Project Assignment (Part I)

A health care centre is planning to manage its population of chronic disease patients using wearable electronic medical devices to monitor health parameters. The devices worn by a patient form a Personal Area Network[1] (PAN), communicating through Continua[2] protocols with a smart phone, which acts as a gateway to the medical centre. Most of the patients will only wear reading devices (*sensors*), to monitor health parameters, such as the heartbeat and glucose level, but some of the patients will also wear output devices (*actuators*), to control an insulin pump[3] or set the speed on a VAD[4]. Your task is to design the database of the medical centre to manage the collected readings and settings of monitored patient devices, together with the medical exams to observe and diagnose their health status. A more detailed description follows:

A medical device can be an input sensor (glucose meter), an actuator (insulin pump) or both. Every device has a serial number from its manufacturer and a description (e.g., "blood pressure meter" or "insulin pump+glucose meter"). Devices handle readings and writings of values of physical measures, such as glucose level (5.9 mmol/L), temperature (37.8 ºC), rotating speed (2000 RPM) or voltage (35 mV). These values and the times of observation/setting are to be recorded in the database. Actuators receive "settings" of values at specific times (e.g., setting the rotating speed of a pump to 2000 RPM). Sensors can collect "readings", sets of values at specific times. For instance, to obtain a signal with the heart rate, a device could send the last 60 values sampled in the past hour to be stored on the database associated to the time of collecting that data from the sensor; in that case, an example reading would store the signal as 60 name-value pairs ("minute 00" : 75, "minute 01" : 78, … "minute 59" : 125) associated to "Fri Sep 29 23:58:29 WEST 2017". Another case is a blood pressure meter which collects in each reading two name-value pairs (e.g., "min" : 7.2 and "max" : 13.8). This reading would also be registered together with the data collection time.

Patients who carry wearable devices have a PAN (in practice a smart phone, and no more than one PAN per patient!). The PAN is used to transfer data (readings and settings) between the wireless medical devices and the database in the medical centre. PANs, each identified by a unique internet domain name ("panXXX.healthunit.org"), have a mobile phone number. PANs are worn by patients over some periods (when prescribed), but a patient may replace a PAN for another PAN after some time (for instance, a given PAN that was used by a recovered patient may be assigned later to a new patient).

[1] https://en.wikipedia.org/wiki/Personal_area_network
[2] http://www.continuaalliance.org
[3] https://en.wikipedia.org/wiki/Insulin_pump
[4] https://en.wikipedia.org/wiki/Ventricular_assist_device

The wearable devices of a patient are connected to a patient's PAN. A given device is connected to one (and only one) PAN during a period of time, but may be disconnected after some time (for instance, to be replaced or connected to the PAN of another patient), or even reconnected again (for instance, after a repair).

Each patient is followed by a doctor, who can prescribe medical exams to their patients. An exam prescription, or "request for examination", by a doctor to a patient on a date and time, may comprise several studies[5]. For example, a doctor may request an X-Ray of both feet to check if there is any fracture, together with an echography of the right foot to observe if there is some inflammation. Each study has a date and a description (e.g. "X-ray both feet", "echography right foot"). A study is performed using a certain equipment. An equipment has manufacturer, model and manufacturer's serial number. Each study collects one or more series of data; each series has a unique id and a name (e.g. "X-ray left foot", "X-ray right foot"). A series may contain multiple elements with a sequential index. For example, an X-Ray series consists of one or more images captured at different angles; each of these images is called an element of the series. A study could also be an MRI scan, in which a series would contain all of the collected images from the different slices. Or, in an ECG, where several electrodes measure heart voltages at different points, each electrode captures a signal, and each signal corresponds to an element of the ECG series.

The raw data of these elements (i.e. images or signals) are stored as files outside the database, and are referenced by an URL. The URL of an element is calculated from a base URL assigned to the series and the index of the element. When a series is collected, the doctor performing the exam may annotate regions of interest in one of more of its elements (for instance, a fracture zone in an X-ray, or an arrhythmia interval in an ECG). If the element is an image, the region is a rectangle defined by two (x, y) points in normalized coordinates (i.e. both x and y in the range [0.0, 1.0]). For signal elements, the region is described by a pair (t_1, t_2) also in the range [0.0, 1.0].

Both patients and doctors are identified by the country's unique citizen number, but doctors also have an additional ID from their professional association. Any doctor can prescribe and perform exams, but by internal regulation a doctor who prescribes an exam may not perform that same exam and the date of an exam request must always precede the date of the corresponding exam.

[5] we are borrowing here terminology from the DICOM standard http://dicom.nema.org/standard.html

Note: To encode periods that have not ended in the database, i.e., periods spanning from sometime ago to the present you could set the final date of the period to a special date, e.g. Dec 31st, 2999. For instance, to encode that a blood pressure device is connected to PAN pan99.healthunit.org since September 29th, 2017 until now, or a patient who moved to the municipality of Lisbon the same date, we would set the start and end dates of the relevant periods to "Fri Sep 29 00:00:00 WEST 2017" and "Tue Dec 31 00:00:00 WEST 2999", respectively.

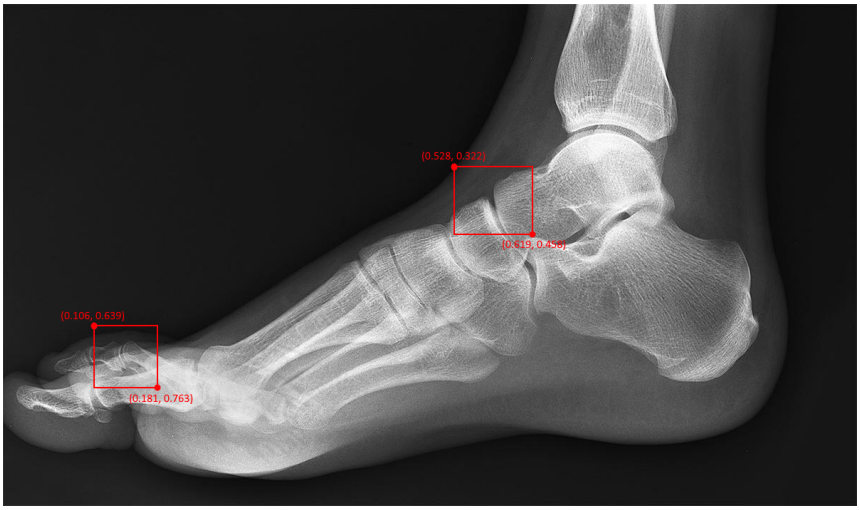

Figure 1. X-ray with annotated regions

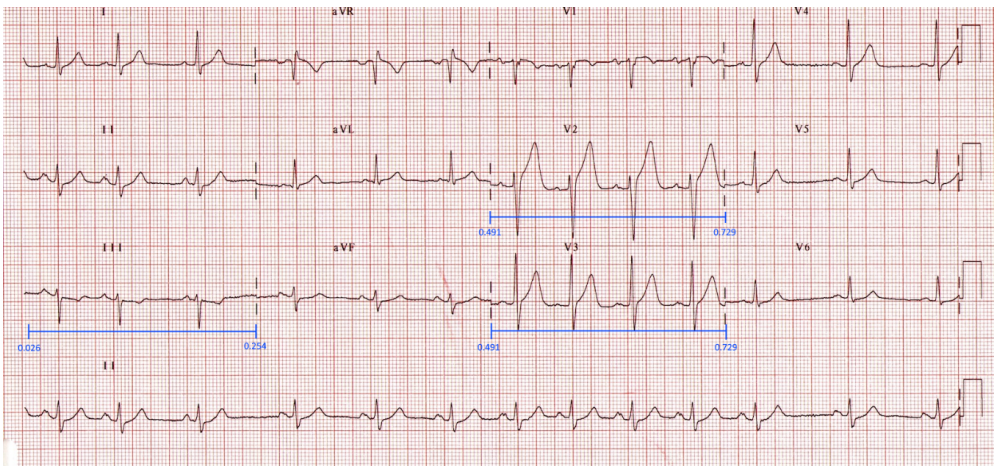

Figure 2. ECG with annotated regions

Expected Results

The report of your group must include two main results:

1. An E-R model describing your proposed database design. Every design decision that can be captured in the E-R model should be represented in the diagram. The E-R notation should be the same as in the slides for this course. You may use a diagram editor, such as *Dia*, to draw the final E-R model.[6]

2. The relational model that is obtained by converting the E-R diagram into a set of tables. Please follow the conversion rules as explained in the slides for this course. To represent the relational model, use the following notation:

$$\begin{aligned} &table_1(\underline{column_1}, column_2, column_3, column_4, \ldots) \\ &\quad column_2 : FK(table_2) \\ &\quad column_3, column_4 : FK(table_3) \\ &\quad \ldots \end{aligned}$$

   where *column₁* is underlined because it is the primary key, and *column₂* is a foreign key to *table₂*.

Submission Notes

The project report should be submitted to Fénix as a single PDF file.[7] Please check that the file is readable with a standard program such as Adobe Reader.

The document cover page should mention the names, student numbers, and group number of its authors.

If possible, the E-R diagram should be presented on a single page, and the relational model also on a single separate page.

The deadline for submission is **Wednesday, October 25 2017 23:59 (Fénix time[8])**.
Plan to submit ahead of time to ensure that the project is delivered.

[6] *Dia* is available for Linux, Mac, and Wndows. See: http://dia-installer.de/
[7] In most word processors, there is a menu option such as: File | Save as... PDF (*.pdf). In *Dia*, you can export a diagram as an image (File | Export...) and then insert the image into a document.
[8] Fénix is not a human, and the designer did not include an association between the *student* and *pardon* entity sets in its conceptual model.