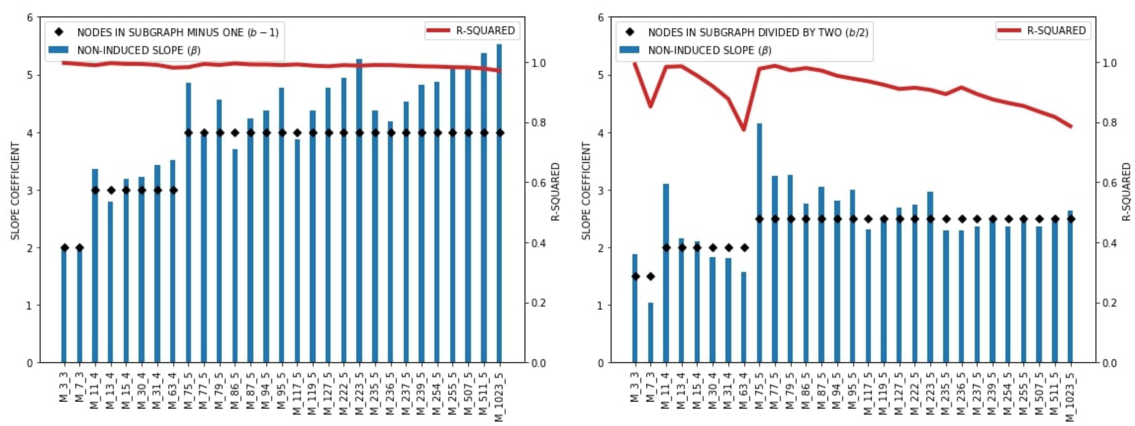
Subgraphs, motifs, and scaling in a dynamic airline network

Steve Lawford, ENAC
(joint work with Marius Agasse-Duval, ENAC)

Abstract

How does the small-scale topological structure of an airline network behave as the network evolves? To address this question, we study the dynamic and spatial properties of small undirected subgraphs using 15 years of data on Southwest Airlines' direct route service on the U.S. domestic market. We use exact enumeration formulae to identify statistically over- and under-represented subgraphs, known as motifs and anti-motifs, with up to five nodes. We discover substantial topology transitions in Southwest's network and provide evidence for time-varying power-law scaling between subgraph counts and the number of edges in the network. We draw comparisons with the implied scaling properties of an Erdős-Rényi random graph and several deterministic graphs, and use a toy regime-switching model to provide insight into changes in scaling behaviour. We also suggest a node-ranking measure that can identify important nodes relative to specific local topologies. Our results extend the toolkit of subgraph-based methods and provide new insight into transportation networks and the strategic behaviour of firms.

Figure — Evidence for Dynamic Scaling Transitions



(a) Regime 1 (b) Regime 2

(a) A summary of log-log least squares regressions of non-induced subgraph count on number of edges, for Southwest's network, over the period 1999Q1 to 2008Q4 (40 datapoints). There is evidence that $\beta \approx b-1$ for each 3-node, 4-node and 5-node subgraph, indicating a power-law relationship between subgraph count and edges. (b) A summary of log-log least squares regressions of non-induced subgraph count on number of edges, for Southwest's network, over the period 2009Q1 to 2013Q4 (20 datapoints). There is evidence that $\beta \approx b/2$ for each 3-node, 4-node and 5-node subgraph, indicating a different power-law relationship to Figure (a).