

# ACHE: an Architecture for Clinical Hypothesis Examination

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## Abstract

*Physiological monitoring equipment can be found in many hospital settings. This allows a wide range of physiological parameters to be stored, which in turn allows clinicians and analysts to investigate a range of medical hypotheses. This paper introduces ACHE (Architecture for Clinical Hypotheses Examination), a framework specifically designed to support the preparation of such analyses.*

*To evaluate the initial version of ACHE, a study to detect Acute Myocardial Infarctions, was conducted with data from Glasgow Royal Infirmary's Intensive Care Unit(ICU). Initial results from the study are very encouraging and ACHE substantially reduced the time required to perform the study. A study of the same phenomena across a much larger patient dataset will be undertaken shortly.*

## 1. Introduction

We, at Aberdeen, have been involved in numerous medical projects[1][2] involving time series data. Future plans for the group, however, involve datasets that are substantially larger, such as data that is routinely collected in the ICU domain. These previous projects led to the identification of the following issues that required resolution before proceeding with larger datasets:

- **Multiple Data Sources** - Every dataset, from clinical departments that we encountered, had unique data models and formats dependent on the clinical monitoring equipment used.
- **Manual Data Pre-Processing** - A significant number of manual data quality checks and pre-processing tasks were often performed before commencing the subsequent study. It became apparent that with much larger datasets, semi-automation of these tasks was required.
- **Amalgamation of Analytical Tools** - Analytical tools from previous studies as well as tools developed in

the future need an extendable architecture to which they can be interfaced to make them accessible to all clinical studies. The reuse of existing analytical tools is very much encouraged, as it reduces costs and increases 'throughput'.

## 2. Description of ACHE

Architecture for Clinical Hypothesis Evaluation (ACHE) provides an extendable architecture for the preparation of time series data for analysis, incorporating some solutions to issues discussed in the last section. Data from numerous clinical sources are stored in one main repository and tools provided for both clinicians and analysts. Figure 1 presents an outline of the main components of ACHE.

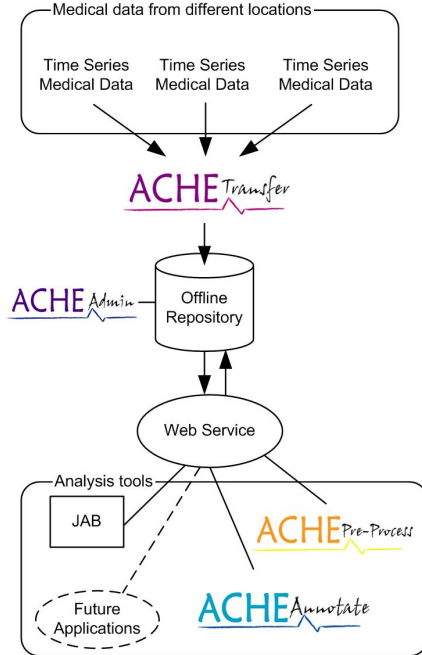
ACHE Transfer maps data from Microsoft Excel, Microsoft Access or MySQL<sup>1</sup> to the MySQL database that acts as the central repository. Mappings are defined by the analyst between the incoming data schema and the central repository schema. These mappings can be saved and reused for future transfers of analogous datasets.

The central repository stores the clinical data along with details of registered users and annotations on the data that are made subsequently to data collection. Access rights and authorization, by researchers and clinicians, can be set using ACHE Admin. This is important as confidentiality of the data must be maintained.

To allow clinicians to annotate data stored in the repository, ACHE Annotate, a web-based tool, has been developed to allow clinicians to view and annotate data stored in the repository. Annotations can be applied to the following subsets of time: the whole session, daily, and hourly. For example, apply the annotation *Cardiovascular Unstable* to a particular patient's dataset for the day period *Aug 4th 2006*.

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<sup>1</sup><http://www.mysql.com/>



**Figure 1. Overview of the ACHE architecture**

ACHE Pre-Process allows common pre-processing methods to be applied automatically to time series data. So far, ACHE Pre-Process allows the user to: create extrapolated data<sup>2</sup>, calculate and append changes in parameters, identify periods of haemodialysis and calculate averages before, during and after the haemodialysis session and convert a subset or the full data from the main repository into a variety of data formats: ARFF[4], Microsoft Excel, CLIPS<sup>3</sup> and XML.

### 3. Related Research

The analysis of medical time series data is an established research area: VIE-VENT[6] and RÉSUMÉ[7] are two such examples of implemented systems. It is acknowledged that working with such data can be time intensive especially with regard to data preparation. Analysis tools such as Weka[4] provide a small amount of pre-processing functionality but do not offer a solution for all the issues we have identified.

A review of related literature led to the identification of two architectures that may have provided adequate solutions, however, upon closer examination they did not fully meet our needs. The first such architecture investigated was

<sup>2</sup>A version of the dataset created when domain specific rules have been applied to create extrapolated values to replace missing parameter values in the data.

<sup>3</sup><http://clipsrules.sourceforge.net/>

TSNet[3]; TSNet, an infrastructure for implementing, evaluating and comparing signal processing tools, allows time series data from different sources to be shared. This aspect may help solve the issue of heterogeneous data sources but does not provide the pre-processing tools that we required. The ICDEV project[5], provided offline access to patient physiological data from CareVue Classic machines installed in various ICUs. Data of differing formats was taken from the machines and stored for future analysis. A disadvantage of their approach was every time a different data model was encountered they had to write a new 'module'. ACHE builds on this early work; ACHE transfer can handle data of differing formats due to the mapping facility presented to the user. ACHE also goes beyond retrieval of data and provides multiple intelligent tools for further analysis.

### 4. Identifying Episodes of Acute Myocardial Infarction in ICU Patients

To evaluate the initial implementation of ACHE, a pilot study was carried out with Glasgow Royal Infirmary to investigate the occurrence of Acute Myocardial Infarctions (Acute MIs) in patients in the ICU. Acute MI is an event where an atherosclerotic plaque ruptures in a coronary artery leading to a decrease in the blood supply to the area of the heart supplied by that artery. Acute MIs may appear as subtle physiological events and can go undetected. It would be advantageous if ICU monitoring equipment could alert clinicians when it is suspected that an acute MI is occurring. The aim of this study is to develop rules to detect an acute MI and at the same time note how effectively ACHE supports such studies.

Data for 30 randomly selected patients was obtained from Phillips CareVue Chart<sup>4</sup>, PiCCO<sup>5</sup> and LiDCO<sup>6</sup> monitoring equipment installed in the ICU. 9 core physiological parameters, for example, heart rate and temperature, were recorded hourly and drug, fluid and dialysis infusions were recorded as applicable. Patient stays ranged from 2 to 44 days. The patient data for the study was mapped successfully via ACHE Transfer to the main repository of ACHE.

#### 4.1 Rule Acquisition & Rule Evaluation

Rules to identify the likely physiological changes which might indicate an acute MI were obtained from domain experts. It was suggested that two stages of parameter changes would be observed in the patient data. Firstly, Stage 1, labelled as a 'Suspected Cardiovascular Derangement' (SusCD), would show a slight increase(10%) in heart

<sup>4</sup>[http://www.medical.philips.com/main/products/patient\\_monitoring/products/icip/index.html](http://www.medical.philips.com/main/products/patient_monitoring/products/icip/index.html)

<sup>5</sup><http://www.pulsion.com/index.php?id=2056>

<sup>6</sup><http://www.lidco.com/>

rate and MAP. Within the next few hours Stage 2 (MAP < 70, Heart Rate > 129 or < 40, FiO<sub>2</sub> ≥ 80, SpO<sub>2</sub> < 95, CVP > 10 and Urine Output < 35) labelled as a 'Highly Suspected Cardiovascular Derangement' (HSusCD), in this case the acute MI, would be seen.

A pilot study was done with these 2 sets of rules. The clinician identified 9 patients as suffering from an acute MI and the computer-based rules, 6. As a result of this study the clinician modified considerably the rules. The previously identified patients suspected of having an acute MI were reviewed again, with both a clinician and a computer program using new rules (MAP < 70 and an FiO<sub>2</sub> ≥ 80).

## 4.2 Results

Table 1 shows the identification of SusCD and HSusCD events by the clinician and the computer based detection of HSusCD. The 2 patients for whom the supplied rules did not detect a HSusCD were explained by the clinician. For patient 128, it was determined after reviewing patient notes, that they had suffered from a cardiac arrhythmia<sup>7</sup>. The clinician, after reviewing the clinical notes of patient 316 suggested that the identified period probably corresponded to the onset of Sepsis<sup>8</sup>. With these two patients explained, successful identification of all the HSusCD events had been achieved by the given rules.

Patient ID	SusCD Time	HSusCD Time	Did the rules detect the HSusCD?
128	Day 5 10.00	Day 5 23.00	No
162	Day 12 16.00	Day 13 07.00	Yes
253	Day 8 04.00	Day 8 07.00	Yes
316	Day 2 21.00	Day 3 03.00	No
406	Day 15 13.00	Day 15 13.00	Yes
583	Day 27 00.00	Day 27 01.00	Yes
696	Day 5 15.00	Day 6 15.00	Yes
705	Day 4 21.00	Day 5 00.00	Yes
720	Day 6 15.00	Day 8 11.00	Yes

**Table 1. Comparison of Clinician & Computer-based Detection of HSusCD events**

## 5. Conclusion & Future Plans

Although we have been unable to fully detect the onset of an acute MI, we have successfully been able to detect the HSusCD events from the data. This is a promising start; the next stage will be to extend the algorithm to detect the SusCD event as well as the HSusCD.

<sup>7</sup>Irregular, fast or slow heart rhythm

<sup>8</sup>A severe and systemic infection of the body

During this study, ACHE provided invaluable assistance; it allowed a study to be completed in a matter of weeks rather than months. Building on this success, enhancements to ACHE Pre-Process, such as the generalization of the facilities provided for dialysis analyses will be undertaken, enabling a previous renal study [1] to be conducted with a significantly larger amount of patients.

The implementation of ACHE allows numerous projects to proceed including a Case-Based Reasoning project and a system for anomalous clinical event detection and resolution.

## 6. Acknowledgements

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