Evidence to support common application switching behaviour on smartphones

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Objectives

- Network motifs have primarily been used to analyze biological and engineered complex systems, as well as social networks. The primary objective of this work is to determine whether network motifs are also useful in examining networks surrounding human behavior.
- In particular, we focus on a common network science task of comparing network similarity, which could then be used for applied tasks such as anomaly detection. The successfulness of this also motivates further research surrounding network motif analysis methods.

Technical Challenges

- Publicly available directed networks are limited in comparison to undirected. Within these, few refer to human behavior at a personal level, rather than across a population (e.g., where nodes are people). So we use app switch networks as a proxy for human habit/routine behaviors.

Approaches

Step 1: We create networks for each individual, representing the sequential flow between their actions over some time period – in this example dataset, switches from one application to another over 6-weeks.

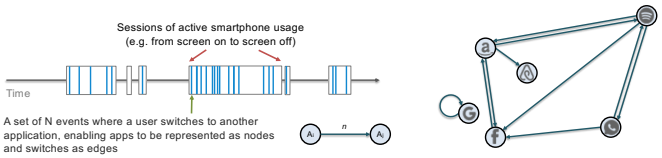

Figure 1: Networks can be created from sequential events representing human actions

Step 2: We examine how network motifs can help with a common network science task – comparing network similarity. To do this we:

1. Count the number of occurrences of each type triad (Figure 2a).
2. Calculate a normalized subgraph ratio profile (SRP) (Figure 2b) which shows whether the triads occur more or less frequently in comparison to random networks.
3. Compare whether these values are similar across the networks.

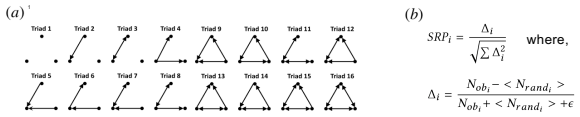

Figure 2: Networks can be created from sequential events representing human actions

Step 3: We also examine how the topological properties of the networks relate to common types of networks – e.g., small world networks.

Military & Coalition Relevance

- Network motif analysis has predominantly only been applied to networks relating to biological systems or social networks. This work highlights the potential for the method to have utility in analyzing networks representing personal human behavior. An example use case is to detect anomalies in 'typical' behavior patterns.
- The dataset also provides a rich basis for use in other network science related research within DAIS-ITA, as a set of directed networks within a single human behavior oriented genre.

[1] Akin, M., Onderdonk, A., & Guo, Y. (2017). Effects of local network topology on the functional reconstruction of spiking neural network models. *Applied network science*, *2*(1), 22.

Results

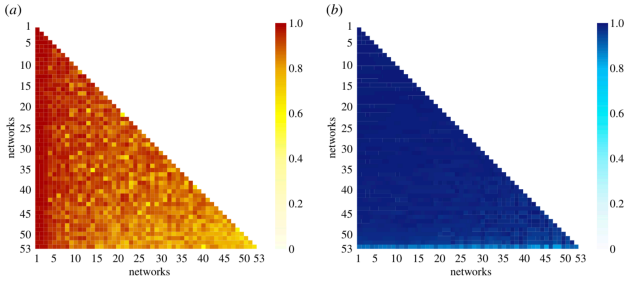

Figure 3: Pairwise comparisons of the app switch networks. (a) Similarity matrix based on edit distance (0 = identical networks (white), 1 = completely dissimilar networks (red)). (b) Correlation coefficient matrix based on subgraph ratio profiles (0 = profile dissimilarity (white), 1 = strong profile similarity (blue)).

- The networks are very different in terms of the exact nodes and edges (Figure 3a shows the pairwise edit distance between the networks). From this perspective, the behavior of users could be regarded as behaving very differently from one another.
- However, analysis of unlabeled network structure using network motifs (Figure 3b shows the pairwise correlation coefficient between the SRPs) and other normalized network measures shows that the networks are highly similar in this regard (i.e, humans have similar habits and mannerisms irrespective of what exact apps they use).
- Within this, we find that triads with at least one reciprocal edge are commonly overrepresented in the networks and those uni-directional are underrepresented.
- Finally, the networks exhibit similar topological properties to common 'classes' of networks. They have small-world characteristics with high node clustering and short paths between them. Additionally, Figure 4b shows that the node strength distribution can be fitted against a truncated powerlaw – a characteristic of 'broad-scale' networks and the degree distribution against single-scale networks.

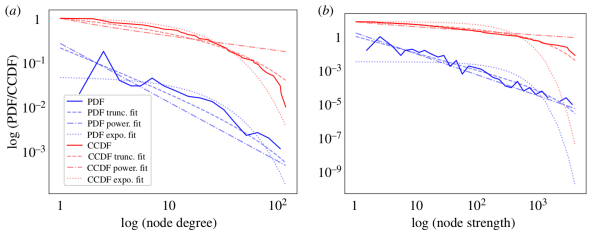

Figure 4: Distribution fitting for an example network showing similarity with broad classes of networks

Summary & Future Work

- Network motifs provide a general purpose method for examining the higher-order structure of human behaviour networks and enable common and unique patterns to be observed, irrespective of the exact behaviors.
- This work motivates further research extending network motif methods to capture more detail in the structure of the behaviour – for example, the extent that the motifs overlap with one another.

Publication(s) & Impact

Turner, L. D., Whitaker, R. M., Allen, S. M., Linden, D. E., Tu, K., Li, J., & Towsley, D. (2019). Evidence to support common application switching behaviour on smartphones. *Royal Society Open Science*, *6*(3).