Algorithmic Aspects of Temporal Graphs

Room: S9 (1st floor)

Speaker	**Abstract**
Paola Flocchini	A large literature exists on distributed computations by mobile agents operating in graphs. Typical problems include exploration, map construction, rendezvous, black hole search, network decontamination, etc. On the other hand, little is known when the agents move and compute in time-varying graphs, where topological changes are a natural and frequent occurrence, and most of these studies are centralized and offline. In this talk I will review recent decentralized online solutions to gathering and exploration in time-varying graphs.

Speaker	**Abstract**
Arnaud Casteigts	We define a new type of robust structure motivated by a large class of highly dynamic networks, namely those networks where temporal connectivity is recurrently achieved (over an infinite lifetime). Such a regularity forces some of the links to reappear infinitely often, although these links are indistinguishable from the ones that appear finitely many times. The resulting uncertainty gives rise to a new notion of heredity in graph, which we will illustrate through a number of basic properties and two classical problems (MIS and MDS). This is a joint work with Swan Dubois, Franck Petit, and John Michael Robson.

Speaker	Abstract
Ralf Klasing	We present a general framework for computing parameters of dynamic networks which are modeled as a sequence $(G_1, G_2, ..., G_\delta)$ of static graphs such that $G_i = (V, E_i)$ represents the network topology at time i and changes between consecutive static graphs are arbitrary. The framework operates at a high level, manipulating the graphs in the sequence as atomic elements with two types of operations: a *composition* operation and a *test* operation. The framework allows us to compute different parameters of dynamic graphs using a common high-level strategy by using composition and test operations that are specific to the parameter. The resulting algorithms are optimal in the sense that they use only $O(\delta)$ composition and test operations, where δ is the length of the sequence. We illustrate our framework with three minimization problems, namely *bounded realization of the footprint*, *temporal diameter*, and *round trip temporal diameter*, as well as with one maximization problem, namely *T-interval connectivity*. We prove that the problems are in the class NC by presenting polylogarithmic-time parallel versions of the algorithms. Finally, we show that the algorithms can operate online with amortized complexity $\Theta(1)$ composition and test operations for each graph in the sequence. This is joint work with Arnaud Casteigts, Yessin M. Neggaz, and Joseph G. Peters.

Speaker	Abstract
Christos Zaroliagis	Computing shortest paths in networks that exhibit a time-dependent metric is a core routine for many applications. In this talk, we present an axiomatic approach which shows that for directed networks that satisfy certain properties we can provide time-dependent distance oracles that exhibit subquadratic preprocessing time and space (independent of the metric's amount of disconcavity) and query time sublinear on the network size, or the actual Dijkstra rank of the query at hand.

Speaker	Abstract
Matthieu Latapy	Money or data transfers, contacts between individuals, or product sales, may all be modeled as temporal interactions. Studying the structure and dynamics of interactions is therefore crucial for many fundamental and applied questions (like event detection in traffic, fraud fighting, recommender systems, network optimisation, and the interplay between relations and interactions). Their structure is studied with graphs and networks (sets of nodes and links); their dynamics is studied with signals and time series (variations of a property over time); to study the dynamics of their structure, one uses graph sequences. However, these approaches poorly capture the both structural and temporal nature of interactions, that calls for a dedicated formalism. I will present a generalization of graphs, that we call link streams and stream graphs, and that makes it possible to consistently handle both aspects. We thus obtain a language for the study of interactions over time, similar to the one provided by graphs for the study of relations.

Speaker	Abstract
Clemence Magnien	Link streams model interactions over time as sequences of triplets (t, u, v) meaning that an interaction between u and v occurred at time t. Such interactions may represent financial transactions, network traffic, mobility, sales, contacts, messages, and many other objects of interest. A variety of graph concepts were recently generalized to link streams, and are useful to describe such sequences of interactions. This includes clustering coefficient, k-cores, connected components, closeness, betweenness, and cliques, that raise many algorithmic challenges. I will present in particular our works on clique computations in link streams, which already received much attention. I will also illustrate their relevance in the contexts of network traffic and of contacts between individual analysis.

Speaker	Abstract
Thomas Erlebach	For a given temporal graph that is connected in every step, the temporal exploration problem asks for a shortest temporal walk that starts at a given start vertex and visits every vertex of the graph at least once. For temporal graphs with n vertices, it is known that $O(n^2)$ steps suffice for an exploration and that $\Omega(n^2)$ steps are also necessary in the worst case. We consider temporal graphs where the graph in every step has bounded degree. For this case, we show that exploration in $o(n^2)$ steps is always possible. This is joint work with Jakob Spooner.

Speaker	Abstract
Eleni Akrida	We study the problem of exploring a temporal graph (i.e. a graph that changes over time), in the fundamental case where the underlying static graph is a star. The aim of the exploration problem in a temporal star is to find a temporal walk which starts at the center of the star, visits all leafs, and eventually returns back to the center. We initiate a systematic study of the computational complexity of this problem, depending on the number k of time-labels that every edge is allowed to have. To do so, we distinguish between the decision version StarExp(k) asking whether a complete exploration of the instance exists, and the maximization version MaxStarExp(k) of the problem, asking for an exploration schedule of the greatest possible number of edges in the star. We present a collection of results establishing the computational complexity of these two problems. This is joint work with George B. Mertzios and Paul G. Spirakis.

Speaker	Abstract
Hendrik Molter	Vertex separators, that is, vertex sets whose deletion disconnects two distinguished vertices in a graph, play a pivotal role in algorithmic graph theory. For many realistic models of the real world it is necessary to consider graphs whose edge set changes with time, more specifically, the edges are labeled with time stamps. While there is an extensive literature on separators in “static” graphs, much less is known for the temporal setting. Building on previous work, we study the problem of finding a small vertex set (the separator) in a temporal graph with two designated terminal vertices such that the removal of the set breaks all temporal paths connecting one terminal to the other. Herein, we consider two models of temporal paths: paths that contain arbitrarily many hops per time step (non-strict) and paths that contain at most one hop per time step (strict). Both versions of temporal separation are known to be NP-hard which motivates a parameterized complexity analysis and studying the complexity of the problem on restricted classes of temporal graphs. This talk will give an overview of recent results based on joint work with Philipp Zschoche, Till Fluschnik and Rolf Niedermeier.

Speaker	**Abstract**
Jessica Enright and Kitty Meeks	The concept of reachability (i.e. which vertices in a graph can be reached by travelling along edges from a given starting vertex) is central to many applications, including the dissemination of information or the spread of disease through a network. Depending on the application, it might be desirable to increase or decrease the number of vertices that are reachable from any one starting vertex. In most applications, time plays a crucial role: each contact between individuals, represented by an edge, will only occur at certain time(s). The relative timing of edges is clearly crucial in determining the reachability of any vertex in the graph. In this pair of talks, we will address the problems of reducing the maximum reachability of any vertex in a given temporal graph by two different means: • we can remove a limited number of time-edges (times at which a single edge is active) from the graph, or • the number of timesteps at which each edge is active is fixed, but we can change the relative order at which different edges are active (perhaps subject to constraints on which edges must be active simultaneously, or restrictions on the timesteps available for each edge). Mostly, we find that these problems are computationally intractable even when very strong restrictions are placed on the input, but we identify a small number of special cases which admit polynomial-time algorithms, and raise a number of open questions. This includes some joint work with George B. Mertzios and Viktor Zamaraev.