# Visualizing Temporal Patterns of Demand, Throughput and Crowding in an Emergency Department

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*Abstract: Emergency department (ED) operational data were calculated at 10-minute intervals throughout 2006 (n = 52561) in the adult ED of an academic medical center. Several operational parameters per observation were measured to better understand temporal patterns of input, throughput, and output of medical services. This may allow for improvement of predictive models of overcrowding. Visualization of this dataset is structured by a calendar template, facilitating discovery of cyclic patterns at diurnal, weekly, and monthly scales.*

**Toward Prediction of ED Overcrowding**

Overcrowding of emergency departments (ED) is recognized as a widespread problem that adversely affects delivery of emergency medical services. It has been associated with decreased quality of care, increased costs and patient dissatisfaction. If ED administrators and decision-makers were alerted prior to severe overcrowding, based on operational parameters recorded in real-time, they may be able to intervene before care quality and access become compromised.

A forecasting model must incorporate a precise definition of crisis episode. Evaluation of the system must take into account the timeliness of warnings issued by the system. For the present research, ED overcrowding is equated with diversion events, i.e., time periods during which ambulances are diverted to nearby hospitals in an effort to alleviate crowding.

A conceptual model of ED overcrowding leads to a distinction between the input, throughput, and output components of patient flow. The input component corresponds to demand for ED services that generally cannot be controlled by the ED. The throughput component is related to operational bottlenecks in ED. The output component includes the external factors that force admitted patients to board for extended periods of time in the ED.

**KDD+Viz**

Knowledge Discovery from Databases and Data Visualization (KDD+Viz) are computationally intensive methodologies that aim to extract informative events, trends and patterns from high-dimensional datasets for exploratory data analysis, i.e. to aid model selection and hypothesis formation. Thus the objective of KDD+Viz is complementary to, but distinct from, classical model-driven confirmatory data analysis methodology, e.g. statistical inference and regression. By taking advantage of our visual system's capacity to parse complex patterns, the graphical output of the KDD+Viz process can reveal detailed relationships latent in data that is not likely to be discernible were the same dataset presented to domain experts in numerical (e.g. spreadsheet) form. A key principle of KDD+Viz is to iteratively present to experts a overview of complex dataset(s), followed by additional filtering and details on demand.

We present preliminary visualizations of a dataset reflecting input, throughput and output parameters recorded at the Vanderbilt University Medical Center (VUMC) ED throughout 2006 by real-time clinical information systems during routine care. This dataset consists of 1) 52561 observations aggregated at 10-minute intervals; each observation contains: timestamp, number of new patients registered in the past hour, percentage occupancy level, number of patients waiting for care, and number of inpatients boarding in the ED. 2) time-stamped onset and offset of ED ambulance diversion events at 1-minute resolution. At VUMC, diversion is based on an objectively defined policy but can be overruled by administrators.

The dataset described above is primarily organized by a calendar template to facilitate discovery of cyclic and complex temporal patterns at various time scales. This visualization shows that while the daily input demand curve seems relatively invariant on calendar date, measures of throughput and diversion display more complex patterns, indicating that hospital-side processes may affect these components.