A Data-driven Process Recommender Framework

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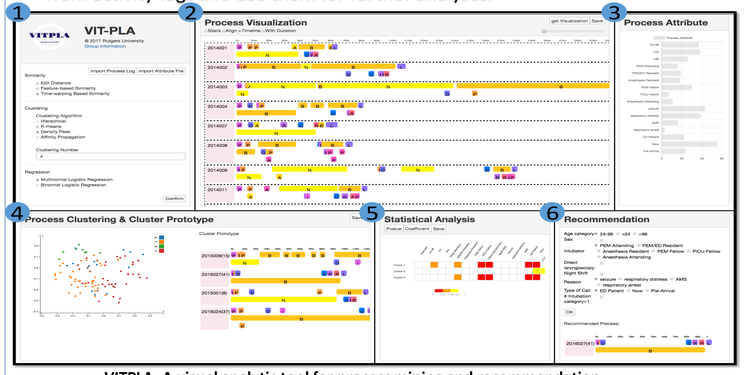
Introduction

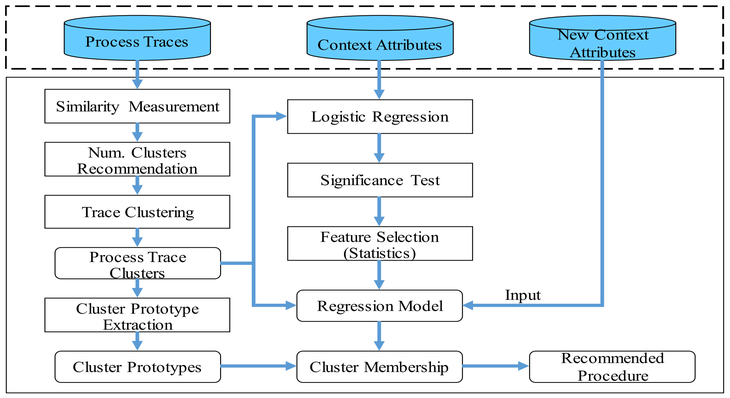
Background: Contemporary information systems, such as personal calendars and electronic health records (EHR), often record activity logs. Process mining techniques attempt to extract non-trivial knowledge and insights from activity logs and use them for further analyses.



VITPLA: A visual analytic tool for process mining and recommendation

Goal: Develop an interactive visual analytic tool to mine historic data to uncover the potential associations between the process performance steps and contextual attributes. If the association tests as significant, we train a recommender system to output a prototypical process performance for the given context attributes.

Framework Overview



(a) An overview of framework

Case ID	Activity	Start Time	End Time
xx1	Patient Arrival	0:00:00	0:00:01
xx1	NRB	0:00:00	0:00:01
xx1	Pre-Oxy Chest Ausc	0:01:08	0:01:23
xx1	Pre-Oxy Breath Verb	0:01:48	0:01:49
xx1	Airway Assessment	0:05:59	0:06:08
xx1	BVM	0:06:43	0:06:44
xx1	Critical Window	0:07:19	0:07:20
xx1	RSI Sedative Meds	0:07:50	0:08:02
xx1	RSI Paralytic Meds	0:08:16	0:08:32
xx1	BVM	0:09:52	0:09:53
xx1	Laryngoscopy	0:10:19	0:10:51

(b) Medical process trace

Case ID	xxx1	xxx2
Age category	24-96	24-96
Sex	Male	Female
Intubator	PEM Attending	PEM/ED Resident
Direct laryngoscopy	1	1
Night Shift	1	0
Reason	Seizure	Respiratory Distress
Type of Call	ED Patient	Now
Height (cm)	86	90
Weight (kg)	13	16.4
BMI	17.6	20.2
Num. Intubation Attempts	3	3

(c) Process case context attributes

Stage 1: Process analysis
(1) clustering of historic traces based on similarity
(2) determining the cluster prototypes that represent the established procedure for each cluster
(3) regression analysis to explore the correlation between cluster membership and context attributes
(4) interactive visualization and statistical analysis of process traces

Stage 2: Recommendation
(1) predicting the cluster to which the given trace belongs based on the observed context attributes
(2) displaying the prototype of the predicted cluster as the recommended procedure

Method

1) Time Warping based Trace Similarity

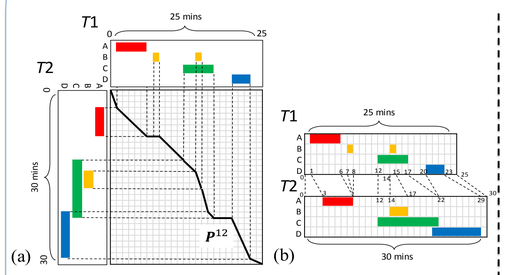


Figure (a) Illustration of the warping path calculated between T1 and T2. (b) Alignment of the warped timelines.

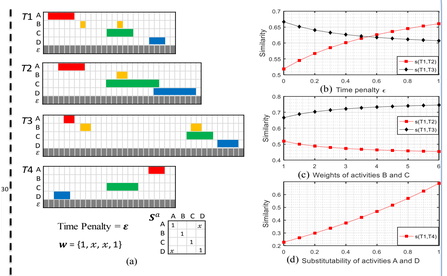


Figure (a) Example traces T_1 – T_4 showing how the similarity results are affected by (b) the time penalty ε, (c) activity weights w, and (d) activity substitutability S^{σ}.

2) Clustering Process Traces

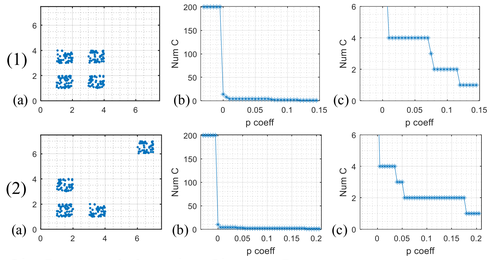


Figure: Two examples of synthetic data in rows (1) and (2) showing how NumC-AP (Algo. 2) decides the number of clusters. (a) The data distribution in a plane. (b) p^c vs. the number of clusters. (c) Zoomed-in view of (b).

3) Determining the Cluster Prototype

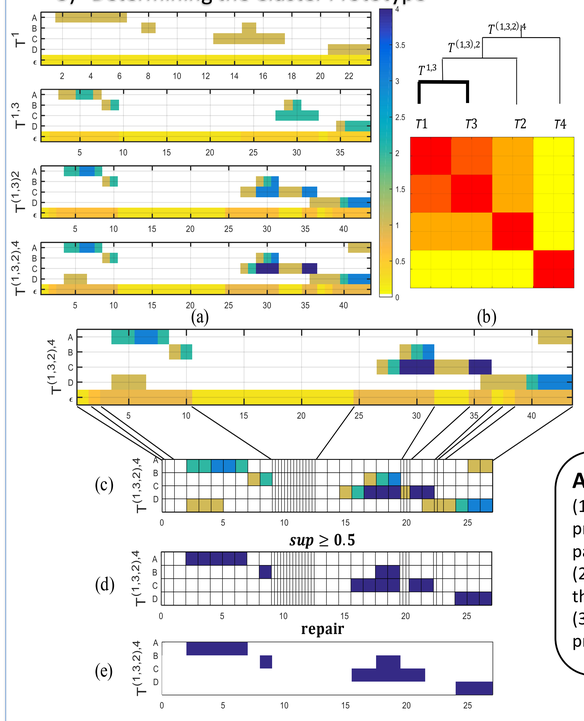


Figure: Steps for calculating a cluster prototype. (a) Calculating prototype q pairwise recursively from a set of process traces. Trace activities are shown in rows. After traces are aligned and activities summed up, the summed value is visualized using the color-bar from 1 to n, where n is the number of traces. (b) A guide tree for directing the prototype calculation for a cluster of traces. (c) Unwarping the warped timeline to restore the timeline and find the prototype. (d) Filtering the prototype using α. (e) Repairing activity C by moving smaller split part to the larger one.

Approach:
(1) discovering the time-warped prototype using time-warping paired with a divide-and-conquer
(2) unwarping the timeline to find the prototype
(3) filtering and repairing the prototype for easier interpretation.

4) The Recommender Model

The trained regression model selects the cluster class label y that maximizes the likelihood function:

$$y = \arg\max_{y} P(y|x', \hat{\beta})$$

where β are regression coefficients for context attributes

To generate recommendations, our system works by taking a new context attribute set **x'** (given by the user) and outputting a recommended procedure.

Experimental Results

1) Dataset Description

Datasets from three medical processes, collected in the emergency department of Children's National Medical Center, a level 1 pediatric trauma center in Washington, DC, were used for evaluating our framework.
Tracheal Intubation Data: Ten context attributes are of three types: (a) patient demographics (b) provider attributes and (c) event attributes.
Trauma Resuscitation Data: The trauma resuscitation is performed by a trauma team comprised of several physicians, nurses and all ancillary medical staff working concurrently. Each case was coded with 17 context attributes of two types

2) Similarity Metric Evaluation

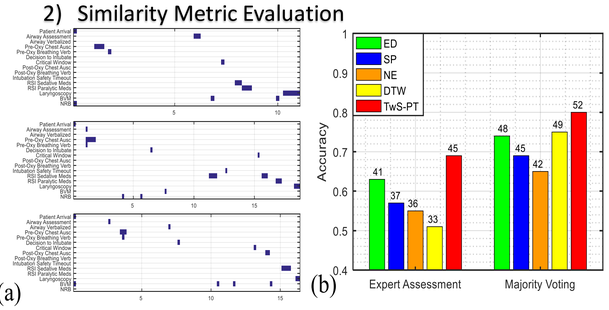


Figure (a) A sample set of Intubation procedures given to medical experts to evaluate. The x-axis denotes time and y-axis denotes different activities types. The blue blocks represent where and how long each activity occurred. (b) Comparison of different similarity metrics.

3) Prototype Analysis

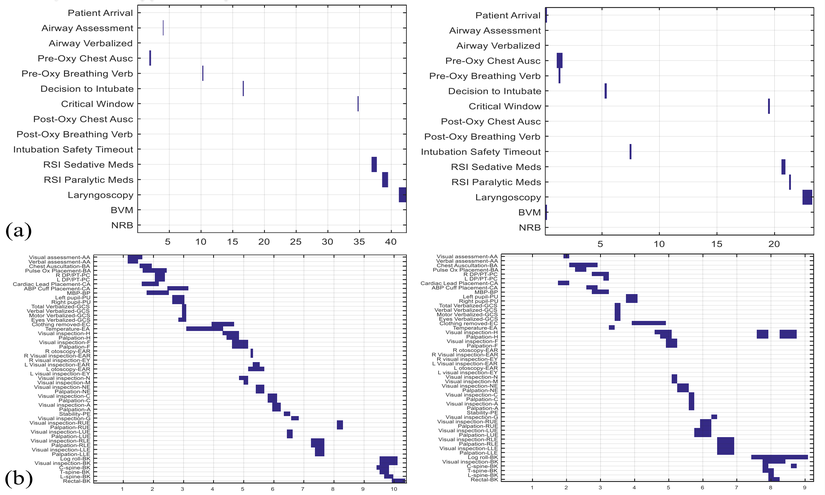


Figure (a) TwCP prototype (left) and medoid (right) for the whole Intubation dataset. (b) TwCP and medoid for Trauma dataset showing the 52 commonly performed activities. The vertical axis labels (activity names) were ordered based on rough temporal order of activities for easier comparison.

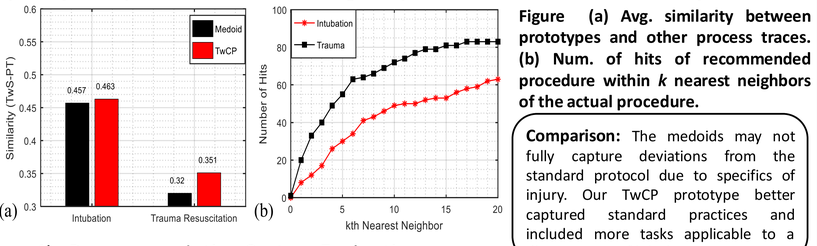


Figure (a) Avg. similarity between prototypes and other process traces. (b) Num. of hits of recommended procedure within k nearest neighbors of the actual procedure.

Comparison: The medoids may not fully capture deviations from the standard protocol due to specifics of injury. Our TwCP prototype better captured standard practices and included more tasks applicable to a diverse range of injuries.

4) Recommendation System Evaluation

	Intubation Data		Trauma Resuscitation Data	
Rec NC	**ED (2), SP (3), Time-Warping (2)**		**ED(2), SP (2), Time-warping (2)**	
Metrics	**F-Score**	**G-means**	**F-Score**	**G-means**
ED + HC	0.505 (0.504)	0.445 (0.479)	0.634 (0.654)	0.448 (0.428)
ED + DPC	0.719 (0.755)	0.383 (0.374)	0.692 (0.686)	0.436 (0.413)
ED + APC	0.415 (0.339)	0.416 (0.500)	0.346 (0.353)	0.392 (0.500)
SP + HC	0.286 (0.275)	0.412 (0.497)	0.637 (0.533)	0.603 (0.471)
SP + DPC	0.446 (0.264)	0.566 (0.496)	0.637 (0.533)	0.603 (0.471)
SP + APC	0.487 (0.277)	0.593 (0.471)	0.645 (0.519)	0.591 (0.475)
TwS-PT + HC	0.596 (0.419)	0.590 (0.495)	0.526 (0.392)	0.520 (0.497)
TwS-PT + DPC	0.605 (0.567)	0.494 (0.461)	0.713 (0.670)	0.556 (0.421)
TwS-PT + APC	**0.700 (0.384)**	**0.695 (0.498)**	**0.767 (0.366)**	**0.683 (0.499)**

Table: Recommendation evaluation on three medical process datasets. The format $\alpha\ (\tau)$ represents the regression model result α and the baseline (ZeroR) result (τ). Rec NC stands for recommended number of clusters.

Acknowledgement

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