Motivation
A World of Event Sequences

Oil Change > Replace Oil Filter > Tire Rotation

Vehicle Maintenance

Shot > Rebound > Steal

Sport Analytics

Admission > Treatment > Discharge

Healthcare

Browse Product > Add to Cart > Checkout

E-commerce

Motivation
Many Domains, Many Systems

Oil Change > Replace Oil Filter > Tire Rotation

Vehicle Maintenance (Sequence Synopsis)

Shot > Rebound > Steal

Sport Analytics (Rasipam)

Admission > Treatment > Discharge

HealthCare (EventThread2)

Browse Product > Add to Cart > Checkout

E-commerce (CoreFlow)

Compare

How do we learn from previous approaches when they seem so different?

Motivation
The Need for a Common Language

Task Abstractions are theoretical frameworks that describe visual analysis tasks in a generalized, domain-independent manner

- Enable meaningful comparisons

- Facilitate knowledge transfer

- Guide future tool development

Task Abstraction for Event Sequences
Facilitate Communication & Understanding

Help researchers understand domain expert goals and requirements

Provide domain experts guidance on choosing visualization systems for new problems

Task Abstraction for Event Sequences
Previous Task Abstraction Taxonomies: Overview & Limitations

Plaisant et. Al (2016)
High-level characterization of user tasks

Lacks mapping to low-level techniques

Task diversity - High Level Tasks:

Heighten awareness:
- T1 Review in detail a few records
- T2 Compile descriptive information about the dataset or a subgroup of records and events
- T3 Find and describe deviations from required or expected patterns

Prepare or select data for further study:
- T4 Review data quality and inform choices to be made in order to model the data
- T5 Identify a set of records of interest

Understanding impact of event patterns; plan action:
- T6 Compare two or more sets of records
- T7 Study antecedents or sequelae of an event of interest
- T8 Generate recommendations on actions to take

Du et. Al (2017)
Data reduction strategies for event sequences

Misses other analysis aspects

S1: Goal-Driven Record Extracting
S2: Goal-Driven Event Category Extracting
S3: Identifying Features Linked to Outcome
S4: Aligning
S5: Temporal Windowing
S6: Selecting Milestone Events
S7: Random Sampling of Records
S8: Temporal Folding
S9: Grouping Event Categories
S10: Coalescing Repeating Point Events into One
S11: Coalescing Repeating Interval Events into One
S12: Converting Hidden Complex Events into One
S13: Bucketing by Time Period
S14: Analyzing Small Subset then Larger One
S15: Partitioning

Peiris et. Al (2022)
Task typology for time-stamped event sequences

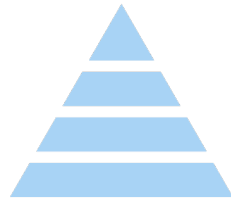Provides only multi-dimensional view of tasks

We present a **multi-level** and **multi-dimensional** task framework for event sequence analysis, providing a structured approach to map analysis goals to visualization and data manipulation techniques

Our Task Framework
Conceptual Structure

Multi-level

Multi-dimension

Objective

Intent

Strategy

Technique
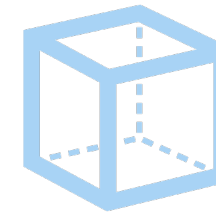
Action Input Output Criteria
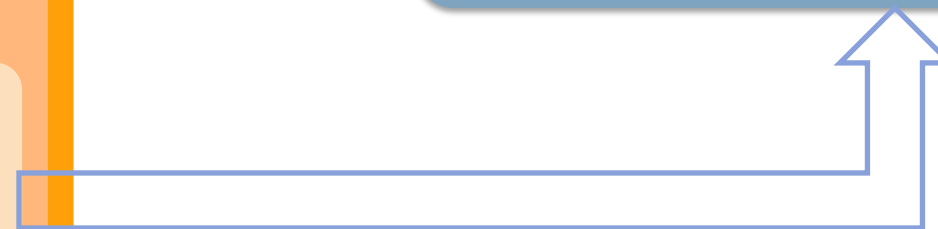
Corpus Assembly
Curating Event Sequence Systems

Publication Venue

Venue	Number of Systems
IEEE Transactions on Visualization and Computer Graphics (TVCG)	26
CHI	8
Computer Graphics Forum	4
ACM Transactions on Interactive Intelligent Systems	3
IEEE International Conference on Big Data (Big Data)	3
CHI Extended Abstracts	2
IEEE VAST	2
IUI	2
ACM Transactions on Intelligent Systems and Technology	1
Electronic Imaging	1
EuroVA (EuroVis Workshop on Visual Analytics)	1
IEEE VIS Posters	1
IEEE VIS Week Workshop on Visual Analytics in Healthcare	1
IEEE VizSec (Symposium on Visualization for Cyber Security)	1
Interacting with Computers	1
KDD Workshop on Interactive Data Exploration and Analytics	1

Number of Systems

Reviewed 58 papers representing 52 unique systems

Task Extraction
Extracting Clauses

Identified clauses describing action

" In the visualizations, users drill down to a link and compute branching patterns on subsequences in that link by double-clicking on the link. "

" users drill down to a link "

" compute branching patterns on subsequences in that link"

Example taken from CoreFlow: Extracting and Visualizing Branching Patterns from Event Sequences
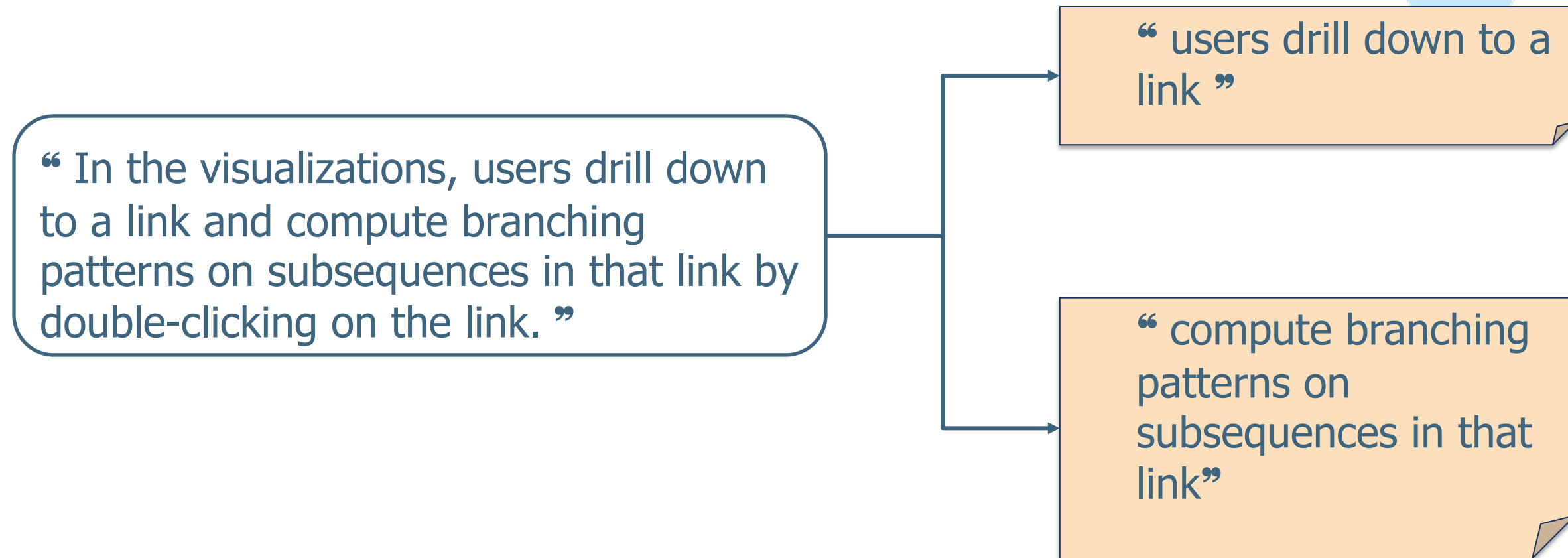
Task Characterization
Covering multi-dimensionality

Identified clauses describing action

Action: extract

Input : Event Sequences

Output : Branching Patterns

Criteria : Rank-Divide-Trim Algorithm

Techniques

"extracts branching patterns from event sequences by recursively applying the Rank-Divide-Trim three-step procedure"

Structuring Tasks
Defining Multi-level Hierarchy

Group into Hierarchical categories

Group related strategies based on the underlying motive

Identifying common patterns

Extracting latent patterns

Summarize

Summarize

Raw Event
Sequence Data

Aggregate

Algorithm

Data Simplification

Summary
Patterns
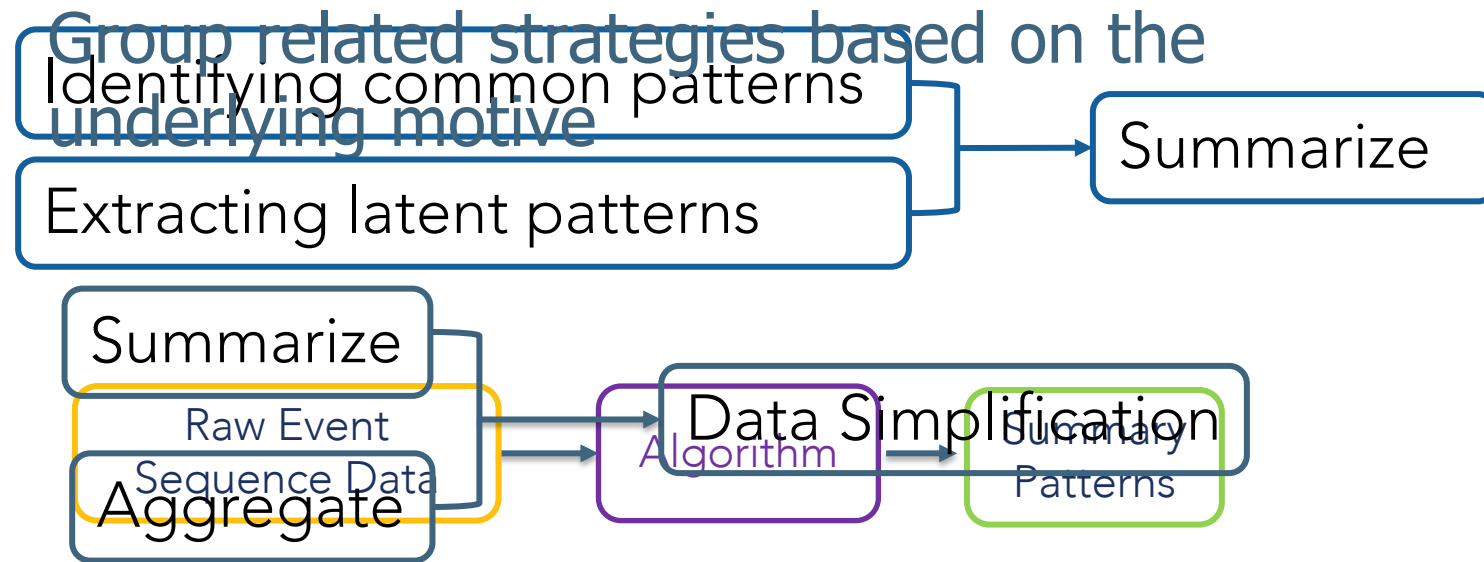
Objective

Intent

Strategy

Technique

Action Input Output Criteria

Structuring Tasks
Defining Multi-level Hierarchy

Objectives: Overarching goals of the analysis

Intents: Purpose of each analysis step

Strategies: Methods to accomplish each intent

Techniques: Specific implementations of each strategy

Objective

Intent

Strategy

Technique

Action Input Output Criteria

Our Task Framework
Four-Level Hierarchy

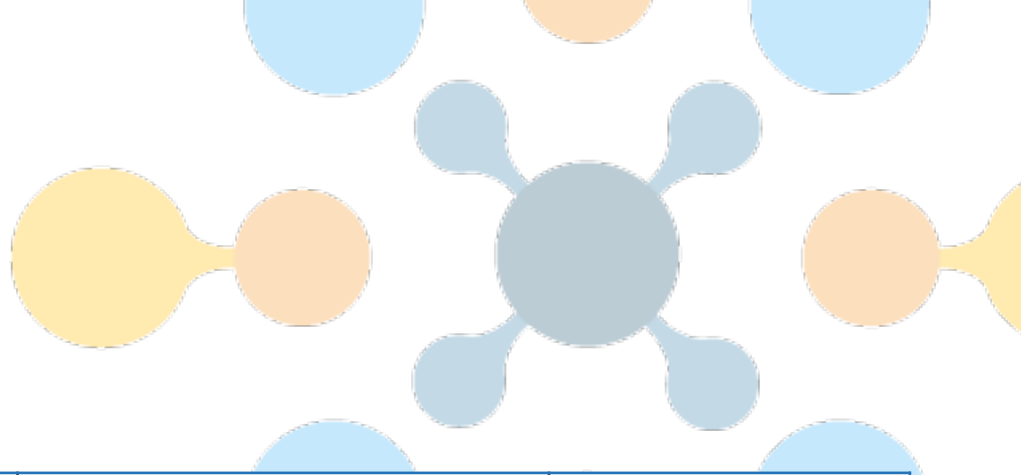| Objectives	Anomaly Detection	Stage Progression	Pattern Exploration	Prediction & Recommendation	Correlation & Causality Analysis	Cohort Comparison

Intents	Augment Data			Simplify Data			Configure Data			Configure Visualization				Create Provenance
Strategies	Derive	Group	Simulate	Aggregate	Summarize	Segment	Refine	Include-Exclude	Abstract-Elaborate	Visualize	Navigate	Focus	Rearrange	Document
Techniques	Obtain embeddings/ projections / attributes Compute similarity Align sequences	Group sequences Create event hierarchy	Mutate event attribute Generate next possible events	Coalesce Repeating Events Combine Events across Sequences	Calculate distribution Extract common patterns Extract latent patterns	Split sequences or patterns Temporal folding	Modify summary Adjust parameters	Execute dynamic queries Cross-filter	Details-on-demand Drill down-Roll up	Create visual representation Customize visual encoding	Zoom Pan	Highlight marks Select & link components	Reposition sequences Reorder/Sort sequences	Annotate representations Save/Record analysis Insert new marker event

Our Task Framework in Action
Codifying Analysis Tasks

"Determine which user behaviors lead to successful purchases on the website"

Example taken from CoreFlow: Extracting and Visualizing Branching Patterns from Event Sequences
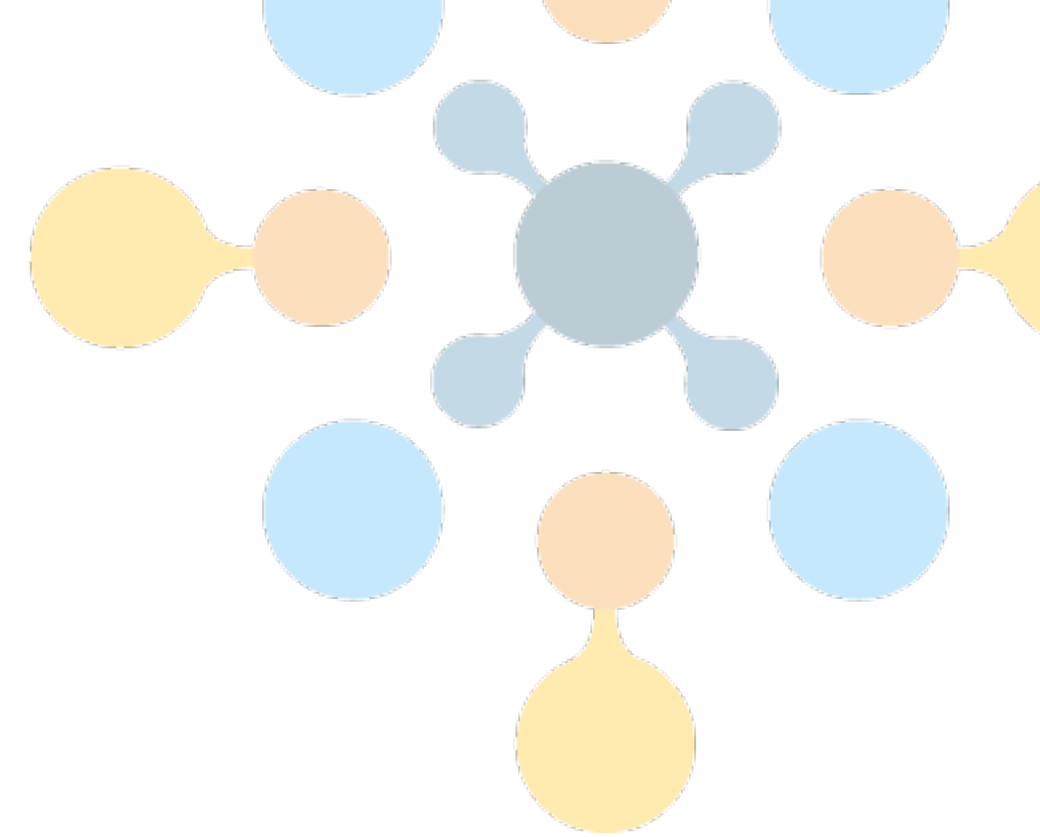
Our Task Framework in Action
Codifying Analysis Tasks : Identifying **Objective**

"Determine which user behaviors lead to successful purchases on the website"

Objectives	Anomaly Detection	Stage Progression	Pattern Exploration	Prediction & Recommendation	Correlation & Causality Analysis	Cohort Comparison

Example taken from CoreFlow: Extracting and Visualizing Branching Patterns from Event Sequences

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Our Task Framework in Action
Codifying Analysis Tasks : Identifying **Intent**

> " extracts branching patterns from event sequences by recursively applying the Rank-Divide-Trim three-step procedure "

Intents	Augment Data			Simplify Data			Configure Data			Configure Visualization				Create Provenance
Strategies	Derive	Group	Simulate	Aggregate	Summarize	Segment	Refine	Include-Exclude	Abstract-Elaborate	Visualize	Navigate	Focus	Rearrange	Document
Techniques	Obtain embeddings/ projections / attributes Compute similarity Align sequences	Group sequences Create event hierarchy	Mutate event attribute Generate next possible events	Coalesce Repeating Events Combine Events across Sequences	Calculate distribution Extract common patterns Extract latent patterns	Split sequences or patterns Temporal folding	Modify summary Adjust parameters	Execute dynamic queries Cross-filter	Details-on-demand Drill down-Roll up	Create visual representation Customize visual encoding	Zoom Pan	Highlight marks Select & link components	Reposition sequences Reorder/Sort sequences	Annotate representations Save/Record analysis Insert new marker event

Example taken from CoreFlow: Extracting and Visualizing Branching Patterns from Event Sequences

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Our Task Framework in Action
Codifying Analysis Tasks : Identifying **Strategy**

> " extracts branching patterns from event sequences by recursively applying the Rank-Divide-Trim three-step procedure "

Intents	Simplify Data		
Strategies	Aggregate	Summarize	Segment
Techniques	Coalesce Repeating Events Combine Events across Sequences	Calculate distribution Extract common patterns Extract latent patterns	Split sequences or patterns Temporal folding

Example taken from CoreFlow: Extracting and Visualizing Branching Patterns from Event Sequences

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Our Task Framework in Action
Codifying Analysis Tasks : Identifying **Technique**

" extracts branching patterns from event sequences by recursively applying the Rank-Divide-Trim three-step procedure "

Intents	Simplify Data		
Strategies	Aggregate	Summarize	Segment
Techniques	Coalesce Repeating Events Combine Events across Sequences	Calculate distribution Extract common patterns Extract latent patterns	Split sequences or patterns Temporal folding

Example taken from CoreFlow: Extracting and Visualizing Branching Patterns from Event Sequences

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Our Task Framework in Action
Codifying Analysis Tasks : Technique Dimensions

Technique: Common pattern extraction

Action: extract
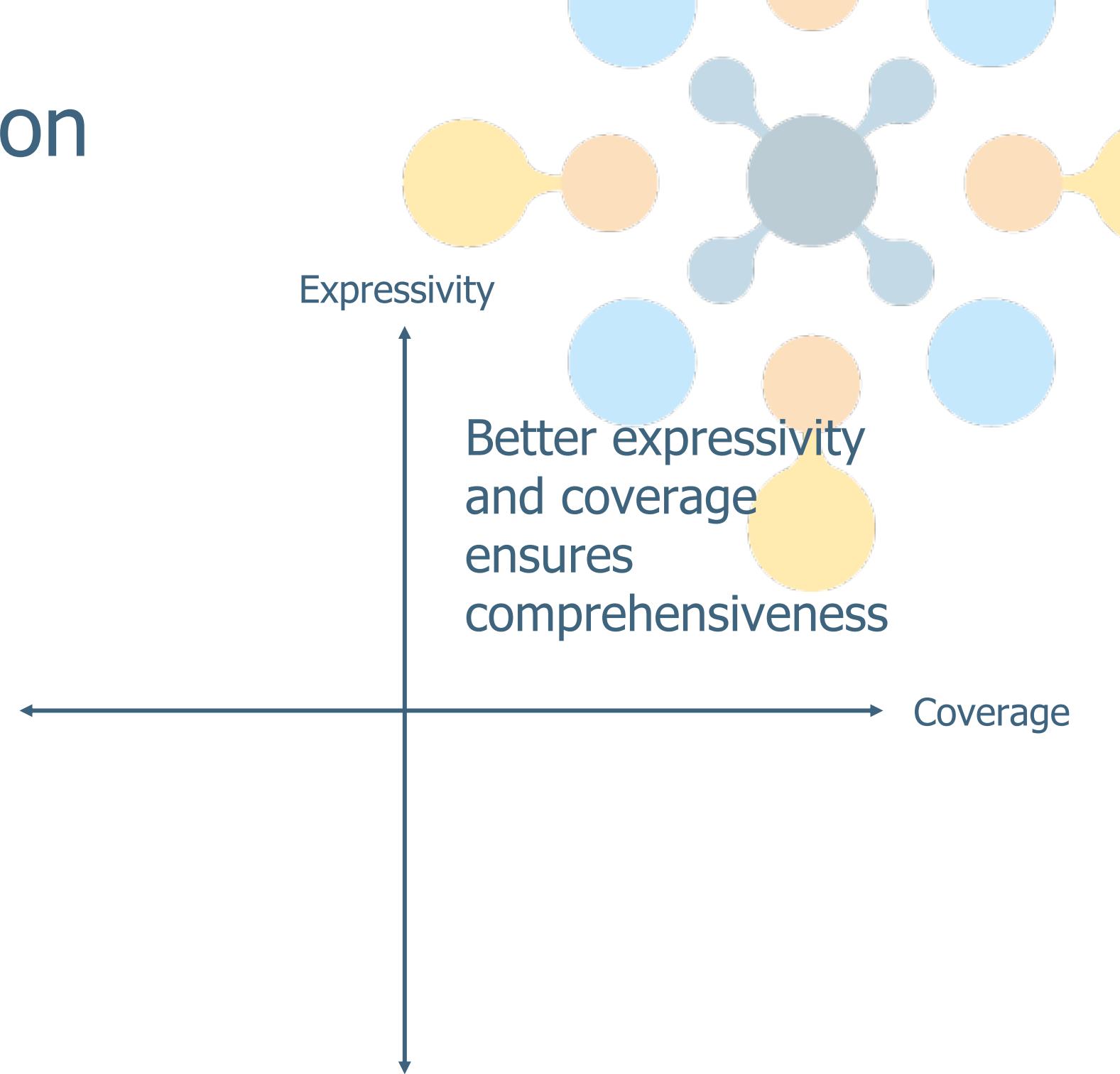Input : Event Sequences
Output : Branching Patterns
Criteria : Rank-Divide-Trim, mining parameters

" extracts branching patterns from event sequences by recursively applying the Rank-Divide-Trim three-step procedure "
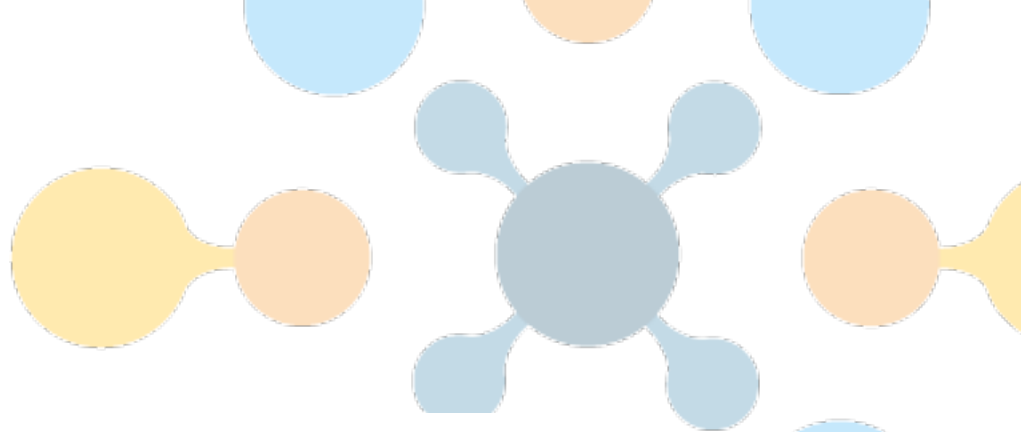
Task Framework Evaluation
Expressivity & Coverage

- **Expressivity**: The depth and detail of information provided by the framework for each task

- **Coverage**: The variety of tasks the framework can effectively describe across analysis pipeline

Expressivity

Better expressivity and coverage ensures comprehensiveness

Coverage

Tasks	C1.T1 [30]	C1.T3 [30]	C1.T7 [30]	C2.T7 [68]	C2.T9 [68]	C3.T7 [41]
Excerpt	The doctors queried a group of 127 middle-aged patients aging from 50 to 60 who were diagnosed with pneumonia.	After several iterations of confirming causalities and model updates, …	The doctors saved the final causality to the analysis history view.	E2 re-ranked the tactics in Tactic View based on the tactical importance …	Experts applied this merging adjustment and obtained a more accurate estimate of the win rate for this serving tactic.	Changing the color attribute to sepsis, …
Plaisant et al. [54]	Prepare or select data for further study. Identify a set of records of interest	Prepare or select data for further study. Review data quality and inform choices to be made in order to model the data	n/a	Prepare or select data for further study. Identify a set of records of interest	Prepare or select data for further study. Review data quality and inform choices to be made in order to model the data	n/a
Du et al. [14]	Extraction Strategies Graph Linear Sequence trACting	n/a	n/a	n/a	n/a	n/a
Peiris et al. [49]	action: Filter target: Event Sequences criteria: Metadata Attributes	action: Derive Metrics target: n/a	action: Annotate target: n/a	action: Sort/Rank target: Event Sequences criteria: Sequences	action: Add/Modify target: Event Sequences criteria: Metrics Attributes	n/a
Ours	Intent: Configure Data Strategy: Include-Exclude Technique: Execute Dynamic Queries action: Query input: Event Sequences output: Filtered Event Sequences criteria: Age	Intent: Configure Data Strategy: Refine Technique: Adjust Parameters action: Adjust input: Current causal model output: Updated causal model criteria: Domain knowledge	Intent: Manage Provenance Strategy: Document Technique: Save/Record Analysis action: Save/Record input: Analysis State output: Saved/Recorded Analysis criteria: User-specified snapshot	Intent: Configure Visualization Strategy: Rearrange Technique: Reorder/Sort Components action: Reorder/Sort input: Tactics output: Reordered Tactics criteria: Tactical importance metric	Intent: Configure Data Strategy: Refine Technique: Modify Summary action: Modify input: Tactics output: Modified Tactics criteria: Domain knowledge	Intent: Configure Visualization Strategy: Visualize Technique: Produce Visualization action: Produce input: Event sequence data output: Visual representation criteria: Visual encoding rules

Our Framework is comprehensive in expressing event sequence analysis tasks
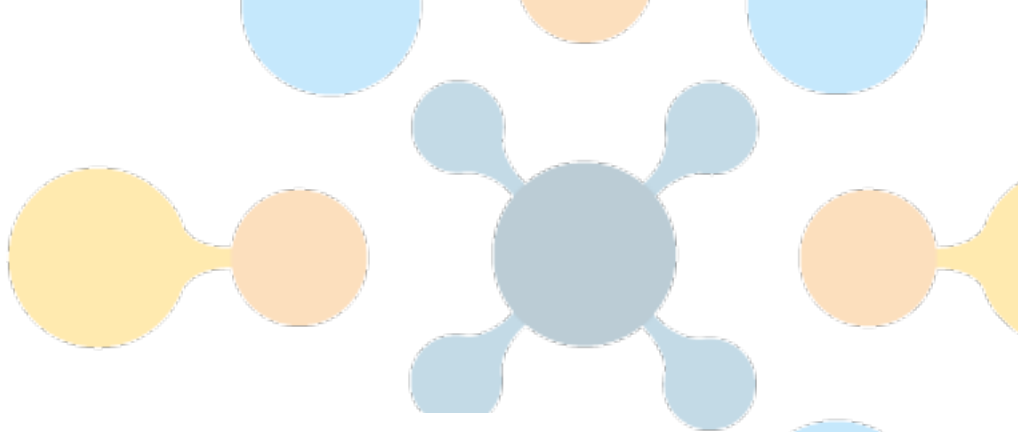
Task Framework Evaluation
Analyzing Coverage: Takeaway

Tasks	C1.T1 [30]	C1.T3 [30]	C1.T7 [30]	C2.T7 [68]	C2.T9 [68]	C3.T7 [41]
Excerpt	*The doctors queried a group of 127 middle-aged patients aging from 50 to 60 who were diagnosed with pneumonia.*	*After several iterations of confirming causalities and model updates, …*	*The doctors saved the final causality to the analysis history view.*	*E2 re-ranked the tactics in Tactic View based on the tactical importance …*	*Experts applied this merging adjustment and obtained a more accurate estimate of the win rate for this serving tactic.*	*Changing the color attribute to sepsis, …*
Plaisant et al. [54]	*Prepare or select data for further study* / Identify a set of records of interest	*Prepare or select data for further study* / Review data quality and inform choices to be made in order to model the data	n/a	*Prepare or select data for further study* / Identify a set of records of interest	*Prepare or select data for further study* / Review data quality and inform choices to be made in order to model the data	n/a
Du et al. [14]	*Extraction Strategies*	n/a	n/a	n/a	n/a	n/a
Peiris et al. [4]	action: Filter / target: Event Sequences / criteria: Metadata Attributes	action: Derive Metrics / target: n/a / criteria: n/a	action: Annotate / target: n/a / criteria: n/a	action: Sort/Rank / target: Event Sequences / criteria: Metadata/Feature	action: Add/Modify / target: Event Sequences	n/a
Ours	Intent: Configure Data / Strategy: Include-Exclude / Technique: Execute Dynamic Queries / action: Query / input: Event Sequences / output: Filtered Event Sequences / criteria: Age	Intent: Configure Data / Strategy: Refine / Technique: Adjust Parameters / action: Adjust / input: Current causal model / output: Updated causal model / criteria: Domain knowledge	Intent: Manage Provenance / Strategy: Document / Technique: Save/Record Analysis / action: Save/Record / input: Analysis State / output: Saved/Recorded Analysis / criteria: User-specified snapshot	Intent: Configure Visualization / Strategy: Rearrange / Technique: Reorder/Sort Components / action: Reorder/Sort / input: Tactics / output: Reordered Tactics / criteria: Tactical importance metric	Intent: Configure Data / Strategy: Refine / Technique: Modify Summary / action: Modify / input: Tactics / output: Modified Tactics / criteria: Domain knowledge	Intent: Configure Visualization / Strategy: Visualize / Technique: Produce Visualization / action: Produce / input: Event sequence data / output: Visual representation / criteria: Visual encoding rules

Our Framework is capable of capturing end-to-end event sequence analysis workflows

Our Contribution
Multi-Level Task Framework

✓ Captures the unique complexities of event sequence data and analysis

✓ Provides multiple levels of abstraction, from high-level goals to low-level operation

✓ Covers end-to-end analysis workflows, incorporates both visualization and data manipulation techniques

✓ Provides both multi-level and multi-dimensional view of tasks

Our Task Framework

Kazi Tasnim Zinat Saimadhav Naga Sakhamuri Aaron Sun Chen Zhicheng Liu

Objectives	Anomaly Detection	Stage Progression		Pattern Exploration		Prediction & Recommendation		Correlation & Causality Analysis		Cohort Comparison

Intents	Augment Data			Simplify Data			Configure Data			Configure Visualization				Create Provenance
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