PERVASIVE INTELLIGENT REAL-TIME DECISION SUPPORT TO INTENSIVE MEDICINE

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Introduction

Intensive Care Units (ICU) are flooded with devices aiming at giving doctors better information regarding their patient's condition. For example, bedside monitors continuously show blood pressure, oxygen saturation, and heart rate together with the values of other variables.

When working with such data we are faced with a wealth of data streams instead of the more usual static data table. Indeed, for each monitored variable in the ICU one has a data stream and, to further complicate matters, it is often the case that data from different sensors are gathered at different time intervals. For example, real-time data acquired from the bedside monitors must be merged together with analysis data, which comes in only once or twice a day. Thus, while traditionally one would have one or two records per patient per day, entered manually by the nursing and/or physicians; automated data acquisition gives us an almost infinite amount of data and allow create new knowledge. With this work was possible obtain ICU Scores, Critical Events and predict organ failure and patient outcome. This system called INTCare has been deployed in the ICU of the Centro Hospitalar do Porto (CHP), Porto, Portugal.

Main Goal

- ✓ Support the ICU decision process in real-time, anywhere and anytime;
- ✓ Disseminate new knowledge through the ICU by using patient data;
- ✓ Predict organ failure and patient outcome.

Method

Change the environment and information system architecture, using the Pervasive Health Care features and ICU needs, automatize the data acquisition and transforming process, explore ensemble Data Mining (DM) and develop / test the models / technique according the quality measure.

Results

To achieve the goals above defined was necessary define the necessities of innovation and features that need to be implemented:

- Reformulate Information System (IS);
- Develop an automatic data acquisition and processing system;
- Open the format of laboratory results;
- Open the access to therapeutics;
- Processes discretization and systems interoperability.

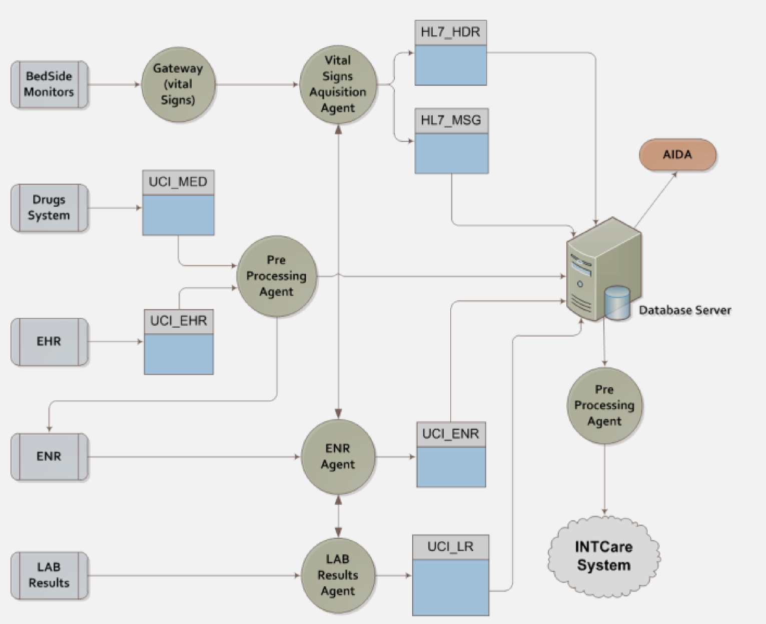


Figure 1: Data acquisition architecture

Figure 1 shows the data acquisition architecture, the data sources and agents used to obtain ICU Scores, Critical Events and induce DM models.

Electronic Nursing Record (ENR) is a platform that was developed with the objective to receive all medical data and put it available to doctors and nurses in an hourly-based mode where all operations can be registered through a simple interface.

Figure 2 depict an overview of the data sources that daily (2009) are used by nurses and doctors in ICU. Besides the high number of data sources and the necessity to use different platforms to consult / store the information, the nursing record were still made in paper and can't be used by other platforms. Orange shapes represent the data sources, associated to the information that normally are requested. The other shapes represent this information.

Figure 3 represents the IS evolution and the interoperability between ENR and the other data sources. Opposing the figure 2 is possible verify that all data sources converge to the same platform: ENR. Now, aren't the ICU professionals who request the data but the platform which is always searching from new data from other data sources.

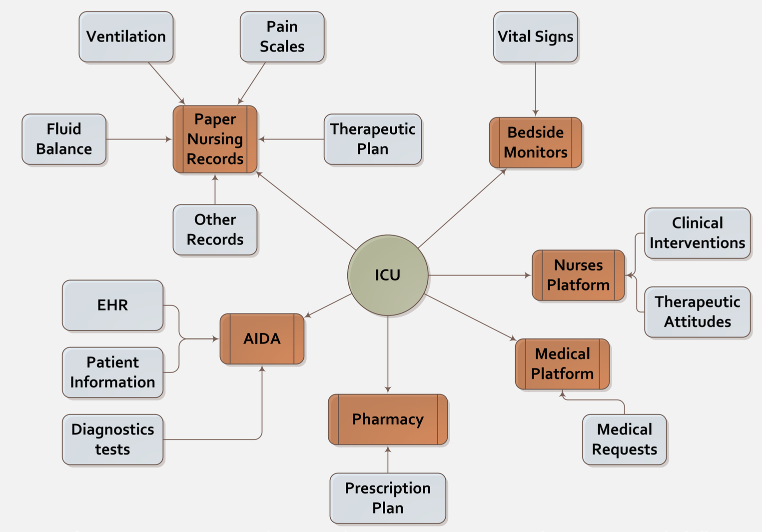
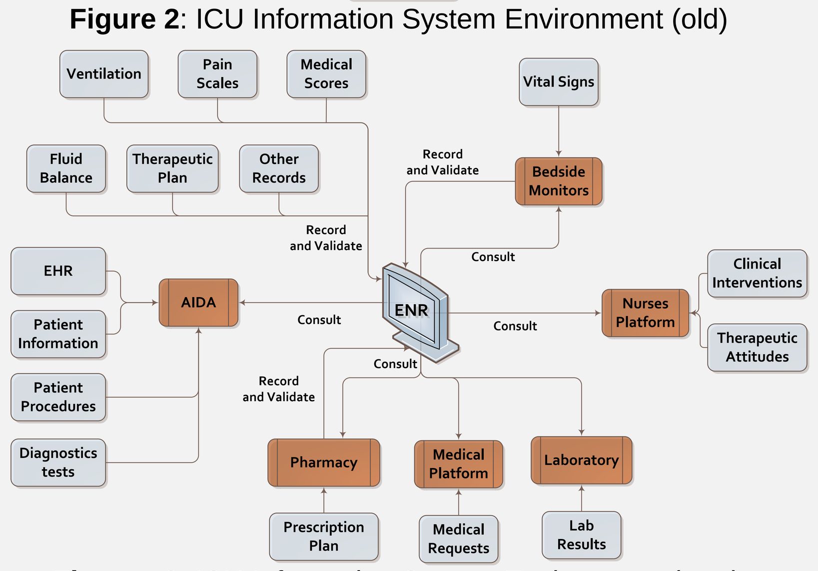


Figure 2: ICU Information System Environment (old)



Figures 3: ICU Information System Environment (new)

Table 1 show the number of pieces of information available electronically (E), online and in real-time (ORT). The initial situation (50% of ORT) evolved to a complete ORT approach.

Table 1 : Information type available in ICU

Information Type	Before		Now	
	Source	ORT	Source	ORT
Ventilation	P	X	E	√
Pain Scales	P	X	E	√
Fluid Balance	P	X	E	√
Therapeutic Plan	P	X	E	√
Other Records	P	X	E	√
EHR	E	√	E	√
Patient Information	E	√	E	√
Diagnostics tests	E	√	E	√
Vital Signs	P	X	E	√
Prescription Plan	P / E	√	E	√
Medical Requests	E	√	E	√
Clinical Interventions	E	√	E	√
Therapeutic Attitudes	E	√	E	√
Lab Results	P	X	E	√
Patient Procedures	P / E	√	E	√
Medical Scores	P	X	E	√

The first result achieved with the changes is the possibility to calculate the ICU Scores (SAPS, Glasgow and SOFA) automatically and in real-time. The Scoring System is integrated in the ENR. This application is also used for registering some values that require a human observation like is Glasgow. Figure 4 presents a print screen of a score's view for SAPS II. The form how the results are presented through real-time scores charts is intuitive and represent a novelty. These charts (figure 5) can be consulted in two different ways: hourly (along the 24 hours) and by day (since the admission day). The user can also consult all variables in simultaneous (default) or can isolate a particular variable for a fine-grained study.

Figure 4: SAPS II score system

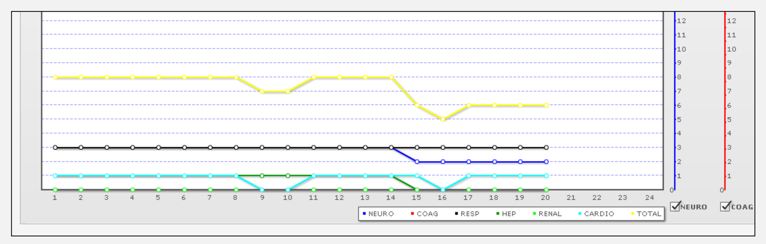


Figure 5: SOFA score chart

At level of Critical Events (CE), it is possible obtain a number of critical events for the patient by hour and category automatically and in real-time. The results are obtained after know the importance of the values, i.e. critic or not. At same time it is calculated the Accumulated Critical Events (ACE) – to reflect the patients' clinical evolution/severity of illness by hour.

Finally the DM process it is autonomous and don't requires a manual action. All processing, transforming tasks and models induction are performed automatically in real-time and using online learning, by the intelligent agents. The variables in use are:

- **SOFA** $_{\text{Cardio, Respiratory, Renal, Liver, Coagulation, neurologic}}$ = {0, 1};
- **Case Mix** = {Age , Admission type, Admission from };
- **Critical Events Accumulated (ACE)** = {ACE Blood Pressure (BP), ACE Oxygen Saturation (SO2), ACE Heart Rate (HR), ACE Urine Output (UR) }
- **Ratios1 (R1)** = {ACE BP/ elapsed time of stay(ETS), ACE /ETS, ACE HR /ETS, ACE /ETS, Total ACE /ETS}.
- **Ratios2 (R2)** = {ACE BP / max number of ACE BP, ACE SO2/ max number of ACE SO2, ACE HR / max number of ACE HR , ACE UR / max number of ACE Ur, Total ACE, Total ACE / Total ACE max}.

To compare and evaluate the results an ensemble and quality metrics are used. Figure 6 presents an overview of how the ensemble works and the process to create predictive models:

- **Predictive Models:** 126 models are induced combining 7 scenarios (S1 to S7), six targets and three different techniques (Support Vector Machine, Decision Trees and Naïve Byes);
- **Ensemble**: the models are assessed in terms of the sensibility, accuracy, total error and specificity. The best model for each target (t) is selected

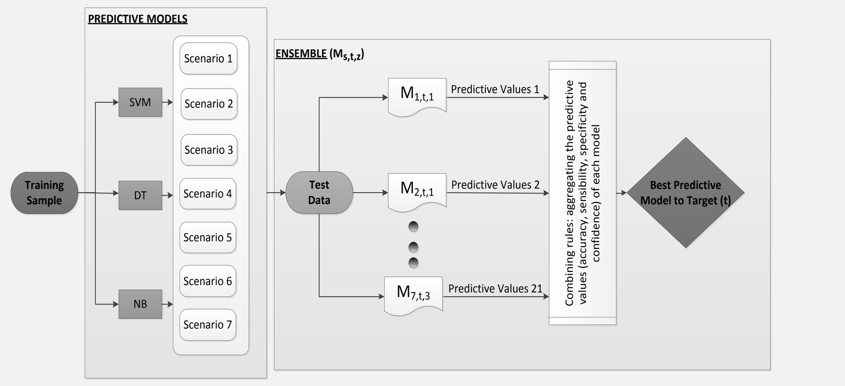


Figure 6: Ensemble main cycle and predictive models induction

Table 2 presents the performance achieved by the ensemble for each target. The values correspond to the average of the measures obtained during ten runs of the ensemble. The respiratory, hepatic and renal systems don't meet the measures established and aren't considered by the system.

Table 2 : Ensemble Results

Target	Meet quality measure	Sensibility	Accuracy	Specificity	Terror
Cardiovascular	YES	97,95 ± 0,31	76,81 ± 2,35	41,81 ± 5,75	23,19 ± 2,35
Coagulation	YES	91,20 ± 3,57	65,69 ± 3,83	49,61 ± 6,15	34,31 ± 3,84
Hepatic	NO	69,24 ± 9,41	82,89 ± 2,57	87,34 ± 3,22	17,10 ± 2,57
Outcome	YES	99,77 ± 0,33	63,58 ± 3,11	49,58 ± 4,90	36,42 ± 3,11
Renal	NO	77,17 ± 12,41	43,08 ± 4,66	43,08 ± 4,66	49,09 ± 5,39
Respiratory	NO	67,11 ± 5,67	63,86 ± 4,27	60,39 ± 6,75	36,14 ± 4,27

Conclusions

This new approach allows the doctors to have a better understanding of patient's condition. This work proves that is possible support the decision process automatically and in real-time anywhere and anytime with a high level of new knowledge and with very good accuracy and sensibility.

Acknowledges

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