A GIS Open Source Application to Perform the Spatial Distribution of Prevention Quality Indicators (PQIs)

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Abstract: Geographical variations carry important information for improving and planning more equitable and sustainable health care services. Geographic Information Systems (GIS) are crucial tools that provide intuitive visual help which contributes to a better understanding of the spatial distribution of health risk factors, resources, care and outcomes. The interest in GISs have stimulated the development of several applications worldwide to publicly inform the geographical patterns of health. However, in Portugal, this type of tools remains underdeveloped for public reporting of health information. The aim of this study was to develop a GIS open source application for spatial analysis of healthcare indicators in Portugal, using hospital data obtained from the *Administração Central do Sistema de Saúde*, I.P. Specifically, given their importance to monitor the quality of primary health care, data regarding Prevention Quality Indicators (PQIs) will be used to establish a proof of concept of this tool. The tool was connected to a spatial database in order to filter the parameters. Several maps based on PQI information were created in order to test the application. It was concluded that the spatial combination of all the data provided in a GIS software and through an intuitive application can contribute to the analysis of quality of primary health care.

1 INTRODUCTION

Geographical variations carry important information for improving and planning more equitable and sustainable health care services. However, understanding geographic patterns can be cumbersome and error-prone if performed through frequency tables and traditional plots, especially if the information covers several data sources and variables such as health care, environmental, social, and economical variables.

Geographic Information Systems (GIS) are important tools that contribute to a better understanding of the spatial distribution of health risk factors, resources, care and outcomes through intuitive geospatial visual interfaces. Therefore, carrying valuable insights for policymakers, health providers and populations. The interest in GIS has stimulated the development of several applications worldwide to publicly inform on geographical patterns of health (DAP, 2020; Atlas, 2020; SAHSU, 2020; HWM, 2020). The use of GIS in public health is increasing as a response to the requirements of queries and analysis of health indicators (Maheswaran and Craglia, 2004).
However, in Portugal, this type of tools remains underdeveloped for public reporting of health information. *GEOSAUDE* (http://www.geosaude.dgs.pt/) a web GIS, and *PORDATA* (https://www.pordata.pt/), a statistical database, offer regional

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variations health-related data interactive maps, within Portugal.

The *PORDATA* only presents statistical data in the form of numerical statistics, graphs and indicators. This information is not spatially represented. The *GEOSAUDE* is a powerful web GIS composed by several indicators and options to filter the information. However, it just allows the visualization of the data. It does not allow to manipulate the information.

The Portuguese administrative hospital database from *Administração Central do Sistema de Saúde*, I.P. (Central Administration of the Health System, ACSS, 2020), is an essential tool to support hospital funding based on diagnosis-related groups (DRG). It also represents a fundamental source of data of the official health statistics (Ferreira et al., 2017; OECD, 2019). This database is easily accessible and well documented, with a high population and temporal coverage, containing information regarding all inpatient and outpatient hospitalizations of Portuguese public hospitals in the mainland territory, since 2000. As it contains data regarding the area of residence of each patient (geographic location), it may be easily usable in a GIS environment. This possibility enhances the interoperability between the data source and environmental data and even other geographical variables. Therefore, potential value may be added to this database through its integration in GIS. The objective of this work was to develop a GIS open source application which allows to easily connect to a database of health quality indicators and spatially represent them. The spatial representation of the data will allow to analyse the indicators in a national level. This analysis allows to relate other factors with these health indicators.

1.1 Ambulatory Care Sensitive Conditions (ACSCs)

The Ambulatory Care Sensitive Conditions (ACSCs) are conditions for which good outpatient care can potentially prevent or reduce the need for inpatient or emergency care due to complications or more severe diseases associated with these conditions (ACSC, 2016). For instance, diabetic complications may arise if diabetes is not adequately monitored or if education regarding patient self-management is not provided (PQIO, 2020; AHRQ Quality Indicators, 2020).

The Agency for Healthcare Research and Quality (AHRQ) developed a set of indicators based on hospital administrative data – the Prevention Quality Indicators (PQIs) – to measure quality of care for several common ACSCs and compare local health care systems across communities (PQIO, 2020).

In Portugal, 12,3% (n=1003602) of inpatient hospitalizations were attributable to PQI-related ACSCs, exhibiting several regional variation patterns depending on the condition. The heart failure hospitalizations were more common in the most northern and interior regions of Portugal and in the central Portugal (WHO, 2016; Sarmento et al., 2015; Rocha et al., 2019). The low hospitalization rates were reported to cluster closer to the coastal zones and around bigger cities; higher hypertensive heart disease hospitalization rates were reported in the interior regions of the country (WHO, 2016; Sarmento et al., 2015; Rocha et al., 2019). Therefore, in Portugal, important insights may be gained regarding the quality of health care in ACSCs from monitoring regional variations of PQIs. This could be used to screen potential problems in primary health care system, direct further investigations to assess causes of problems, and to compare performance of regional community health care, which may assist in the definition of public health recommendations and ultimately improve health care in ACSCs.

To our knowledge, at the moment, there is no GIS covering ACSCs care-related metrics such as the PQIs. In this context, the development of a GIS application under GIS software environment can help to analyse and generate more information.

1.2 Objective

The aim of this study was the development of a GIS open source application for spatial analysis of healthcare indicators in Portugal, using hospital data obtained from the ACSS. Specifically, given their importance to monitor the quality of primary health care data regarding PQIs will be used to establish a proof of concept of this tool. The tool was connected to a spatial database in order to filter the parameters.

2 MATERIAL AND METHODS

The GIS open source application was developed under the open source software QGIS version 3.10, (QGIS, 2019). Several Python libraries and Application Programming Interfaces (APIs) were used to develop the application, such as QGIS API and Qt API (QGIS, 2020; Qt API, 2020). QGIS supports spatial databases such as PostgreSQL and PostGIS (PostGIS, 2020). The most recent versions of QGIS provides a *Qt Tool* named *Qt Designer* for designing and building graphical user interfaces

(GUIs) with *Qt Widgets* (Qt Designer, 2020). The *Qt Designer* was used to create the application GUI. The main objective of this GIS application was to improve the connection to a spatial database, implemented in PostGIS and spatially represent the PQIs. This database is composed by multiple data. The focus is to represent spatially the information and provide some functionalities that can be useful to analyse the database provided.

2.1 Data Sources/Database

In the database, the PQIs were estimated based on the AHRQ definitions, using the hospital administrative data and population estimates between 2014 and 2017 (INE, 2020). The hospital data cover all hospitalizations of mainland Portuguese public hospitals, containing demographic and clinical information of the patients, such as age, sex, residence, diagnoses, procedures, and the patient disposition after discharge. Until 2016 the diagnoses and procedures were coded according to the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM). In 2016, a few pilot hospitals initiated the transition to the ICD-10-CM. During this transitional year the two clinical classification systems coexist. This is an existent attribute in the database of this study. As of the 1st of January 2017, all public hospitals were instructed to code in ICD-10-CM.

The PQIs encompass sixteen ambulatory care sensitive conditions (Table 1). These are then aggregated into four additional composite indicators (Table 2).

Table 1: PQIs description.

PQI Code	Description
PQI01	Diabetes Short-Term Complications
PQI02	Perforated Appendix
PQI03	Diabetes Long-Term Complications
PQI05	COPD or Asthma in Older Adults
PQI07	Hypertension
PQI08	Heart Failure
PQI09	Low Birth Weight
PQI10	Dehydration
PQI11	Bacterial Pneumonia
PQI12	Urinary Tract Infection
PQI14	Uncontrolled Diabetes
PQI15	Asthma in Younger Adults
PQI16	Lower-Extremity Amputation Among Patients with Diabetes

Table 2: PQIs composites description.

PQI Code	Description
PQI90	Prevention Quality Overall Composite
PQI91	Prevention Quality Acute Composite (PQI11, PQI12)
PQI92	Prevention Quality Chronic Composite (PQI1, PQI3, PQI5, PQI7, PQI8, PQI14, PQI15, PQI16)
PQI93	Prevention Quality Diabetes Composite (PQI1, PQI3, PQI14, PQI16)

The PQIs were computed by sex, year, month and the residence of the patient. The unit of analysis considered was the district and Nomenclature of Territorial Units for Statistics (NUTSIII).

2.2 PostGIS Database

The PostGIS database is a spatial database extender for PostgreSQL object-relational database (PostGIS, 2019). PortGIS allows to query in Structured Query Language (SQL) language and supports geographic objects. It is released under the GNU General Public License (GPL). There are several plugins developed in QGIS which uses PostGIS such as *DB Style Manager*, *Fast SQL layer*, *PostGIS manager*, among others (QGIS plugins, 2020).

2.3 Application Development

As referred before, the application interface was created through *Qt Designer*. Also, a PostGIS database was created, and connected to the application.

The application was developed using Python programming language (Python, 2020). Several libraries were also used such as PyQt5 and QGIS API. The SQL language was implemented in order to perform a selection based on the query applied by the user. The SQL conditions run through *pgsql2shp.exe* from PostgreSQL. In order to define the SQL queries, a batch file is automatically created to run the exe with the parameters defined by the user in the GUI. The batch file is automatically saved in the plugin folder and it is built in the moment that the user chose the variables. Through the *os.system* function the batch file runs and the shapefile is created and automatically added to the canvas.

The application is composed by a button on QGIS environment which opens a dialog composed by two tabs: *Symbology* and *Mapping*. The first one allows to represent spatially the PQIs data by a certain level (district or NUTS) and using two types of symbology (Figure 1), *Categorized* or *Graduated*; the *Mapping* tab (Figure 2) allows to: i) incorporate a base map in the QGIS canvas in order to overlap with other information; ii) add some additional information such as the connection to *Bing Aerial Map*, the location of hospital facilities and/or primary health care facilities (as point shapefile); iii) create a layout in order to print the map; iv) convert the shapefile to KML format and; v) to export a bar plot with the variation of PQIs along the years (existent years in the database).

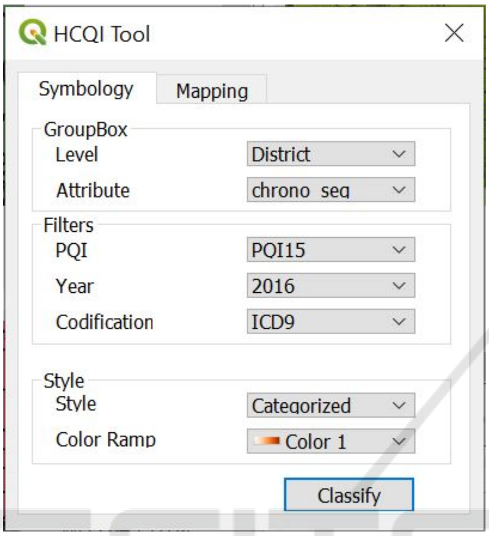

Figure 1: *Symbology* tab of the HCQI application.

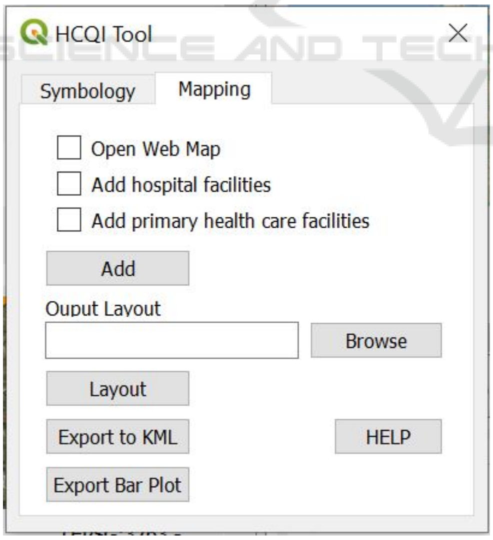

Figure 2: *Mapping* tab of the HCQI application.

In the second tab, *Mapping*, three check boxes were added, and the user checks the box that pretends to overlap and clicks on *Add button* to add the information to the canvas. The *Layout* button allows to create a layout with the information selected by the user and composed with the main elements: north arrow, scale, map and legend. The button *Export to KML* connects to a new GUI. In this GUI, the user selects the layer that pretends to convert in KML format and save it. The *Export Bar Plot* connects to other GUI (Figure 3).

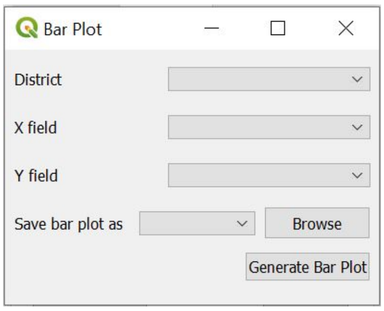

Figure 3: Bar Plot functionality.

In this GUI, the user must choose a district, the attribute to insert in the x axis and the attribute to insert in the y axis. This functionality allows to create a bar plot to a specific district and for the assigned attribute. This functionality was implemented based on *Bar Plot* algorithm from QGIS *Processing Toolbox* (QGIS, 2020).

3 RESULTS

In order to test the application, a shapefile with the district level was incorporated in the PostGIS database. This shapefile allowed to select between two levels: district or NUTSIII. Some maps based on PQIs information were created in order to test the application. Figure 4 presents the result of the selection of PQI value for PQI90 in 2016 year with a graduated symbology.

Other options were also tested, such as the possibility of overlapping a web map to the data already opened (Figure 4).

The proximity with primary care facilities and hospitals are, among other factors, crucial in the utilization of hospital care to treat ACSC (Carneiro, 2018). Therefore, the application was also complemented with the possibility to add the national hospital facilities and the primary health care facilities. Figure 5 presents the overlapping of these information with the aerial map (*Bing Aerial Maps*).

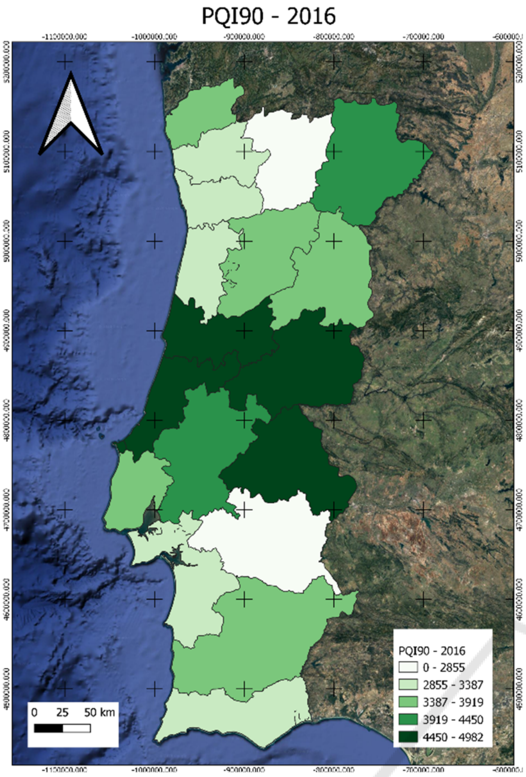

Figure 4: PQI90 in 2016 overlapped to Bing Aerial Map.

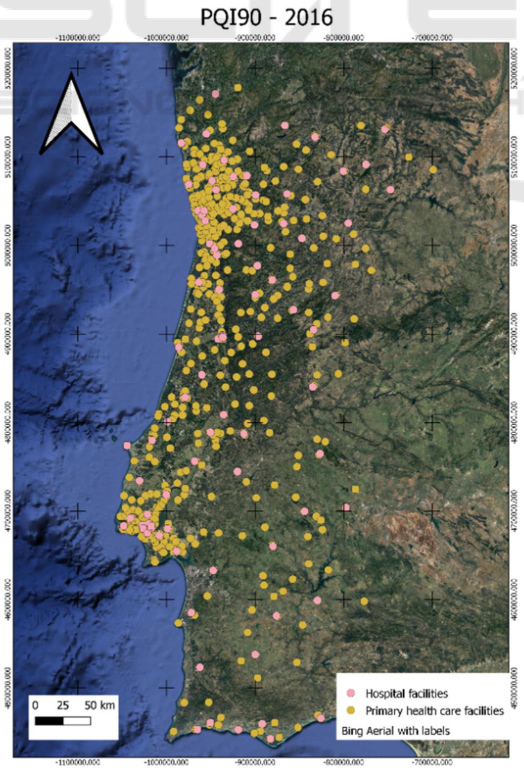

Figure 5: Overlapping of Bing Aerial Map with hospital and primary care centres.

The implementation of these functionalities (the addition of the hospital facilities and the health care facilities) combined with the PQIs information, provides the possibility to analyse the quality of access to health care. Longer distances to primary health care may represent a barrier to seek primary health care, leading patients to use the hospital care when conditions have worsened. Figure 6 presents the overlapping between the facilities and the PQIs information for PQI90 for 2016 year. In addition, since the database is composed by data from 2014 to 2017, it would be very useful to analyse the PQIs variation along the 4 years, so the possibility to create bar plots with that variations was also tested. Figure 6 also presents a bar plot with the variation of PQIs for Porto district.

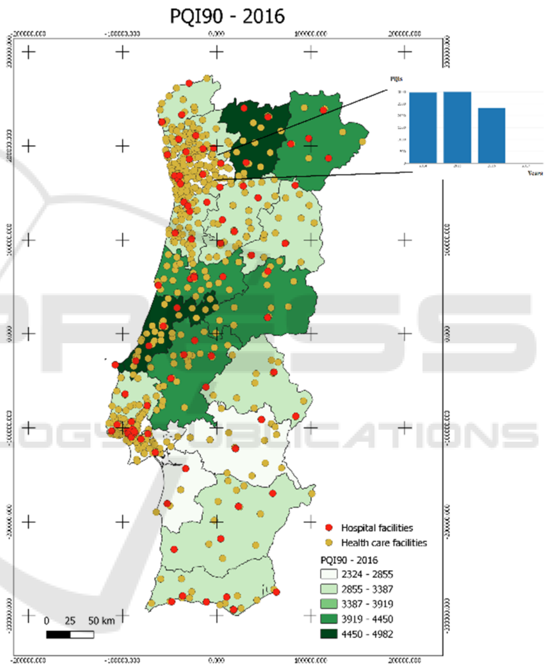

Figure 6: Overlapping between hospital and primary care centres and the information of PQIs.

From Figure 6 we can conclude that the number of hospitalizations with ACSCs in Porto showed a positive trend. Besides this possibility, the application also converts a shapefile to KML format. This can be very useful to open and overlap the data in Google Maps® or Google Earth®.

4 CONCLUSIONS

The GIS application will be very useful to help the health experts to understand the geographical distribution of PQI values (by district or NUTS), even apply filters in terms of PQI values, years and the clinical codification system. The spatial combination of all the data provided in a GIS software and through an intuitive application can contribute to the analysis of quality of primary health care. The implemented filters may already provide insight to questions regarding where (e.g. which districts?), when (e.g. which year? Quality of care is getting better?) and why (e.g. proximity to hospital? Distance to primary health care facilities?) PQIs indicate better quality of care. These are relevant questions to policymakers, health care providers and the general population.

Even though among the list of indicators in *GEOSAUDE* there is "the number of inpatient hospitalizations with an ACSC", this is still not operational. Thus, to our knowledge there is no application representing PQIs for Portugal.

In the future we intend to improve the GIS application with the ability to infer and point out any problems or areas needing further analysis in the data.

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