-face and remote meetings were scheduled including the MD, FFAA and developers in order to concentrate efforts to list and mature the peculiarities of the system, reflected in the proposed framework.

The request for data from MB, EB and FAB was accelerated by technical visits to their production centers. Thus, the adoption of the system aims to enable adequate data-driven decision making.

3.3. Collection evidence

Several governmental designs were taken into account to discuss the framework [5, 19]. Military documents were evaluated, and the data standard used by each FFAA was considered.

In this scenario, it is highlighted that "SisGEODEF implies the effective management of Defense Geoinformation, to support national Security and Defense activities, being guided by doctrines, manuals and standards" [19], with the following objectives:

I - "to guarantee the standardization of Geoinformation produced by different institutions, ensuring coherence, continuity and interoperability";

II - "to define and promote the use of norms of geospatial data related to national Security and Defense";
III - "carry out the efficient management of public resources destined to the production of Geoinformation"; and
IV - "ensuring access to Defense Geoinformation, according to the demands, with an emphasis on planning and controlling joint operations".

ISO/IEC/IEEE 29148:2018 supported the discussion among MD, FFAA, analysts and developers, idealizing the framework architecture for the defense system for geoinformation governance, which was part of the SisGEODEF ConOps [17].

3.4. Analysis of collected data

Several providing geoinformation and military users were identified for the collaborative development and use of SisGIDE. Data from several sources and standards indicated the need to import them for internal treatment, in particular for the construction of a standardized database with shared access to the theater of joint operations.

Some bodies and entities of the federal public administration already have access to SisGIDE, through an invitation ratified by a council. Thus, in its development, it was essential to provide mechanisms that could guarantee aspects of security, confidentiality and data integrity.

User management, through profiles that established privileges and restrictions in the operation of the system, was an essential aspect of SisGIDE's security policy. It is important to highlight that this management controls access to geoinformation and system tools, based on authentication rules and permission level.

The system tools that process critical data and use profiles with access restrictions had their security requirements supported by the decree, which regulates procedures for security accreditation and treatment of classified information in any degree of confidentiality and the appropriate use of mechanisms security, such as the use of encryption in the storage and management of data.

The various decentralized databases encourage the design of microservice architecture, which also ensures flexibility to the technologies used in any of the modules.

After surveying the requirements presented, the MD and stakeholders were willing to develop a framework that reflected the requirements of the military context, considering its functional aspects.

3.5. Reporting

For the development of SisGIDE, MD, FFAA working groups and systems engineers designed the defense system framework. Due to the need for the software to communicate with different services, the framework architecture was designed to operate in microservices architecture. Fig. 1 presents the framework with its modules. The arrows connect the modules and demonstrate the direction of the information flow.

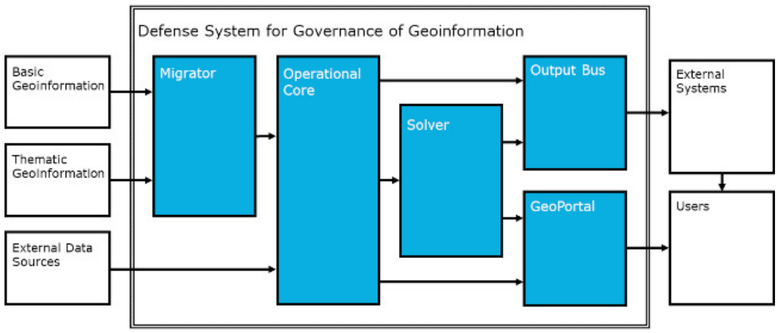

Fig. 1. Defense System Framework for Geoinformation Governance.

The following are the components of the defense system framework for geoinformation governance:

- Basic geoinformation: it is understood as the raw data;
- Thematic geoinformation: essentially, it is basic geoinformation worked on;
- External data sources: other sources of geoinformation that adhere to the adopted standard;
- Migrator: components responsible for obtaining and transforming data. Each migrator is specific to connect to the database of each FFAA, with affinity to its various models, such as S-57 from the Navy, EDGV 3.0 from the Army and AIXM 5.1 from the Air Force;
- Operational core: module that stores the data that need some kind of processing. It also includes user access control;
- Solver: covers tools with intelligence to operate by solving calculations or other specific functions.
- Output bus: module that provides data that is ready to be consumed by other systems adhering to defense;
- GeoPortal: consists of a web interface, structured to promote the visualization of geospatial data from the databases of the producing centers. Through this friendly interface, MD and FFAA users will be able to: search the integrated metadata catalog; visualize geospatial data combined by layers of information; generate geoinformation by applying the available functionalities; export the geoinformation generated for consumption in other defense systems; creating maps; and download the products available in the metadata catalog in formats such as Shapefile and Geotiff, among others. GeoPortal consolidates, with these potentialities, support for the fulfillment of military missions and subsidiary actions, with an emphasis on joint operations.
- External systems: these are FFAA proprietary GIS software; and
- Users: military users qualified by the MD to operate with integrated geoinformation.

The framework enabled the realization of SisGIDE, which focuses on building a consolidated and reliable base of integrated and interoperable geoinformation to support qualified military users. This objective has been achieved with the implementation of SisGEODEF, involving the obtaining, standardization, storage, traffic and visualization of geoinformation relevant to defense.

SisGIDE is hosted on a network restricted to the FFAA and can be accessed at: http://sisgeodef.defesa.mil.br. Fig. 2 shows an imported layer in the EDGV standard.

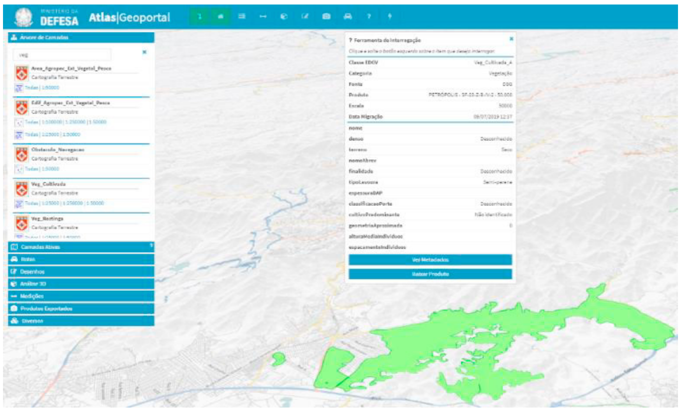

Fig. 2. Displaying a layer of the EDGV standard.

4. Discussion

The framework presented was designed so that the Migrator module could obtain the data exported by the production centers. This process could be streamlined if the centers had an API (Application Programming Interface) for providing geoinformation, such as GeoServer or MapServer. In other words, access to databases would be facilitated and fast if the production centers served the data through an API instead of files. Instead of downloading the entire database, a simple call via the web to extract the portion of interest would be enough for the importing module to make. The API would also facilitate access to the system in real time, allowing the application, which depends on updated data, to obtain them quickly.

Despite the advantages of using an API, this would result in the accountability of the producing centers, not only to make the data available, but also to develop and keep the API functioning in a stable and reliable manner, which is expensive.

In any case, it is suggested the implementation of an API in data sources that are easy to implement. However, for this case study that involved military organizations, it was preferred that SisGIDE had the task of importing and extraction of data from the files made available instead of passing this activity on to producing centers.

Another major effort in implementing the framework for the prototype was related to the integration of data from different standards. The definition of the same standard among data providers will facilitate the importing and processing in SisGIDE, that can be adapted in different settings.

As presented, the framework was developed for application in the context of national defense, such as signaling natural disasters, tracing routes, identifying troop access, and vessel position. However, with some adaptation, it can also be applied to different contexts.

5. Conclusion

The framework design was elaborated over two years, going through the conceptual validation of Brazilian MD and FFAA. Requirements elicitation for the SisGIDE prototype was carried out considering the framework of the geoinformation defense system and following the guidelines of ISO/IEC/IEEE 29148 and considering several security requirements. Finally, the SisGIDE prototype was presented at the 2nd Defense Geoinformation Workshop and approved by its representatives.

The contributions of this work are:

- Obtaining a framework that comprises the governance of geoinformation according to the needs of the FFAA; and
- Proof of the viability of the microservice architecture in the development of a Defense GIS.

By fragmenting the components of the initial application into different services, each of them was allowed to be implemented in technologies and used with different persistence, which is one of the greatest attractions of microservices.

For future studies, it is envisaged the integration of other data sources and consider the restriction of specific areas for the conjecture of different scenarios.

Acknowledgements

The authors of this publication would like to thank the “Ministério da Defesa do Brasil”, the “Centro de Análises de Sistemas Navais (CASNAV)” and all participants in the Apolo and SisGEODEF projects for their support in the development of technology.

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