

Temporal Knowledge Discovery and Data Visualization for Clinical Process Improvement

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Introduction

From a systems perspective, clinical processes are dynamic and complex. Facilities operating near capacity limits are "tightly coupled", rendering them vulnerable to inefficiencies and risk of failures, degrading delivery of care. These characteristics also make it difficult to study and optimize these processes without appropriate systems engineering tools.

However, conventional analysis methods face limitations when applied to complex systems, primarily due to unwarranted assumptions made in classical models. This limits process improvement efforts.

We apply Knowledge Discovery in Databases (KDD) and data Visualization (Viz) or KDD+Viz, as exploratory data analysis methodologies for the study and optimization of clinical processes, and in particular, time-sensitive processes, hence **Temporal KDD+Viz**. Two application use-cases are described, one clinical the other related to disaster response medical processes.

A key advantage of KDD+Viz is the ability to deliver an accurate overview of high-dimensional datasets to domain experts, followed by additional filtering and details on demand.

WiSARD Performance Aug 2006 drill, La Jolla CA

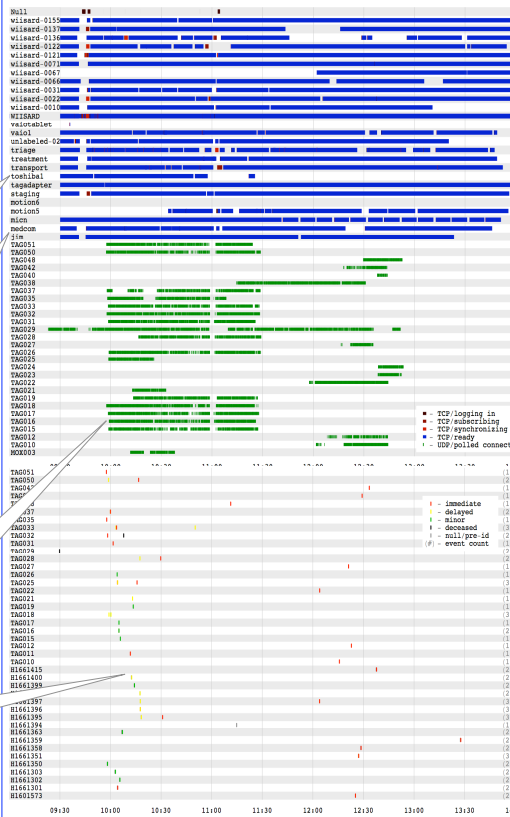
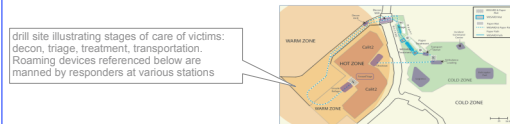
Network connectivity performance and triage updates during a wirelessly enabled disaster response drill visualized with timeline-based event actograms

WiSARD (Wireless Internet Information System for Medical Response to Disasters) is an experimental 802.11-based wireless infrastructure being developed to enhance healthcare aspects of disaster response: coordinating triage, field-treatment, transport and vital-sign telemetry of victims while providing increased situation awareness for multi-agency responders. WiSARD is periodically deployed during disaster response drills. The effectiveness of time-critical group-oriented work processes enabled by any wireless informatics platform is sensitive to the patterns of intermittent connectivity in roaming client platforms, e.g. custom triage tags, PDAs, handheld tablets, deployable 802.11 access points. Intermittent connectivity can be due to several causes. To characterize these, timeline-based actograms were developed to display the patterns of network-related and response-related medical server-timestamped data logged during a day-long, multi-agency drill organized by San Diego Metropolitan Medical Strike Team.

Key Findings

By structuring measures of clinical performance and information system performance along timelines via actograms presented to the development teams, we were able to quickly identify critical process faults in this complex and dynamic health care delivery system.

Visual comparison of performance with a previous drill's logs shows qualitative improvement of network-level functionality and can be used for system evaluation.



communication among WiSARD roaming devices (wireless Access Points, PDAs, Tablets, wireless triage TAGs and PulseOx units) is enabled by a client/server architecture. The WiSARD server interfaces to an SQL database (PostgreSQL) which acts as centralized repository for persistent objects ("models") shared by the roaming clients.

TCP clients run on PDAs and Tablets. These actograms faithfully represent connection state transitions. Interval-like PDA and Tablet (TCP) client connections made to WiSARD server. While disconnected, updates to shared models are cached locally, and opportunistically synchronize to server state upon reconnection (push messaging)

point-like TAG and PulseOx (UDP) connections made to WiSARD server

Triage status updates from roaming TAGs and PDAs logged by WiSARD server. Temporal clustering reflects care of successive waves of victims

Vanderbilt UMC Emergency Department 2006

Periodic and complex temporal patterns in operational parameters electronically logged at an ED, structured via a calendar-based viz

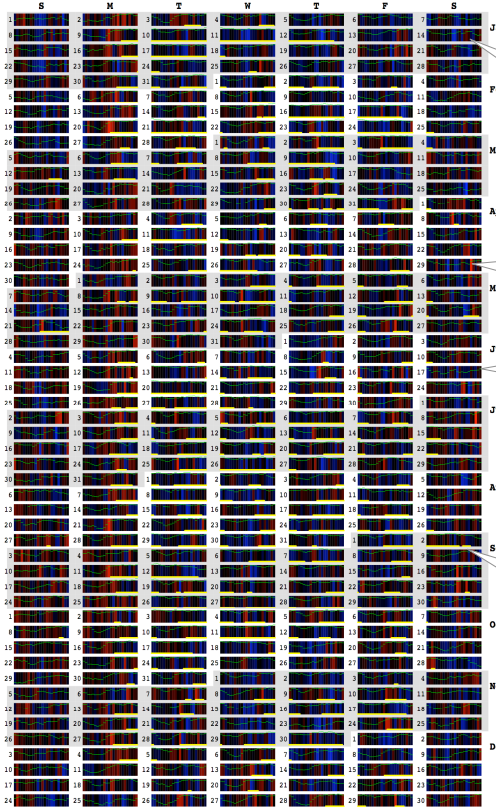
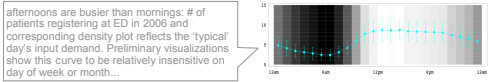
Overcrowding of emergency departments compromises health care quality nationwide. A real-time early warning system for overcrowding may allow decision-makers to take action before reaching a crisis state (e.g. ambulance diversion). At Vanderbilt University Medical Center ED, operational parameters that reflect input (patient demand), throughput (clinical process factors that lead to process bottlenecks) and output (adverse consequences) factors are displayed and logged electronically in real-time. Understanding temporal patterns in these dynamic records may lead to improvement in computational models of this clinical process being developed to predict ED overcrowding. In particular, diversion onset. Evaluation of these models must take into account not only their classification accuracy but also on their timeliness: how far in advance can the system anticipate a crisis? A calendar-based visualization serves to highlight cyclic as well as more complex patterns at daily, weekly and monthly scales.

Key Findings

Although the daily profile of ED registrations is stable throughout the year (varying little with day of week or month), ED occupancy ratio (measuring throughput) and diversion episodes (measuring output), trace out less predictable curves, suggesting a complex interplay of these factors.

This is consistent with the view that hospital-side overcrowding has an effect on ED bottlenecks.

Indirectly, this suggests that to capture the temporal patterns displayed here, process-level dynamical models may need to be developed to improve prediction efforts.



Methods

KDD deals with methods for making sense of data logged by information systems by querying, linking, and transforming low-level databased records that are too voluminous to be digested directly, into more structured forms to reveal patterns that would otherwise remain hidden due to the complexity of the systems.

Viz is an approach to data analysis that focuses on accurate graphical displays of the results of the KDD stage and seeks to reveal informative events, trends and patterns latent in the data, taking advantage of our visual perceptual system's ability to parse complex patterns.

KDD+Viz is computationally intensive. Unlike classical statistical tools it is not an "out-of-the-box" approach, but requires algorithmic development.

Visualizations were developed in Mathematica (wolfram.com) using its custom programming language.

Data extraction, preliminary structuring queries and domain expertise were provided by SW Brown for WiSARD use-case; N Hoot for VUMC-ED.

...since this is not surprising, we subtract this stable daily ED registration curve and display the detrended deviations from the 2006 mean

red bars indicate a greater, and blue bars fewer, ED registrations relative to 2006 mean for that given hour. Color intensity is proportional to the magnitude of deviation

green curve shows % occupancy in ED. Although these trends display clear regularities, their qualitative features can differ from day to day

yellow bars indicate occurrence of ED diversion episodes based on objectively defined policy criteria, although human decision-making is also involved