## TVCG Papers in EuroVis 2019

# Understanding User Behaviour through Action Sequences: from the Usual to the Unusual

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**Abstract:**
Action sequences, where atomic user actions are represented in a labelled, timestamped form, are becoming a fundamental data asset in the inspection and monitoring of user behaviour in digital systems. Although the analysis of such sequences is highly critical to the investigation of activities in cyber security applications, existing solutions fail to provide a comprehensive understanding due to the complex semantic and temporal characteristics of these data. This paper presents a visual analytics approach that aims to facilitate a user-involved, multi-faceted decision making process during the identification and the investigation of unusual action sequences. We firstly report the results of the task analysis and domain characterisation process. Then we describe the components of our multi-level analysis approach that comprises of constraint-based sequential pattern mining and semantic distance based clustering, and multi-scalar visualisations of users and their sequences. Finally, we demonstrate the applicability of our approach through a case study that involves tasks requiring effective decision-making by a group of domain experts. Although our solution here is tightly informed by a user-centred, domain-focused design process, we present findings and techniques that are transferable to other applications where the analysis of such sequences is of interest.

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# ViSeq: Visual Analytics of Learning Sequence in Massive Open Online Courses

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**Abstract:**
The research on massive open online courses (MOOCs) data analytics has mushroomed recently because of the rapid development of MOOCs. The MOOC data not only contains learner profiles and learning outcomes, but also sequential information about when and which type of learning activities each learner performs, such as reviewing a lecture video before undertaking an assignment. Learning sequence analytics could help understand the correlations between learning sequences and performances, which further characterize different learner groups. However, few works have explored the sequence of learning activities, which have mostly been considered aggregated events. A visual analytics system called ViSeq is introduced to resolve the loss of sequential information, to visualize the learning sequence of different learner groups, and to help better understand the reasons behind the learning behaviors. The system facilitates users in exploring learning sequences

from multiple levels of granularity. ViSeq incorporates four linked views: the projection view to identify learner groups, the pattern view to exhibit overall sequential patterns within a selected group, the sequence view to illustrate the transitions between consecutive events, and the individual view with an augmented sequence chain to compare selected personal learning sequences. Case studies and expert interviews were conducted to evaluate the system.

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## Exploratory Visual Sequence Mining Based on Pattern-Growth

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**Abstract:**
Sequential pattern mining finds applications in numerous diverging fields. Due to the problem's combinatorial nature, two main challenges arise. First, existing algorithms output large numbers of patterns many of which are uninteresting from a user's perspective. Second, as datasets grow, mining large number of patterns gets computationally expensive. There is, thus, a need for mining approaches that make it possible to focus the pattern search towards directions of interest. This work tackles this problem by combining interactive visualization with sequential pattern mining in order to create a "transparent box" execution model. We propose a novel approach to interactive visual sequence mining that allows the user to guide the execution of a pattern-growth algorithm at suitable points through a powerful visual interface. Our approach (1) introduces the possibility of using local constraints during the mining process, (2) allows stepwise visualization of patterns being mined, and (3) enables the user to steer the mining algorithm towards directions of interest. The use of local constraints significantly improves users' capability to progressively refine the search space without the need to restart computations. We exemplify our approach using two event sequence datasets; one composed of web page visits and another composed of individuals' activity sequences.

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