SIMONEV: Visual Neonatal Monitoring System - A Dashboard for managing highly complex patients

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Abstract. In 2019, based on R&D+i work between the Universidad Nacional del Sur and the General Dr. José Penna Interzonal Hospital, a neonatal monitoring system called SIMONE was developed to help reduce the incidence of safety problems in neonatal care. In this article, we present SIMONEV, an extension of SIMONE that integrates a visualization dashboard for the control of patients and critical processes in the hospital's Neonatal Intensive Care Units. SIMONEV is a free and open-source visualization dashboard that allows the Hospital staff to easily follow statistics and indicators from patients at the neonatal intensive care units. Through this dashboard, a visual representation of statistics, monitoring information, and instrument indicators on patients is presented to the professionals. For this, a series of visualizations were proposed, where data collected by SIMONE is monitored through visual resources and interactions. The proposed software was implemented on the web through technologies such as Angular and Firebase under an open-source policy.

Keywords: Visualization Dashboard · Neonatal Intensive Care Units · User Experience.

1 Introduction

The application of visual representation of information in multiple fields has been growing steadily for many years. These visual representations have become a

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fundamental tool in the analysis and decision-making processes, as they increase the efficiency of data analysis by reducing the user cognitive workload.

In this work, we present SIMONEV, a free and open-source visualization dashboard that is integrated with the information collected by SIMONE [9] and allows the Hospital staff to easily follow statistics and indicators from patients at the neonatal intensive care units. The dashboard offers different configurations depending on the role of who is using it; for example, a particular configuration of visualizations is offered for nurses who require information about what is happening in real-time; while another set of visualizations is offered for the senior staff that requires statistical and trend information to establish long-term actions.

The definition, design, and implementation of the application and its interactions were done under a User-Centred Design strategy [3] and with consideration of the work done by Johnson et. al in [7]. This solution was created as the thesis of a student from the Ingeniería en Sistemas de Información degree at the Department of Computer Science and Engineering under the direction of two research professors and the collaboration from the staff at Hospital Interzonal General Dr. José Penna, and the Departamento de Economía. This thesis is part of the strategy carried out by the Department of Computer Science and Engineering [8] to promote joint work between members of the university and external actors.

The rest of the paper is structured as follows. In Section 2 we detail briefly present SIMONE, its features, and the information it collects. Then, we present our work in Sections 3 and 4 with all its features. Finally, in Section 5 we conclude with a brief discussion on the limitations and advantages of our approach and the future work. Due to the current pandemic and social isolation situation, SINOMEV could not be installed in the PENNA hospital yet. For this reason, it has not yet been possible to generate test cases in real situations.

2   SINOME

In Neonatal Intensive Care Units (NICU), the proclivity to error and the occurrence of adverse events is large, given the vulnerability of newborns who require admission and the complexity of the care they require. From the General Dr. José Penna Interzonal Hospital (Penna Hospital), a combined strategy of dissemination and integration of a comprehensive package of safety interventions was developed to improve the climate, acceptability, and willingness of the team to participate in its implementation and reduce the incidence of safety problems in neonatal care. One of the key aspects of this strategy is the development of a safety checklist (LVS for its Spanish meaning *Lista de Verificación de Seguridad*). The LVS constitutes a tool that facilitates the review of critical processes in patients and facilitates the detection of safety problems. They have been widely used in surgery and obstetrics and recently, in the NICU. So far, all LVS usage was done through paper and pen. This method proved to be inefficient and demotivating for the staff.

As a result of a collaboration between the Department of Computer Science and Engineering, the Department of Economy, and Penna Hospital's staff an open-source system called SIMONE (*SIstema de MOnitoreo NEonatal*) was designed and developed. SIMONE has a safety checklist, a system of alerts, and patient management. The application provides speed and simplicity to the task of daily check-up and storage of information for future analysis. The LVS defined by Penna Hospital staff is a 4-page document that contains 25 questions, many of which generate new questions based on the answer given. The SIMONE's team transformed this document into a series of intuitive and easy-to-use screens, in addition to incorporating functionality that would increase the utility of the system. From interviews with hospital staff, it was determined that the extra functionality that should be offered in the system was an alarm system and a single patient registry. A priority objective of this development was to maintain it as open-source and freely available.

The SIMONE application was developed specifically for tablets with the Android operating system. It was decided to develop it only for Android devices since the hospital had tablets with this system, and has no plans in the future to obtain a tablet with a different system. All the code of the application was written in Kotlin language. During the development of this application, the need arose to have another system to visualize the collected data, this is how SIMONEV emerged.

3   Our Proposal

To monitor the process of caring for highly complex patients, a virtual dashboard [5] within a web application is proposed as a solution. Through it, a visual representation of statistics and monitoring of indicators on patients in real-time is sought. For this, a series of views was proposed, composed of visualization techniques and graphic iconography.

Regarding the hospital, it was proposed to have different types of visualizations for the different roles that are in charge of the neonatology area. These differences exist due to the different functions or positions performed by the professionals who belong to this area. Three views were defined within SIMONEV: immediate, particular, and historical.
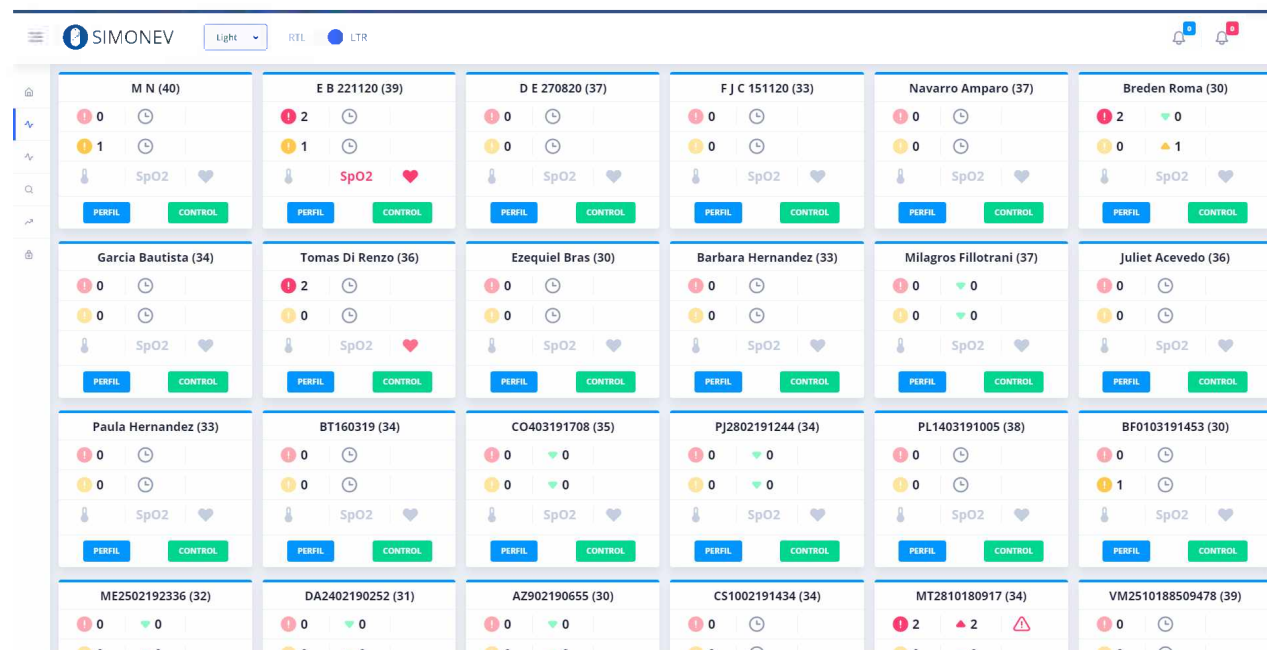
3.1   Immediate

Dedicated view for the control by the nursing area towards the neonates in real-time (Figure 2). The objective of this view is to provide important information, easy to detect and in time for decisions about the quality of patient care. Also, it is a critical point for those patients who need to have a higher degree of observation.

This view is divided into two identical interfaces that reflect the physical inpatient rooms that the hospital has today, one of them is the intensive care unit (ICU) and the other is the special care unit (CSU). Each page houses its

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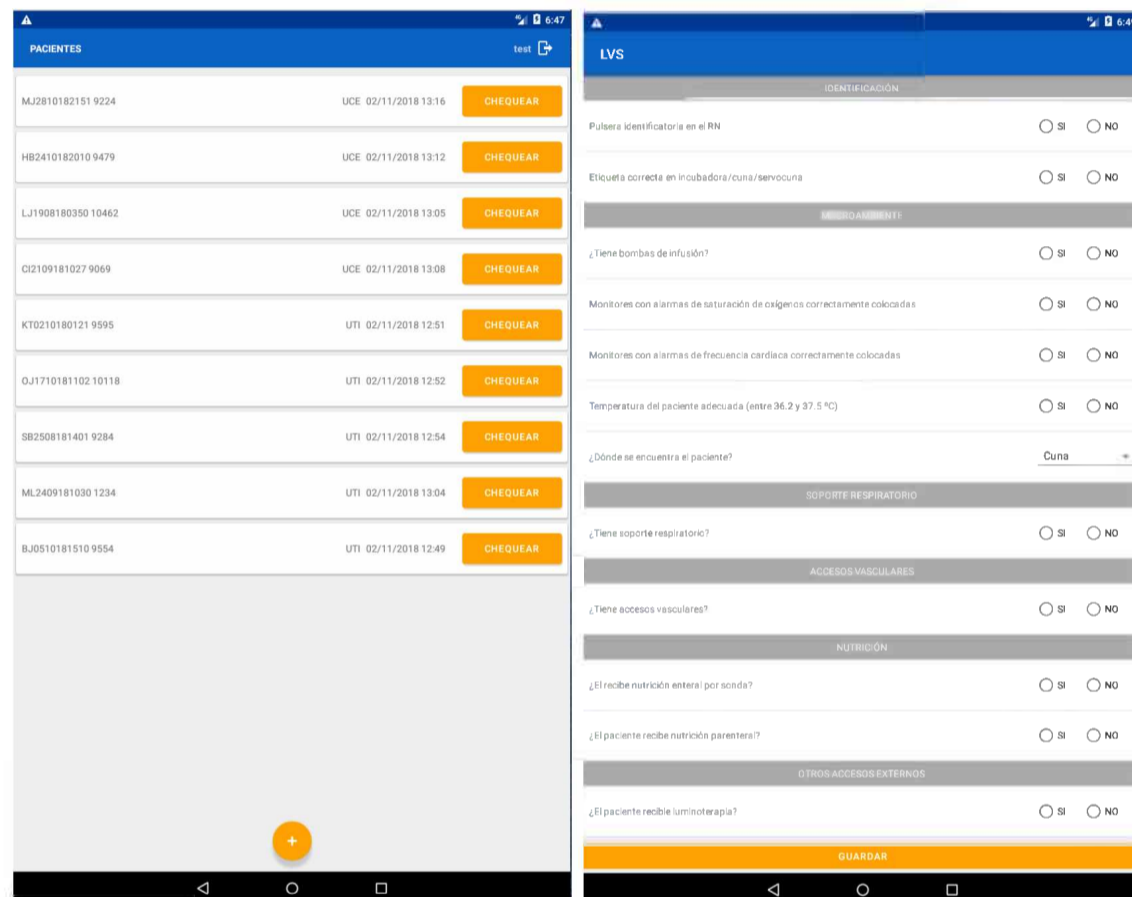
Fig. 1. On the left, we can see the SIMONE home screen where the user can see all patients currently hospitalized. By touching on each patient the user can access a summary of the checks made with the LVS. Touching the button starts a new check. On the right we can see the screen of a check by LVS.

Fig. 2. Immediate view for one of the Neonatal Intensive Care Units rooms.

active patients respectively, these are those who are hospitalized in some hospital room. Newborns are represented using a card headed by an identifier, conformed by her/his name concatenated to her/his date of birth. In the body of the card, there is a matrix, as illustrated in Figure 3, whose cells try to reflect the state of a patient through the last two checks carried out on her/him in the last twenty-four hours. Finally, at the bottom of the card, there is quick access to the patient's profile, where the nurse can obtain all kinds of information about the checks performed, alarms triggered, and raw information about the patient. Here, among other things, information about the weight registered when the patient was born, the gestational age, and the last check-up or control carried out (including the alerts that were triggered) is included.

In this work, proposals from [5] on how to improve the dashboard presentation were also applied. In particular regarding the use of icons and their color tones to facilitate the perception of information. The greater the number of registered alerts, the greater the intensity of the colors in the alerts. The immediate view seeks to offer real-time data on what is happening in the hospitalization rooms, such as a new check-up performed on a patient, the admission of a new newborn to one of the hospitalization rooms, or the discharge/transfer of a patient.

3.2   Particular

This view is dedicated to the control, by a supervisor or a doctor, over the checks and triggered alerts of a particular patient. The objective is to provide important information in a way that is easy to detect and in time for decisions about the quality of patient care. Also, it is a critical point for those patients who need to be with a greater degree of observation. It also provides information about patient care processes, to take into account when making decisions.

This view, illustrated in Figure 4, shows the history of checks and alerts triggered by a patient. It is divided into two sections, one for the reports of the

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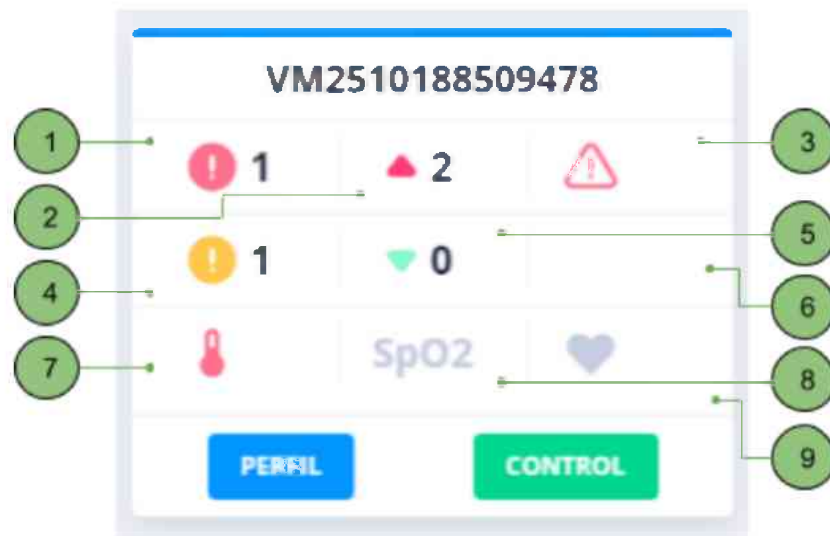
Fig. 3. Representative card of a neonate hospitalized in immediate view. 1) Number of red alerts triggered in the last check-up performed on the patient. 2) Number of red alerts triggered in the last check-up performed on the patient. 3) Repetition of one or more red alerts between the last two checks performed on the patient. If this happens, it will be symbolized by a red triangle with an exclamation mark inside it. Otherwise, it shows nothing. 4) Number of yellow alerts triggered in the last check-up performed on the patient. 5) Number of yellow alerts triggered in the checkup before the last one. 6) Repetition of one or more yellow alerts between the last two checks performed on the patient. If this happens, it will be symbolized by a yellow triangle with an exclamation mark inside it. Otherwise, it shows nothing. 7) Its appearance in red describes the triggering of the red alert: "Inadequate patient temperature" in the last check-up performed on the patient. 8) Its appearance in red color describes the triggering of the red alert: "Monitors with oxygen saturation alarms incorrectly placed" in the last check-up performed on the patient. 9) Its appearance in red color describes the triggering of the red alert: "Monitors with incorrectly placed heart rate alarms" in the last check-up performed on the patient.

current date and another for the total reports obtained from the patient, from their admission to the hospital to the current date, which we will call historical.

Regarding the day's reviews, we can find a row for each check-up performed on the patient during the day, which contains two interactive graphs. One of the graphs allows seeing the total number of triggered alerts discriminated by their type: white, yellow, and red. The other graph allows seeing the distribution of descriptions of alerts triggered in that control. The number of rows is limited by the number of check-ups performed on the patient during the day. This idea arose from the fact that the hospital staff commented that the patient care process had a series of between four and five daily check-ups carried out at different times.
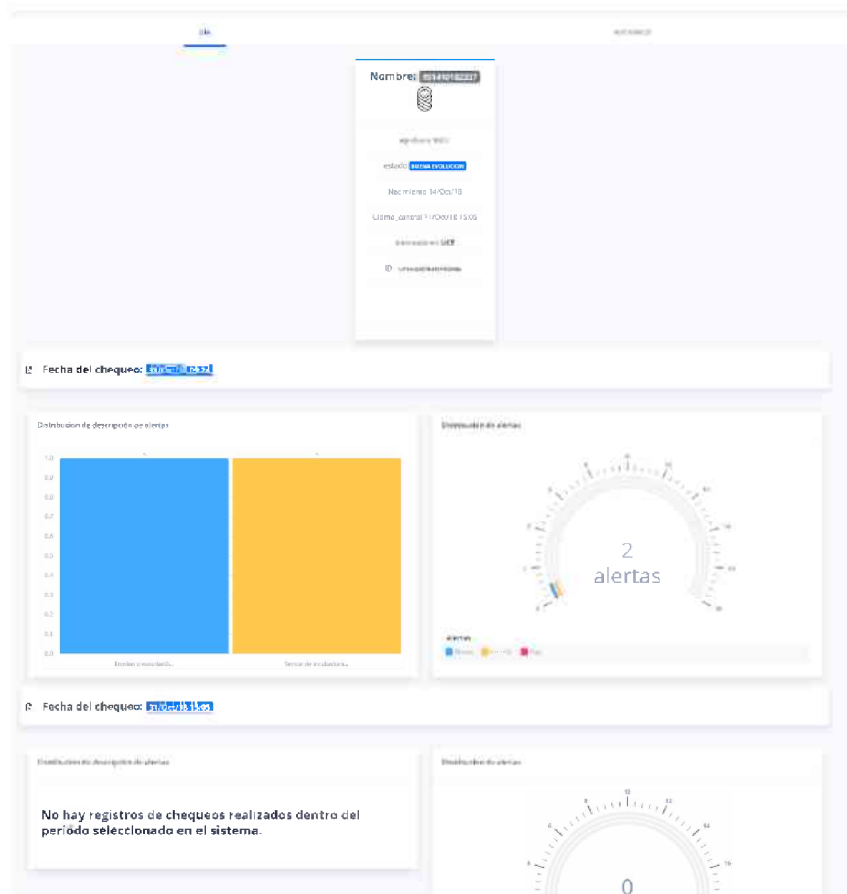
Fig. 4. Particular view of a patient where the user can view a summary of the alerts from his/her last check-up.

The bar graph seeks to show the distribution of alerts for a specific patient on one or more checks carried out, the calculation of the size of the bar being the sum of alerts of the same type and the same description. Similarly, for the historical section, the same infographic was implemented, both graphs are bounded by the set of checks selected from the total of controls registered to the patient as illustrated in Figure 5.

3.3   Historical

This view is dedicated to the analysis of statistics for the generation of reports, audits, etc. The objective is to provide information about patient care processes, to take into account when making long-term impact decisions. This view is also intended to facilitate the delivery of statistical data and also for internal and/or external audits of the hospital.

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Fig. 5. Particular view of a patient where the user can view a summary of all the alerts from all his/her check-ups.
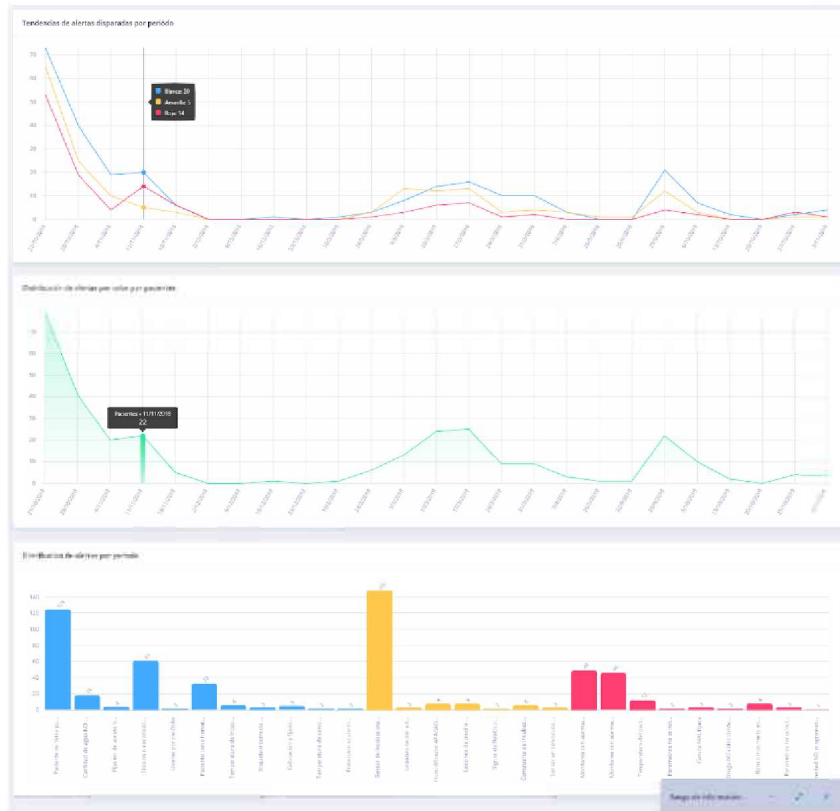

Fig. 6. Historical view of all alerts, checks and registered patients.

Through this view, it is sought to have a visual representation of the information that is recorded day by day in the system, both checks, alerts, and patients. The first graph in Figure 6 shows a series of sets of points connected with a single line. In this case, there are three lines, one for each type of alert (white, yellow, or red) and a set of points that are defined by the sum of alerts of the same type that have been triggered throughout the registered controls of all patients in a certain period.

Then, the infographic in the middle of Figure 6, is again a line graph, which has the same time intervals as the one previously described but has a single line that describes the number of patients in which they are distributed the alerts triggered in that period. For example, if in the first graph at any point in time P it is described that there were a total of six alerts, two yellow, one red, and three white, in the second graph, at the same time point P, it will only show the number of patients to which those six alerts are distributed. Then, the second graph can show one, two, or perhaps up to three or four patients who have distributed those six alerts in that period.

Finally, the third graph describes the distribution of the alert descriptions triggered in the checks recorded in a given period. The length of the bars is associated with the sum or the amount of recurrence in which an alert with the same description has been fired, within a time interval.

The interaction between the aforementioned graphs is linked using any of the lines of the first and/or third graph. If any type of alert is selected from these, this action will affect the results shown in the rest of the graphs, showing the distribution of alerts for only that type of alert. Following the example described in the previous paragraph, in case of choosing a white alert, the sum of patients who had alerts of this type will be shown in the second graph, therefore, point P would go from being linked to six alerts to three white alerts which is not a determining factor for the total number of patients. In other words, this means that point P in graph two could still be one, two, or three patients.

The view also allows filtering of the data to be analyzed defined by a range of temporal data, the start date and the current date up to the current date, and from that to generate the corresponding data subset. Also, it allows a change in the time intervals, having a scale of checks per day, week, month, quarter, and/or year.

4   Implementation

This project was implemented using Angular which is a web application framework developed in TypeScript [6], open-source, maintained by Google, and used to create and maintain single-page web applications. Its goal is to augment browser-based applications with Model View Controller (MVC) capability, to make development and testing easier. The library reads the HTML that contains additional custom tag attributes, then obeys the custom attribute directives, and binds the input or output pieces of the page to a pattern represented by standard JavaScript variables.

Angular is based on "Components" type classes, whose properties are used to bind the data. In these classes, we have properties (variables) and methods (functions to call). The proposed solution was developed from the complementary RxJS library [2], which allowed operating in reactive programming, a paradigm focused on working with asynchronous data flow, through the observer design pattern. Angular relies on RxJS to enable the reaction to events asynchronously and with high performance. This allows the platform to "react" to different changes in the database without having to "redraw" a component or refresh the entire page.

The visualizations used were created with Ngx-admin [1] and D3.js [4]; Ngx-admin is a free and open-source customizable administration dashboard based on Angular 8+, Bootstrap 4+, and Nebular (customizable Angular User Interface) that provides numerous customizable graphic components and mockups for different types of screen renderings. D3.js or simply D3 for Data-Driven Documents is a JavaScript library to manipulate documents based on data sets and to be able to generate with these dynamic and interactive visualizations in web browsers. It makes use of well-supported technologies like SVG, HTML5, CSS and offers a large number of types of graphics and tutorials on how to create them.

5   Conclusions and future work

SIMONEV is the result of an innovative work between the Department of Computer Science and Engineering and the Neonatology area of Hospital Penna. It is a work that continues the one previously carried out with SIMONE and that proves that it is possible to establish long-term projects and give them continuity between public institutions. From this project, which was a thesis from the Information Systems Engineering degree, a visualization dashboard was created, with multiple views which adjust to different user-profiles and objectives.

As previously mentioned, the current situation of pandemic and social isolation did not allow the installation of this system in Penna hospital, however, SINOMEV can be freely tested at this URL https://simonev-v2.herokuapp.com/ We hope to be able to put this platform into operation next year so that we can begin to collect user feedback and evaluate future changes and updates.

SINOMEV is an application that seeks to assist and facilitate the control of patients and critical care processes, as well as help in the definition of long-term policies and strategies at the Neonatal Intensive Care Units. The application is available as an open-source project, which means that not only was a software product developed but also a foundation was created that will allow future development teams to continue expanding its functionality and application areas.

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