Modelling Trauma Physiology for Large Crisis Management

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CNR+UCSC

The **School of Medicine UCSC** provides healthcare at the **Policlinico Universitario "A. Gemelli"** in Rome, with 1400 beds and a turnover of 70,000 patients annually, for all clinical specialties.

CNR-UCSC is present and has participated in numerous **EU-funded research projects**

CNR-IASI Biomathematics Laboratory operates within UCSC the under an institutional agreement between **CNR** (Italian National Research Council) and **UCSC**

The CNR-UCSC group has expertise in the fields of **mathematical modelling, statistics, model parameter estimation in biomedicine**

Motivation

- Recent rise in Major Incidents with big impact on the citizens health and the society
- Vulnerability of our health care system to such situations has increased
- No possibility of conducting live experiments when it comes to physical trauma
- Relocation and mobilization of resources can be enhanced through the introduction and proliferation of good and accurate mathematical models to manage incident medical response

Objectives

- Development and implementation of a mathematical model for the physiological patient evolution during/after physical trauma, utilizing modelling and simulation techniques:
  - Design of integrated models of pathophysiological evolution.
  - Implementation of modules for the simulation of the evolution of the emergency situation, from arbitrary observations of field conditions.

Methodology

- In trauma incidents, **the patient is modelled** by means of continuous physiological variables;
- Accordingly, **the physiological patient evolution is described** through systems of Ordinary Differential Equations (ODEs), which determine the “trajectory” of the physiological variables.

Scenario Generation

- A lesions library has been built, including physical trauma lesions: head/neck, face, chest, abdomen, extremities, external.
- Each lesion has a probability of occurrence and has an associated maximum instantaneous damage and a maximum damage rate for each physiological variable.
- According to the lesions (independently) “sampled” for each individual, the average danger associated to the type of event, the event size, his distance from the event, and a random “individual” component, the initial condition of the patient is determined.

Patient model

Goal: assessment of the patient health status in accordance with evolving time. Modelling of the effects of injuries of several types on civilian victims.

In agreement with the ABCDE Primary Survey and Resuscitation, there are only five main ways to die, from fatal complications involving: Airways (A), Breathing (B), Circulation (C), Disability of Nervous System (D), Extra Damage or Exposure (E).

Patient model

Accordingly, the patient dynamics can be described by a set of (normalized) physiological variables, based on ABCDE paradigm:

- A1 (airway patency: intact, at risk, partially obstructed, or completely obstructed);
- B1 (respiratory rate and drive);
- B2 (tidal volume and mechanics);
- B3 (oxygen saturation and transport);
- C1 (heart pump function);
- C2 (circulation filling and resistances);
- D1 (central nervous System Function, Glasgow Coma Scale (GCS));
- D2 (seizures);
- D3 (cholinergic activity);
- E1 (exposure, hypothermia, burns).

Patient model

At time 0 (event time), the patient functionalities have a sudden relative damage Δ; then they decrease at a rate α

$$x(t_0) = 1 - \Delta$$

$$\frac{dx(t)}{dt} = -\alpha + u(t) \qquad t \geq t_0$$

The values (Δ,α) are different for each patient (according to their severity) and for each physiological variable.

Health care effect model

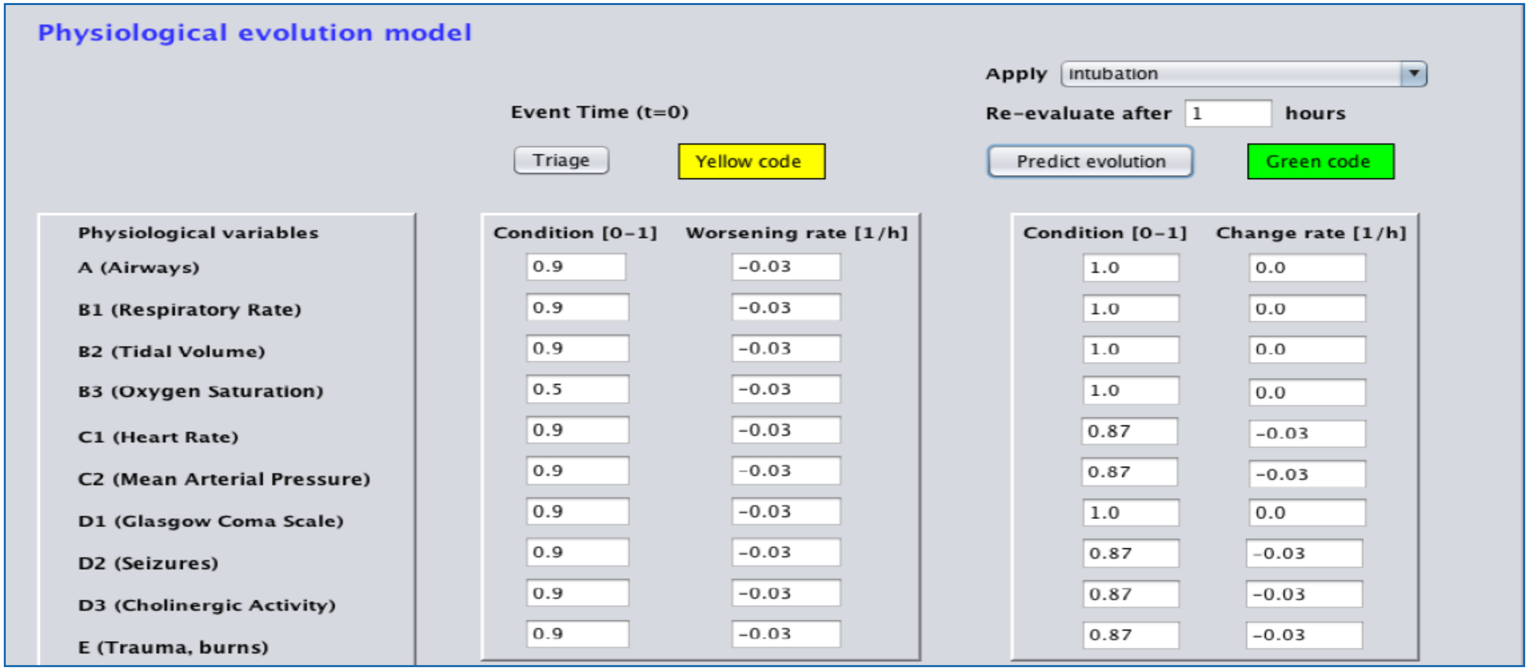
Goal: continuous assessment of the patient health status in accordance with evolving time and treatments administered

- Modelling of effect of treatment and first aid personnel activities in case of crisis.

Health care effect model

- A resource library has been built, including: ambulance, Emergency Room, operating theatre, police car, first responders, Advanced Medical Post.
- A resource can provide a collection of therapeutic maneuvers. Each maneuver has an associated instantaneous increment and a healing rate for each physiological variable.
- Resources have a spatial position and are allocated to patients according to their injuries and to their individual severity.
- According to the resource allocated for each patient, the evolution of the treated patient is determined.

Java Client


Physiological evolution model
Apply
intubation
Event Time (t=0)
Re-evaluate after
1
hours
Triage
Yellow code
Predict evolution
Green code
Physiological variables
A (Airways)
B1 (Respiratory Rate)
B2 (Tidal Volume)
B3 (Oxygen Saturation)
C1 (Heart Rate)
C2 (Mean Arterial Pressure)
D1 (Glasgow Coma Scale)
D2 (Seizures)
D3 (Cholinergic Activity)
E (Trauma, burns)
Condition [0-1]
Worsening rate [1/h]
0.9
0.9
0.9
0.5
0.9
0.9
0.9
0.9
0.9
0.9
-0.03
-0.03
-0.03
-0.03
-0.03
-0.03
-0.03
-0.03
-0.03
-0.03
Condition [0-1]
Change rate [1/h]
1.0
1.0
1.0
1.0
0.87
0.87
1.0
0.87
0.87
0.87
0.0
0.0
0.0
0.0
-0.03
-0.03
0.0
-0.03
-0.03
-0.03

Parameter Tables

	B1 Delta	B1 Alpha	....	C2 Delta	C2 Alpha	....	D1 Delta	D1 Alpha	E Delta	E Alpha
Head/Neck	-0.3	-1.2	....	0	-0.6	....	-0.9	-1.2	-0.1	-0.3
Face	-0.2	-1.2	....	0	-0.6	....	-0.6	-0.6	-0.1	-0.3
Chest	-0.9	-0.6	....	-0.9	-1.2	....	-0.4	-0.6	-0.1	-0.3
Abdomen	-0.2	0	....	-0.9	-1.2	....	-0.2	0	-0.1	-0.3
Extremities	0	0	....	-0.5	-1.2	....	-0.2	0	-0.1	-0.3
External	0	0	....	-0.4	-0.6	....	0	0	-0.9	-0.6

Instantaneous maximum damage Δ and maximum rate of worsening α

Effects of some therapies on the PSVs in terms of instantaneous modifications (in fraction) and of variation of the rate of change (in fraction/hour)

	B1 Delta	B1 Alpha	....	C2 Delta	C2 Alpha	....	D1 Delta	D1 Alpha	E Delta	E Alpha
Oxygen	0	0.06	....	0	0	....	0	0.06	0	0
Intubation	1	60	....	0	0	....	0.1	0.3	0	0
Ambu bag	0.5	30	....	0	0	....	0.05	0.15	0	0
Saline infusion	0	0	....	0.2	6	....	0	0	0.2	3
Blood infusion	0	0	....	0.4	6	....	0	0	0.1	3
....	....	....	....	....	....	....	....	....	....	....

Conclusions

- Developed and implemented a mathematical model of the physiological patient evolution during/after physical trauma events
- The ultimate goal is to predict adverse outcomes with simplified methods for triage and personalize the treatment of the patients with available therapeutic maneuvers
- The results could provide a benchmark for potential introduction and proliferation of applications to be employed in real operation during MIs medical response, with potential improvements on the safety and security of citizens

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IMPRESS

IMproving Preparedness and Response of hEalth Services in major criseS

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no [608078]

What is IMPRESS?

- Drawback in the handling of Major Health Incidents: disproportion between the needs and the available human/material resources in the response capacity and the inherent time constraints of an emergency.

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- More details: http://fp7-impress.eu