VETENSKAPSRÅDET
THE SWEDISH RESEARCH COUNCIL

Kansliets noteringar Kod	Dnr
2013-42910-104025-66	2013-4939

2013
Project Grant Junior Researchers

Area of science
Natural and Engineering Sciences
Announced grants
Research grants NT April 11, 2013
Total amount for which applied (kSEK)

2014	2015	2016	2017	2018
1742	1783	1824	1857	

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ADMINISTRATING ORGANISATION

Administrating Organisation
Linköpings universitet

DESCRIPTIVE DATA

Project title, Swedish (max 200 char)
Ett användarcentrerat informationsvisualiseringsramverk för identifiering och utforskning av förändringar i högdimensionell tidsvarierande data

Project title, English (max 200 char)
A user-centered information visualization framework for detecting and exploring change in high-dimensional temporal data

Abstract (max 1500 char)
The effective representation and analysis of high-dimensional temporal data is one of the major challenges in visualization. Such data are produced daily by a huge number of disciplines, including medical health records over time, financial data accumulated every day, and industrial event data logs.

Analysing high-dimensional temporal data involves understanding the relationships between the various variables and how these vary over time. The large size and complex structure of these data make their analysis a challenge. In addition, the diverse characteristics of this type of data make it impossible to create generic methods for efficient analysis. There is a substantial lack in existing methods in that the expertise of the user is not adequately exploited. This is a vital step for developing efficient analysis tools in our data intensive society. To address these issues, our goal is to develop user-centered methods for the detection and analysis of patterns of change in high-dimensional temporal data and integrate such methods into an interactive visualization framework.

The project will develop: (1) visual representations and interaction methods for highlighting change in high-dimensional temporal data, (2) methods for making use of domain expert knowledge to create and refine the definition of change depending on the data and task, and (3) computational methods for the identification and comparison of temporal patterns in the data.

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Abstract language
English

Keywords
Information visualization, High-dimensional temporal data, Change detection, Temporal patterns, User-centered analysis

Research areas
*Nat-Tek generellt

Review panel
NT-2, NT-14

Classification codes (SCB) in order of priority
10201, 10204,

Aspects
Ethical considerations are described in enclosed appendix A on page: 9

Application is also submitted to

similar to:

identical to:

ANIMAL STUDIES

Animal studies
No animal experiments

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Academic title

Doctoral degree awarded (yyyy-mm-dd)

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ENCLOSED APPENDICES

A, B, B, B, C, C, C, N, S

APPLIED FUNDING: THIS APPLICATION

Funding period (planned start and end date)
2014-01-01 -- 2017-12-31

Staff/ salaries (kSEK)

Main applicant	**% of full time in the project**	**2014**	**2015**	**2016**	**2017**	**2018**
Jimmy Johansson	30	349	358	367	376	
Other staff						
Katerina Vrotsou	30	336	345	353	362	
Matthew Cooper	15	222	228	234	240	
Doktorand	90	699	716	734	753	
Total, salaries (kSEK):		1606	1647	1688	1731	

Other projectrelated costs (kSek)	**2014**	**2015**	**2016**	**2017**	**2018**
Travel	126	126	126	126	
Computer and accesories	10	10	10		
Total, other costs (kSEK):	136	136	136	126	

Total amount for which applied (kSEK)

2014	2015	2016	2017	2018
1742	1783	1824	1857	

ALL FUNDING

Other VR-projects (granted and applied) by the applicant and co-workers, if applic. (kSEK)

Funded 2013	**Funded 2014**	**Applied 2014**
		1572

Project title
Perceptually Accurate Haptic Interaction with High Resolution, Inhomogeneous 3D Tissue Data

Applicant
Karljohan Palmerius

Funds received by the applicant from other funding sources, incl ALF-grant (kSEK)

Funding source
ELLIIT funding for temporary visitors at LiU 2013

Total
600

Proj.period
2013

Applied 2014

Project title
PODD: POrtable Diary Data collector

Applicant
Katerina Vrotsou

Funding source
Nordforsk

Total
2000

Proj.period
2012-2015

Applied 2014

Project title
Increasing Nordic Homeowners´ Adaptive Capacity to Climate Change (visualization research)

Applicant
Jimmy Johansson

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Funding source
Norrköping fund for research and development

Total
1600

Proj.period **Applied 2014**
2013-2015

Project title
Norrköping Decision Arena - Research and development of a visualization platform for sustainability planning and climate adaptation

Applicant
Björn-Ola Linnér

POPULAR SCIENCE DESCRIPTION

Popularscience heading and description (max 4500 char)

Informationsvisualisering är ett mycket kraftfullt verktyg för att analysera stora datamängder. Detta görs genom att producera bilder som är lättare att tolka för den mänskliga hjärnan än traditionell presentation i siffror. Vanligt inom informationsvisualisering är att man representerar och tolkar högdimensionell data i storleksordning upp till 20-100 dimensioner. Den snabba utvecklingen av dator- och sensorteknik gör att det produceras mer data än någonsin tidigare och det är idag mycket vanligt att de data som samlas in även har en tidskomponent. Dessa högdimensionella data som varierar över tid ger upphov till komplexa, tidsberoende förändringar mellan dess dimensioner vilka är svåra att analysera. Denna typ av data är dock mycket vanlig och förekommer exempelvis inom områden som hälso- och sjukvård, bioinformatik, klimat och processkontroll.

För att illustrera denna problematik ger vi ett exempel från hälso- och sjukvården som idag har stora utmaningar när det gäller analys av data. I dagens elektroniska patientjournaler samlas information om patienters sjukdomar, utredningar, behandlingar och hälsotillstånd. De data som samlas in innehåller många olika dimensioner som ofta är kopplade till varandra inom en vårdprocess och över tid. Dessutom samlas data om patienters vård i nationella kvalitetsregister och hälsodataregister. En viktig del i analys av dessa data är att beskriva relevanta samband och hur de förändras över tid. Visualisering av dessa förändringar kan göra information mer överskådlig och därmed lättare att tolka. Vidare underlättas analys av vilka för- och nackdelar olika behandlingar kan ha hos olika patientgrupper. På så sätt kan effektivare och säkrare behandlingar identifieras och även tidigare okända biverkningar eller patientgrupper som är särskilt lämpade för behandling eller särskilt utsatta för biverkningar.

Det finns således ett stort behov av tekniker som kan hjälpa användaren att effektivt analysera högdimensionell tidsvarierande data. Sådana tekniker bör stödja användaren att få en överblick av data, att framhäva information som är relevant och även att identifiera och representera trender, förändringar och temporala mönster. För att adressera dessa behov kommer det föreslagna projektet att bedriva grundforskning inom interaktiv visualisering och informationsutvinning med syfte att producera metoder som stödjer visuell analys av förändringar i högdimensionella tidsvarierande data.

Vi kommer initialt att kartlägga vilka specifika typer av förändringar som är intressanta att studera inom en rad applikationsområden. För detta kommer vi ta hjälp av den expertpanel som är associerad till projektet. Medlemmarna i denna panel representerar områden som: hälso- och sjukvård, bioinformatik, studier av klimatförändringar och väder, och tidsgeografi. Informationen som erhålls från dessa studier kommer ligga till grund för utvecklandet av matematiska beräkningsmetoder, s.k. algoritmer, och nya visualiseringstekniker specifikt anpassade för att identifiera och visuellt framhäva viktiga komplexa förändringar. Utöver detta kommer vi att utveckla metriker för att kvantifiera den kunskap av förändringar som erhålls från våra användare inom

de olika områdena. Detta kommer att användas som underlag för att utveckla tekniker för att gruppera intressanta förändringar och på detta sätt åskådliggöra temporala trender i data.

Vi kommer vidare att utveckla specialanpassade interaktiva verktyg, bl.a. tredimensionella stereoskopiska representationer för att utforska dessa stora datamängder, samt utveckla avancerade tekniker för att effektivt kunna navigera i dem. För att säkerställa nyttan av våra metoder kommer vi kontinuerligt att arbeta tillsammans med vår expertpanel för att säkerställa att dessa behandlar korrekta och viktiga frågeställningar. Detta kommer även kontinuerligt att utvärderas i studier med potentiella slutanvändare.

Då antalet system som producerar högdimensionella tidsvarierande data är enormt och många av dem är av stor vikt inom samhälle och industri kommer resultaten från detta projekt ha stor inverkan inom många områden och på många användare. Förmågan att snabbt och tillförlitligt kunna identifiera och presentera komplex information blir bara viktigare och viktigare i dagens samhälle. Resultaten från detta projekt kommer i högsta grad bidra till detta.

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Title of research programme
þÿA user centered information visualization framework for detecting and exploring chang

Appendix A

Research programme

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A RESEARCH PROGRAM

A.1 PURPOSE AND AIMS

High-dimensional temporal data is one of the major challenges in visualization. Such data sets are characterized by a large number of variables and a large number of time steps, making them hard to manage but more importantly difficult to represent in an understandable way. High-dimensional temporal data are produced daily by a very large number of disciplines. Examples include: (1) medical health records where each patient is associated with various diagnoses, treatments etc. over time, (2) data collected at regular intervals from weather stations, or (3) process control data where information about events that occur with a certain time interval is logged.

Analyzing high-dimensional temporal data involves understanding the relationships between the various variables as well as how these and the relations between them alternate over time. A primary goal is to be able to form an overview of the behaviour of the system under study as well as reveal important temporal changes. The large size and complex structure of the data make this a grand challenge to be addressed. In addition the diverse characteristics of the different data sets that fall into this category of data make it impossible to create generic methods for their efficient analysis. There is a substantial lack in existing methods in that the expertise of the user is not adequately exploited in the analysis process. This is a vital step for developing efficient analysis tools in our data intensive society. The overall goal of this project is thus to:

develop user-centered methods for the detection and analysis of patterns of change in high-dimensional temporal data and integrate such methods into an interactive visualization framework

To this end we will conduct research on:

- visual representations and interaction methods for highlighting patterns of change in high-dimensional temporal data
- the incorporation of domain expert knowledge into the analysis process to create and refine the definition of change and interestingness depending on the data and the task at hand
- computational methods for the identification and comparison of temporal patterns in the data
- validation and usability assessment of the researched results

To address the proposed research efforts, new visual representations that efficiently convey temporal changes need to be designed and evaluated. Temporal changes can greatly differ between data types and must therefore be defined and quantified with respect to these data. Domain knowledge should be incorporated into this definition process, we will therefore develop an interactive framework that allows experts to tailor their definition of change with respect to the data and the task at hand. This accumulated knowledge will be used as input for further algorithmic analysis that enables automatic identification, exploration and comparison of important temporal patterns. Moreover, we will perform continuous evaluations in order to ensure the validity and efficiency of the developed methods.

This research builds on combinations of interactive visualization and computational methods within which the members of the proposed research team have a significant track record. Furthermore, a panel of domain experts across various application areas producing high-dimensional temporal data have committed to provide relevant input.

A.2 Survey of the field

Information visualization research is a growing scientific field, with its importance increasing along with the increase in the amount and complexity of data produced daily in industry and science. This proposal addresses the development of support mechanisms facilitating the identification, representation and analysis of change in high-dimensional temporal data. The effective visualization of such data is one of the grand challenges of the field due to their continuous expansion with time, their complexity and their dynamic character.

Many research efforts have been dedicated to the efficient representation of high-dimensional temporal data (see for example [12, 1, 6]). Most existing visualization techniques, however, do not adequately convey both the temporal and multidimensional aspects of the data to reveal structures of complex temporal changes [1], which is the focus of this research project. When it comes to storing and efficiently conveying information about such complex temporal change, existing work on density maps [23, 15, 16] as well as work related to stereoscopic rendering and highlighting [2, 22] are interesting topics to study and further develop to suit the specific needs of this project.

An analytic task of interest in the exploration of high-dimensional temporal data commonly involves the identification of interesting changing patterns in the data. Data mining methods for temporal pattern extraction [3, 11, 26, 4, 21] and change detection techniques [10, 17] are examples of popular approaches for achieving such tasks. Clustering techniques are an alternative means of revealing trends in the data by grouping similar behaviour over time [33, 29]. Finally visualization, often combined with data transformations, interaction techniques and computational methods, is another effective approach to the identification and representation of temporal variation in the data [5, 1]. Examples of such approaches applied to categorical data, which is one of our focus areas, for identifying and comparing interesting sequences of events as patterns can be found in [7, 28, 32, 30, 31].

A.3 Project description

This project aims at the development of user-centered methods for the detection and analysis of change in high-dimensional temporal data and the integration of these into an interactive visualization framework. We plan to research visual and algorithmic approaches for representing and exploring the changing character of these data, while continuously strengthening and confirming our input and results with domain knowledge provided by expert users. A detailed outline of the three research themes we intend to pursue is provided in the following sections, these will hereinafter be referred to as RT 1, 2, and 3 respectively. The work flow we plan to follow in our performed research is conceptually illustrated in figure 1.

A.3.1 RT 1: Interactive Representations for exploring high-dimensional temporal data with a focus on change detection

In this topic we will explore ways of visually representing change in multi-dimensional temporal data. There are many approaches to displaying change and, based on our experience, the following three areas have been identified as particularly promising for achieving our goals.

Stereoscopic 3D representations (RT 1.1): A common way to visualize data with a temporal dimension is to extend traditional 2D visualization techniques (such as scatter plots, parallel coordinates and line charts) into 3D, where the third dimension is used to represent time. A general limitation of this approach is that the 3D model displayed on a standard 2D computer monitor lacks sufficient depth cues in order for users to efficiently separate the data in the third

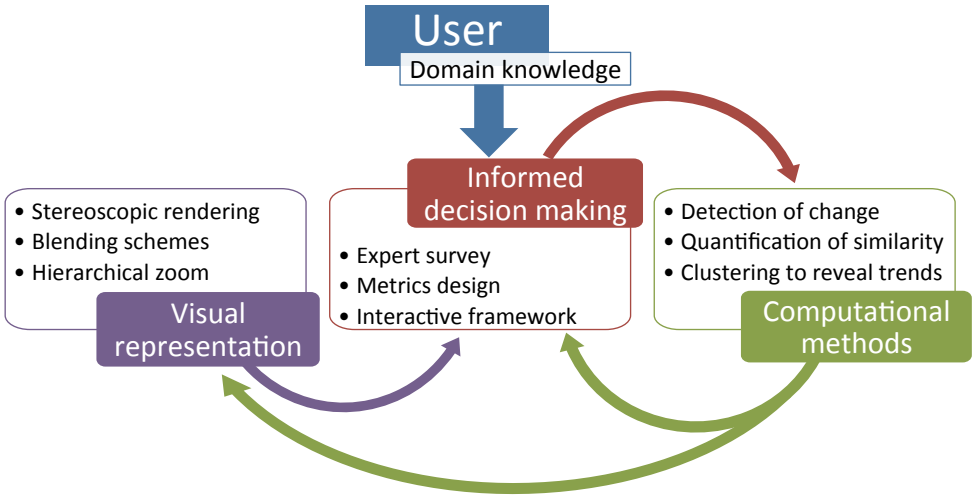
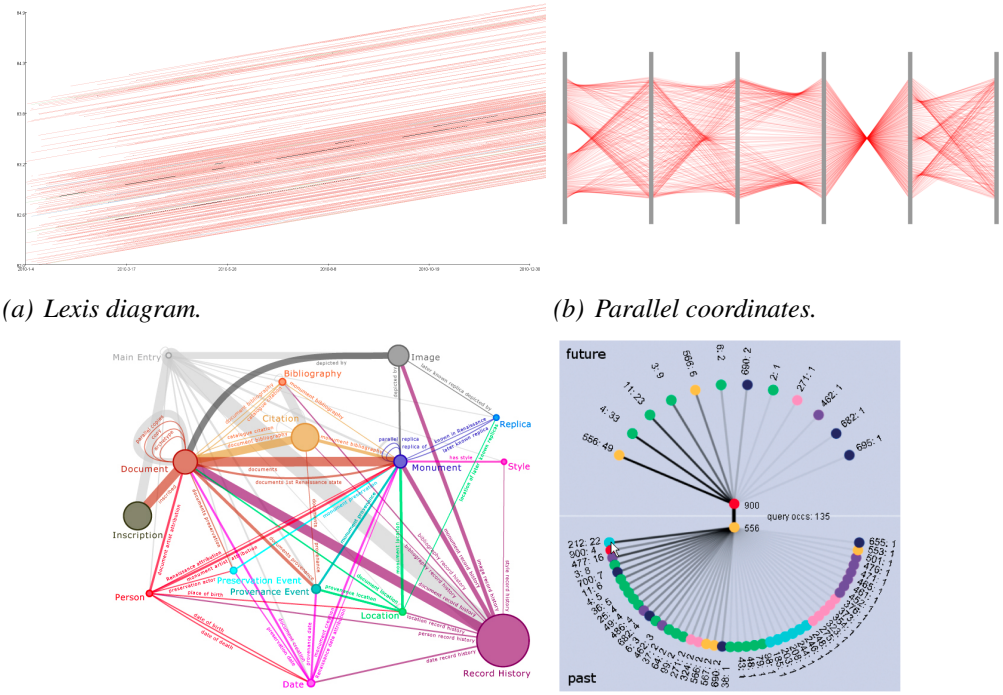


Figure 1: Schematic representation of our planned work flow.

dimension. To overcome this limitation we will use stereoscopic rendering of the display which will significantly improve the depth perception and make it easier to analyse complex patterns in 3D representations of large temporal data. Within the proposed research team there exists substantial knowledge in the use of stereoscopic rendering (see for example the work in [22], a collaboration between our team and NASA Ames, which addresses issues of clutter in 3D displays). Stereoscopic rendering is now a commodity technology, used in video games and film as well as in the areas of virtual reality, scientific and medical visualization, but has not been significantly introduced in information visualization. Preliminary studies by the proposed research group [14] have indicated that a 3D display of parallel coordinates, while not generally very effective, is a promising method for analysis of multidimensional temporal data. We will use our previous work as a basis and develop stereoscopic 3D parallel coordinates specifically for the analysis of temporal changes in data. Using state-of-the-art graphics hardware will enable a stereoscopic representation of large temporal data sets at interactive frame rates.

Advanced blending schemes (RT 1.2): Today it is common to render data as semitransparent points or lines and additively blend them together to create a density map [13, 23]. Within this project we see great potential for more complex density maps and advanced blending schemes to make it possible for users to explore specific structures related to change. To create such density maps it is necessary to separate and classify interesting structures in data. For this step both user specific structures and automatically extracted ones will be used as input. These will be obtained through research performed in RT 2 and RT 3. The information about structures stored in the density map can then, using transfer functions, be assigned to different colours and opacities and blended together using novel algorithms to form the final image. In addition to colour, animation will be considered in order to attract users' attention to interesting areas. The blending schemes can be applied to a majority of already existing visualization techniques. Within this project we will focus mainly on four techniques: parallel coordinates, the lexis diagram, node-linked diagrams and the ActiviTree representation [28], see illustrations in figure 2.

Hierarchical change-based zooming (RT 1.3): The density maps presented above will form the basis for an hierarchical zooming technique based on interesting change in the data. As opposed to a traditional geometric zoom that alters the actual size of a representation we will develop a semantic-based zooming that progressively enhances structures in the data, according to user preferences. The density map with encoded information about the changing behaviour



(a) Lexis diagram. *(b) Parallel coordinates.*

(c) Node-link diagram. *(d) ActiviTree.*

Figure 2: Examples of visual representations that will be used within the project.

of the data will be subdivided into an hierarchical data structure. Transfer functions will then be developed to interactively map the hierarchical information to geometric objects with assigned colours and opacities. Our previous work on transfer functions for parallel coordinates [16] will act as a starting point for this step. This will enable users to interactively explore temporal changes at different resolutions to provide both an overview as well as a detailed representation.

A.3.2 RT 2: Informed decision making framework for specifying an analysis context

Different disciplines employ different measures and definitions in order to specify what an interesting change in their data is and how similarity between collected data is defined.

Expert survey (RT 2.1): In this research theme we will start with conducting a survey for identifying what defines an interesting change for each of several disciplines. To achieve this we will make use of the knowledge and network of our expert panel (see section A.3.6). This survey, in combination with our previous research on the definition of similarity of event-sequences between disciplines [27, 29], will enable us to create a rich knowledge base concerning such definitions and will ensure that the gathered information is valid and useful for the different application areas. The application areas we will initially consider within the scope of this project are concerned with: climate change and weather data, pharmacoepidemiology data, time-use data, socio-demographic data, and process data.

Metrics design (RT 2.2): Having collected this knowledge we will conduct a thorough literature review on existing metrics for identifying change and quantifying similarity. We will make adjustments to existing metrics to match our needs and we will, moreover, design new metrics based on the results from our expert panel survey.

Interactive framework (RT 2.3): The knowledge collected through such a survey will build the

basis for an interactive framework which will allow the user to create an appropriate context of analysis. The user will be able to interactively select the attributes of interest in the explored data set, these may be single attributes or, most likely, combinations of such. Our previous work on developing tools for interactive exploration of data (see, for example [25, 8]) will facilitate a rapid development of the framework. The way each of these attributes varies over time or changes state or the way several attributes change with respect to each other will then become the definition of an interesting change. For example, in medical data an interesting feature may be a change in medication substance or dosage, and in a climate data set it may be interesting to explore a change in mean value of temperature and precipitation over a number of years.

The results obtained within this research theme will directly feed into RT 3 as input into algorithmic computations and, indirectly, also into RT 1 where features can be visually enhanced in the representation.

A.3.3 RT 3: Algorithmic methods for detecting and analysing change based on the context definition

The complexity and continuously increasing size of high-dimensional temporal data makes their representation and analysis challenging. Within this project we intend to explore interactive methods that aim to reduce the size of the data while preserving their structural characteristics and contextual overview. This will be done by identifying and considering areas of interest in the data at full detail, while aggregating less interesting areas both in the representation and the analysis. As previously discussed, what is of primary interest in the analysis of such data sets are periods that display some change in the behaviour of the data. How this change is defined, however, varies with data type and task. This makes it vitally important to take into consideration the informed opinions of the domain expert driving the analysis. Furthermore change involves comparison, this means that in order to identify change in the form of dissimilarities over time, one needs to first define what is meant by similarity within a particular analysis context. Based on these facts, we will focus on algorithmic methods aiming to identify change, quantify similarity and explore the changing character of high-dimensional temporal data.

Quantification of similarity (RT 3.1): Detection of change involves comparison within and between data elements which in turn involves a measure of similarity. In high-dimensional temporal data this similarity relates both to multiple attributes and the time element. Furthermore this similarity is subjective, since it also depends on the data type and task performed. To address this we will research metrics that quantify similarity and interestingness in a flexible manner. Such metrics will take advantage of the knowledge base of the domain experts by allowing them to interactively set the analysis context and define what is interesting in the currently processed data set, as described in RT 2. We will also investigate the applicability and adjustment of similarity metrics used in the comparison of event-sequences and event-interval sequences [20, 27, 18, 29]. We will then create interfaces that allow these metrics to be appropriately tuned in order to guide algorithmic analysis, such as pattern mining in searches for change and cluster analysis for exploring trends, in different application domains.

Detection of change (RT 3.2): We intend to research techniques for identifying areas of interest in high-dimensional temporal data defined as temporal periods that display various types of change in the behaviour of the data. These types can involve change in single attribute values or change in the relationships of several attributes. Methods to detect such change, and designed for the particular data type, will therefore be investigated. We will take inspiration from statistical and signal processing approaches to change detection [10, 24] in order to process temporal multi-dimensional data of a continuous nature. We will also, investigate data mining techniques

for sequential data in order to detect interesting patterns of change within data of a categorical nature. Inspiration for these will be taken from bioinformatics research on sequence comparison [19], graph mining research [9] on web session and social network analysis, and sequence mining research on, for example, transaction data [11]. The time element is often not taken into proper consideration in approaches like these, which affects the retrieved results. Furthermore, the knowledge base of the domain expert is usually not considered either. To this end, we will further develop existing approaches by adding visual and interactive components to them in order to provide algorithms that are tailored to the type of data and the task at hand (as described in RT 3.1).

Clustering to reveal trends (RT 3.3): Clustering and classification techniques will be investigated which can aid in the detection of similarly behaving groups as well as outliers and anomalies in the data. Of particular interest is to perform cluster analysis over time in order to study how the overall structure of the data is evolving, and also to detect periods that require further exploration. Our initial plan is to approach this from two directions: (1) to cluster the time steps with respect to the data values and explore the temporal distribution within the clusters, (2) to cluster the data values over certain time intervals and explore how the clusters themselves change over time and how the elements within the clusters are redistributed. We will also investigate the creation of a dynamic clustering method which will be continuously refined as new data elements are added. Furthermore we will add interactivity to the clustering process, for example allowing a user to adjust a temporal clustering threshold dynamically will give direct feedback concerning the effect of a time step in the clustering. Density based clustering that considers time will be researched for exploring the changing behaviour of clusters. Hierarchical clustering methods will be explored that decrease the size of the data while preserving the existing relationships within and between clusters at different levels of hierarchy. This latter type of clustering will have a direct application in the *hierarchical change-based zooming* display discussed in RT 1.

A.3.4 Validation of results

This important part of the project will be devoted to usability aspects, evaluation and validation of the developed techniques. Relevant domain knowledge about interesting structures of change will be available through the expert panel and will be used as input to the planned evaluations in order to ensure that we focus on appropriate user tasks. The results from these evaluations will enable continuous refinement of requirements, specifications and solutions throughout the course of the project.

A.3.5 Preliminary Time Plan

The project can be divided into three major areas: research on interactive representations, development of an informed decision making framework, and research on algorithmic methods for detecting and analysing change. Research in these three areas will often run in parallel since they depend on each other. Our research results will be continuously evaluated by input from relevant domain experts as well as through controlled user experiments. A preliminary time table is shown in figure 3.

Year 1: We will immediately start by conducting surveys to identify what characteristics of change are considered interesting and important in the various application domains. In parallel, we will start researching stereoscopic 3D representations. Towards the end of the year we will perform the first evaluation and begin investigations on the quantification of similarity based on the results of the survey.

Quarter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Visual Representations	RT 1.1								RT 1.2				RT 1.3			
Informed decision making framework	RT 2.1			RT 2.2			RT 2.3									
Algorithmic extraction				RT 3.1				RT 3.2					RT 3.3			
Validation of research results																

Figure 3: Preliminary time plan.

Year 2: During the second year we will finalize our research on similarity quantification and initiate research on techniques for detection of change. The development of the interactive framework will begin halfway through the second year and will run in parallel throughout the remaining project time. This part does not include basic research but will combine the results from all other research themes to form the final visualization framework at the end of the project. The researched techniques will be evaluated by the end of this year.

Year 3: During the third year research on change detection techniques will continue. Research will also be made on blending schemes which will be based on our results from year one and two. As in previous years, we will perform evaluations towards the end of the year to ensure the validity of the developed techniques.

Year 4: During the final year, research will be carried out on computational methods for clustering and this result will be used when developing hierarchical interaction techniques for navigating in large data. The framework will also undergo a final evaluation.

A.3.6 Proposed Research Group

Dr. Jimmy Johansson is the PI of the project. He is doing research in information visualization, and is one of the leading researchers within this field in Sweden. He is also an internationally leading expert in efficient visualization of multivariate data using parallel coordinates. Johansson has presented several high impact articles in the area at the most prestigious conferences and published his work in the top information visualization journals. Johansson will devote 30% of his time to the project.

Dr. Katerina Vrotsou is a post-doctoral research associate at Linköping University working with interactive visual analysis of multidimensional event-based data. Her research interests include information visualization, visual analytics, data mining, and interactive knowledge discovery. Her track record includes publications in peer reviewed conferences and journals in all of these areas. Dr. Vrotsou will devote 30% of her time to the project.

Dr. Matthew Cooper is the director of C-research at the Norrköping Visualization Centre, C, and is the head of the visual interactive data analysis group at Linköping University. He has published more than 70 papers on interactive visualization and its applications. Dr. Cooper will provide his expertise in the field and will further work on the visualization approaches within the project. He will devote 15% of his time to the project.

Ph.D Student A new Ph.D. student will be recruited at the beginning of the project. The student is expected to work with the senior staff on all relevant research questions addressed within the project. We shall receive funding for a teaching assistant-ship covering 10% of the salary costs.

Expert Panel An expert panel will be associated with the project. The members of the panel have all agreed to contribute with their expert knowledge within their respective application domain to ensure that the definitions of change used are valid. The expert panel will also assist in the evaluations performed throughout the course of the project. The expert panel

consists of the following members: *Prof. Morten Andersen* (Karolinska Institutet), expert in pharmacoepidemiology and clinical pharmacology. *Dr. Mikael Hoffmann* (Network for pharmacoepidemiology-NEPI), expert in pharmacoepidemiology and e-health. *Prof. Kajsa Ellegård* (Department of Thematic Studies - Technology and Social Change, Linköping University), expert in time-geography, everyday life and energy use studies. *Prof. Björn-Ola Linnér* (Center for Climate Science and Policy Research), expert in research on climate change and sustainable development. *Dr. Jane Shaw* (Unilever Research Port Sunlight), expert in product design and bioscience.

A.4 Preliminary results

The members of the proposed research group have a long history of research projects focusing on developing and validating interactive techniques for data visualization. Our earlier work on density maps and blending schemes [13, 16] will form an excellent basis for researching new visualization methods for exploring changing properties in high-dimensional temporal data. Recent work [14] investigating the use of 3D parallel coordinates for data visualization suggests that the technique would be applicable for exploring high-dimensional temporal data. We will use this result together with the knowledge obtained from our earlier studies on stereoscopic representations in the field of virtual reality [22] to develop 3D representations specifically targeted towards exploring change.

In addition, we have extensive experience in interactive approaches facilitating visual analysis of event-sequence data [28, 25], which are one type of high-dimensional temporal data. Research conducted so far has concentrated on the extraction of sequences as patterns from the data and constitutes a solid basis for future methods on the identification of changing temporal patterns. Furthermore, we have carried out some initial work in using clustering for quantifying and exploring similarity between temporal patterns in event-sequences [27, 29]. These initial results have proven very promising but more work is required to continue this development and many promising avenues of research remain. Finally, we have had experience in performing qualitative and quantitative user studies [27, 14] which will aid us in the gathering of the knowledge from domain experts and in validating our research results.

A.5 Significance

The number of systems which produce high-dimensional temporal data is enormous, many of them being significant to society, business and industry. Examples can be found in most domains including climate change research, the financial and banking sectors, in studies of bacterial populations in bioinformatics, in epidemiology through the use of medical records for diagnostics and treatment planning, and in the social sciences through, for example, time-use data. In many of these areas humans play a central role in the process of analysing the collected data, but are often overwhelmed by the volume and complexity of the information of which they must make sense.

The ability to quickly and reliably identify and present information to research colleagues, stake holders, and end users will have enormous benefits in terms of efficiency and accuracy. The research conducted within this project will advance the field of information visualization, and in particular visual analysis of high-dimensional temporal data. The project will produce novel interactive techniques that will allow efficient analyses which are not possible today.

The scientific outcomes of the project will be disseminated through academic contributions to suitable academic journals and international conferences. The project will also have access to

the facilities and programmes of the Norrköping Visualization Centre, C, the Norrköping National Meeting Place for Visualization, C-site, and Norrköping Science Park (NOSP). These centres actively and successfully promote visualization through activities supporting collaboration between academia, industry and society.

A.6 Equipment

Through Norrköping visualization centre C, we have access to state-of-the-art eye tracking hardware (Tobii TX300) that will be used in controlled user experiments to help validate the research results. We have also access to large stereoscopic displays which will be used for developing and experimenting with 3D visual representations for the exploration of complex change.

A.7 Ethical Considerations

The research conducted within this project will adhere strictly with the ethical guidelines stipulated by Vetenskapsrådet. Data from evaluation studies will be gathered only from consenting individuals who volunteer to participate and written consent will be obtained when necessary. The identities and anonymities of participants will be considered at all times.

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VETENSKAPSRÅDET
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Kod
2013-42910-104025-66

Name of applicant
Johansson, Jimmy

Date of birth
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Title of research programme
A user-centered information visualization framework for detecting and exploring change in high-dimensional temporal data

Appendix B

Curriculum vitae

Vetenskapsrådet, Box 1035, SE-101 38 Stockholm, tel. +46 (0)8 546 44 000, vetenskapsradet@vr.se

Curriculum Vitae – Jimmy Johansson

1. Master of Science Degree

- Media Technology and Engineering at Linköping University, Sweden, 2003.

2. PhD Degree

- Visualization and Interaction at Linköping University, Sweden. May 2008. Title of dissertation: Efficient Information Visualization of Multivariate and Time Varying Data. Supervisor: Professor Mikael Jern.

3. Postdoctoral Research

- June 2008 - January 2010. Postdoctoral researcher at the Division of Visual Information Technology and Applications (VITA) at the Department of Technology and Science (ITN), Linköping University, Norrköping. 70% research time and 30% teaching and administration in the position.

4. Docent

5. Present Academic Position

- Research assistant at the Division of Media and Information technology, at the Department of Technology and Science (ITN), Linköping University, Norrköping. 65% research time and 35% teaching and administration in the position.

6. Previous Academic Positions

- June 2003 - June 2008. PhD candidate at the Division of Visual Information Technology and Applications (VITA) at the Department of Technology and Science (ITN), Linköping University, Norrköping.

7. Leave of Absence

8. Graduated PhD students

- Sara Johansson Fernstad, 2011 (co-supervisor).

9. Current PhD Supervision

10. Grants

- Visualization of complex patterns in health care (EpiVis). Funded by Norrköping Science Park and Stiftelsen NEPI - nätverk för läkemedels-epidemiologi, 35 000 €. 2011. Jimmy Johansson (PI) and Mikael Hoffman.
- Increasing Nordic Homeowners' Adaptive Capacity to Climate Change (VisAdapt). Funded by Nordforsk, 540 000 $. 2012-2014. Michael Goodsite (PI), Jimmy Johansson, Björn-Ola Linnér, Tina Neset, Richard Klein and Brynhildur Davidssdottir.

10. Organizational Committees

- Member of the International programme committee of Visual Analytics Science and Technology (IEEE VAST).

- Member of the International programme committee of Eurographics/IEEE Symposium on Visualization (EuroVis).
- Member of the programme committee of the International Conference on Information Visualization.
- Program Committee member of the ACM SIGKDD Workshop on Visual Analytics and Knowledge Discovery.
- Symposium committee chair of the International Symposium on Information Visualization Evaluation (IVE).
- Executive committee member of the curriculum planning board for Computer Science and Media Technology.
- Chairman of the curriculum planning workgroup for Media Technology and Engineering, and Advanced Computer Graphics.
- Curriculum coordinator for Media Technology and Engineering.

11. Conference Management Experience

- Organizer of the International Symposium on Information Visualization Evaluation (IVE), 2008-
- Organization of a birds-of-a-feather meeting at IEEE VisWeek 2009 jointly with Alfred Inselberg, Tel-Aviv University, Israel. Title: Taming Parallel Coordinates - Why, What & Who.
- Organizer of the ACM SIGKDD Workshop on Visual Analytics and Knowledge Discovery — VAKD '09, 2009. http://www.hiit.fi/vakd09/
- Tutorials local coordinator for Eurographics 2010, Norrköping, Sweden
- Student volunteers coordinator for Eurographics 2010, Norrköping, Sweden
- Session chair at Visual Analytics Science and Technology (IEEE VAST) conference, 2011

12. External Relations

- One of three teachers of a diploma course in visualization directed to Swedish industry in collaboration with Linköping University and C-site (Norrköping Knowledge Arena for Visualization) and Norrköping Science Park
    - Linköping University, Norrköping, December 2008.
    - KTH, Stockhom, December 2009.
- Cooperation with Centre for Climate Science and Policy Research within the science communication project “World View: new ways of visualizing climate change”
- “Forskare blåser upp klimatfrågan i taket”.Article in Ny Teknik, December 2009

Katerina Vrotsou
Postdoctoral Research Associate,
Department of Science and Technology
University of Linköping

Personal Number: 800920-9340

1 **Higher education degree(s)**,

1999-2004: MSc in Media Technology with focus in visualization from the Department of Science and Technology at Linköping University, Sweden. The final thesis project involved the development of a visual programming interface for constructing visualization pipelines.

2 **Doctoral degree**

2005-2010: PhD in Visualization and Interaction at Linköping University, Sweden. The research focused on methods for identifying and representing patterns in event-based data. Thesis, entitled "Everyday mining: Exploring sequences in event-based data", was successfully defended on 17th September 2010.
Supervisors: Dr. Matthew Cooper, Prof. Anders Ynnerman, Prof. Kajsa Ellegård.

3 **Postdoctoral positions**

2011-2012: Postdoctoral researcher in Visual Analytics working with visual and algorithmic analysis of event-based movement data. Joint between Department of Computer Science, University of Bonn, and the Knowledge Discovery Department at Fraunhofer Institute for Intelligent Analysis and Information Systems (IAIS), at Sankt Augustin, Germany. Working with Dr. Gennady Andrienko and Dr. Natalia Andrienko.

4 **Docent level**

Not Applicable

5 **Present position**

From 2012/4: Postdoctoral research associate in visual data analysis methods for event-based data at the Department of Science and Technology at Linköping University, Sweden.

6 **Previous positions and periods of appointment**

See point 3 and 5 above

7 **Supervision**

No direct supervision of PhD students but has had fruitful collaborations with several co-students and been involved in the supervision of Masters students:

2013: Daniel Svärd & Gustav Lysell Smålänning, Masters student in media technology at Linköping University, Sweden. The work involves the creation of a framework for visualization of salesmen activity in business environments based on iPad application usage data.

2013: Ali Khashan, Masters student in media technology at Linköping University, Sweden. The work involves the development of a platform for interactive visualization of game player event data collected from an online computer game.

2009-2010: Avraz Hirori, Masters student in media technology at Linköping University, Sweden. The work involved the interactive representation of thematic attributes associated to events using a parallel sets visualization approach.

2011-2012: Iulian Peca, Masters student in computer science at University of Bonn, Germany. Working with the development of algorithms for clustering of event-based data with respect to space and time. Also involved in the development of a web interface for the exploration of event-based data extracted from georeferenced photographs.

2011-2012: Haolin Zhi, Masters student in computer science at University of Bonn, Germany. Working with the development of an interactive web system for the exploration of event-based data extracted from georeferenced photographs.

8 **Deductible time**

None

9 **Other information relevant to the application**

Matthew Cooper
Senior Lecturer, Department of Science and Technology
University of Linköping

Personal Number: 650317-7450

1,2. Academic degrees

B.Sc.: Graduated in Theoretical Physics (first class) from The University of Exeter, UK. July 1986.

M.Sc.: Graduated in December 1987 in Computer Science from the University of Manchester, UK. The research programme was in the development of methods and applications for the display of terrain derived from standard contour map data.

Ph.D.: Graduated in June 1990 in Computational Chemistry from the University of Manchester, UK. Thesis entitled "The implementation of Ab Initio Quantum Chemistry calculations on Transputers."

3. Postdoctoral positions

1990-1992: Postdoctoral researcher in applications of parallel computing in the Department of Computer Science, University of Manchester, UK.

1992-1996: Postdoctoral researcher massively parallel computing for Computational Chemistry at the Department of Chemistry, University of Manchester, UK.

4. Docent: Not Applicable

5. Present position

Since 2001: Senior lecturer in Information Visualization in the Department of Technology and Natural Sciences, University of Linköping, Sweden since 2001-12-01. Currently 45% teaching, 55% research funding.
Lecturing on undergraduate courses in both Introductory and Advanced Computer Graphics, Information Visualization and Data Mining, and Virtual Reality Technology and Programming.

6. Previous positions

1998-2001: Research Project Manager within the Manchester Visualization Centre, University of Manchester, UK. This position involved responsibility for research and development in visualization and high performance computing across a wide range of application areas including Physics, Medicine, Chemistry, Engineering and Climatology.

1996-1998: Visualization software engineer with Manchester Visualization Centre, University of Manchester, UK, working on a range of visualization applications in a variety of scientific areas including Chemistry, Medicine, Engineering and Social Sciences.

7. Leave of absence: None

8. Graduated PhD students

2005-2007: Karljohan Lundin, researching in haptic visualization of volumetric data.

2004-2008: Jimmy Johansson, researching in methods for information visualization applied to large-scale discrete data sets as seen in system identification and business data.

2005-2009: Stephen Peterson, studying stereoscopic label placement in AR and VR in collaboration with Eurocontrol Experimental Centre, the European centre for research and development in Air Traffic Control

2005-2010: Katerina Vrotsou, studying visual data mining approaches to the analysis of event data for sequence and pattern identification with particular reference to Time-Geographical data.

2006-2011: Petter Bivall Persson, studying haptic interaction in chemical interaction through semi-empirical force field models of electrostatic interactions. The work had particular relevance to the teaching of Biochemistry concepts at undergraduate and postgraduate level as well as interpretation of chemical interactions.

2005-2011: Magnus Axholt, studying calibration methods in stereoscopic head-mounted augmented reality systems. 2011 in collaboration with Eurocontrol Experimental Centre and NASA Ames research centre, USA.

9. Current PhD Supervision

2008-Present: Advisor to PhD student Umut Koçack studying haptic interaction with deformable volumetric data through materials modelling and evaluation of human haptic perception.

10. Postdoctoral research associates

2007-Present: Dr. Camilla Forsell. Postdoctoral Research Associate in Evaluation methodologies for visualization methods. Dr. Forsell has been involved in many aspects of the research within the group from the perspective of human-centred evaluation and experimental design.

2007-Present: Dr. Jimmy Johansson. Postdoctoral Research associate in Information Visualization with particular reference to large, multivariate data.

2012-Present: Dr. Katerina Vrotsou, postdoctoral researcher in visual data analysis methods for event-based data. Dr. Vrotsou recently joined the VIDA group in Linköping University after completing a one year Postdoctoral position with the University of Bonn/Fraunhofer Institute.

11. Relevant ongoing collaborations

Cooper has a number of ongoing collaborations with researchers in areas where event-based data are a very important element in the work:

Social Sciences – Kajsa Ellegård

Since 2003 Cooper has had an ongoing collaboration with the TEMA-T group at Linköping University, using visualization and data mining techniques for the analysis of the event-based data gathered in Time-Geographical studies. This project was funded by Vetenskapsrådet from 2005-2008 and by Energimydigheten from 2008-2011, culminating in Katerina Vrotsou's PhD in 2011.

ABB Corporate Research AB – Magnus Larsson

Since 2009 Cooper has had an ongoing research collaboration with ABB visualization systems for event-based data in process control systems such as the large engineering projects and electrical distribution networks which ABB supply.

Skolverket

An ongoing project with Skolverket using event-based data analysis tools developed by the group to examine teacher practices and provide insight into varying practices, and their relative effectiveness, across the education system.

Pharmacoepidemiology – NEPI (Mikael Hoffman)

An ongoing project to explore medical records of pharmaceutical treatment regimes to identify patterns of prescription and patient behaviour with significant effect on treatment outcomes, good and bad, to improve both treatment effectiveness and cost-effectiveness of pharmaceutical use.

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Title of research programme
þÿA user centered information visualization framework for detecting and exploring chang

Appendix C

List of publications

Vetenskapsrådet, Box 1035, SE-101 38 Stockholm, tel. +46 (0)8 546 44 000, vetenskapsradet@vr.se

List of Publications – Jimmy Johansson

Database used for citation count: Google Scholar, **H-index 12, i10-index 15**

1. Peer-reviewed articles

(*) "On the usability of three-dimensional display in parallel coordinates: Evaluating the efficiency of identifying two-dimensional relationships" Jimmy Johansson, Camilla Forsell and Matthew Cooper. Information Visualization Journal, Advance online publication, doi:10.1177/1473871613477091. 2013. Number of citations: 0

"Quality Based Guidance for Exploratory Dimensionality Reduction" Sara Johansson Fernstad, Jane Shaw and Jimmy Johansson. Information Visualization Journal, volume 12, issue 1, pages 44-64, 2013. Number of citations: 0

"Interaction Support for Visual Comparison Inspired by Natural Behavior" Christian Tominski, Camilla Forsell and Jimmy Johansson. IEEE Transactions on Visualization and Computer Graphics, volume 18, issue 12, pages 2719-2728, 2013. Number of citations: 0

"Visual Analysis of Mixed Data Sets Using Interactive Quantification". Sara Johansson and Jimmy Johansson. SIGKDD Explorations, Special Issue on Visual Analytics and Knowledge Discovery, 2010 volume 11, issue 2, pages 29–38, 2010. Number of citations: 0

(*) "Interactive Dimensionality Reduction Through User-defined Combinations of Quality Metrics". Sara Johansson and Jimmy Johansson. IEEE Transactions on Visualization and Computer Graphics, volume 15, number 6, pages 993–1000, 2009. Number of citations: 31

"ActiviTree: Interactive Visual Exploration of Sequences in Event-Based Data Using Graph Similarity". Katarina Vrotsou, Jimmy Johansson and Matthew Cooper. IEEE Transactions on Visualization and Computer Graphics, volume 15, number 6, pages 945–952, 2009. Number of citations: 18

(*) "A Screen Space Quality Method for Data Abstraction." Jimmy Johansson and Matthew Cooper. Computer Graphics Forum, volume 27, number 3, pages 1039–1046, 2008. Number of citations: 11

"Perceiving Patterns in Parallel Coordinates: Determining Thresholds for Identification of Relationships". Jimmy Johansson, Camilla Forsell, Mats Lind, and Matthew Cooper. Information Visualization, volume 7, number 2, 2008, pages 152–162. Number of citations: 16

"Revealing Structure in Visualizations of Dense 2D and 3D Parallel Coordinates". Jimmy Johansson, Patric Ljung, Mikael Jern and Matthew Cooper. Information Visualization, volume 5, issue 2, pages 125–136, 2006. Number of citations: 23

2. Peer-reviewed conference publications

"Interactive Visualization of Prescriptions of Drugs to Individuals within Large Populations—Analyses of Temporal Relationships of Events" Jimmy Johansson, Morten Andersen, Alexander Fridlund and Mikael Hoffmann. Workshop on Visual Analytics in Healthcare, 2012.

"Visualization of Power System Data on Situation Overview Displays" Christine Mikkelsen, Jimmy Johansson and Matthew Cooper. Information Visualisation (IV), 2012, pages 188-197. Number of citations: 0

"Visual Exploration of Microbial Populations." Sara Johansson Fernstad, Jimmy Johansson, Suzi Adams, Jane Shaw and David Taylor. In proceedings of the 1st IEEE Symposium on Biological Data Visualization (BioVis), pages 127–134, 2011. Number of citations: 3

"Visualization for Sensemaking in Power Grid Supervisory Control Systems." Christine Mikkelsen, Jimmy Johansson and Mikko Rissanen. Interactive Information In proceedings of the 15th IEEE International Conference on Information Visualization, IV11, pages 119–126, 2011. Number of citations: 3

"A Task Based Performance Evaluation of Visualization Approaches for Categorical Data Analysis." Sara Johansson Fernstad and Jimmy Johansson. In proceedings of the 15th IEEE International Conference on Information Visualization, IV11, pages 80–89, 2011. Number of citations: 1

"Exploratory Visualization for Weather Data Verification. "Patrik Lundblad, Hanna Löfving, Annika Elovsson and Jimmy Johansson. In proceedings of the 15th IEEE International Conference on Information Visualization, IV11, pages 306–313, 2011. Number of citations: 0

"Evaluating Climate Visualization: An Information Visualization Approach." Jimmy Johansson, Tina Schmid Neset and Björn-Ola Linnér. In proceedings of the 14th IEEE International Conference on Information Visualization, IV10, pages 156–161, 2010. Number of citations: 0

"An Heuristic Set for Evaluation in Information Visualization". Camilla Forsell and Jimmy Johansson. In Proceedings AVI '10: International Conference on Advanced Visual Interfaces, pages 199-206, 2010, ACM Press. Number of citations: 14

"Visualizing climate change: The potential of dome presentations as a tool for climate communication" Tina Neset, Viktoria Wibeck, Ola Uhrqvist and Jimmy Johansson. Eurographics 2010-Areas Papers, pages 31-35, 2010. Number of citations: 3

"Interactive Exploration of Ingredient Mixtures Using Multiple Coordinated Views". Sara Johansson, Kristina Knaving, Amanda Lane, Mikael Jern and Jimmy Johansson. IEEE Information Visualization, IV09, pages 210–218, 2009. Number of citations: 1

"Many-to-Many Relational Parallel Coordinates Displays." Mats Lind, Jimmy Johansson and Matthew Cooper. IEEE Information Visualization, IV09, pages 25–31, 2009. Number of citations: 5

"Interactive Quantification of Categorical Variables in Mixed Data Sets". Sara Johansson, Mikael Jern and Jimmy Johansson. Information Visualisation, IV08, pages 3–10, 2008. IEEE Computer Society. Number of citations: 11

"The GAV Toolkit for Multiple Linked Views". Mikael Jern, Sara Johansson, Jimmy Johansson, Johan Franzén. IEEE Coordinated & Multiple Views in Exploratory Visualization, pages 85–97, 2007. EEE Computer Society. Number of citations: 28

(*) "Depth Cues and Density in Temporal Parallel Coordinates". Jimmy Johansson, Patric Ljung and Matthew Cooper. Eurographics/IEEE-VGTC Symposium on Visualization, pages 35–42, 2007. Eurographics Association. Number of citations: 12

"Task-Based Evaluation of Multi-Relational 3D and Standard 2D Parallel Coordinates". Camilla Forsell and Jimmy Johansson. SPIE / IS&T Electronic Imaging, SPIE Vol.6495, 64950C-1-12, 2007. SPIE / IS&T. Number of citations: 16

(*) "Revealing Structure within Clustered Parallel Coordinate Displays". Jimmy Johansson, Patric Ljung, Mikael Jern and Matthew Cooper. IEEE Symposium on Information Visualization, pages 125-132, 2005. IEEE Computer Society. Number of citations: 106

"3-Dimensional Display for Clustered Multi-Relational Parallel Coordinates". Jimmy Johansson, Matthew Cooper and Mikael Jern. IEEE Information Visualisation, IV05, pages 188-193, 2005. IEEE Computer Society. Number of citations: 28

"Visual Data Analysis using Tracked Statistical Measures within Parallel Coordinates Representations". Daniel Ericson, Jimmy Johansson and Matthew Cooper. IEEE Coordinated & Multiple Views in Exploratory Visualization, pages 42-53, London, 2005. IEEE Computer Society. Number of citations: 14

"Tailor-made Exploratory Visualization for Statistics Sweden". Nina Feldt, Henrik Pettersson, Jimmy Johansson and Mikael Jern. IEEE Coordinated & Multiple Views in Exploratory Visualization, pages 133-142, 2005. IEEE Computer Society. Number of citations: 8

"Interactive Visualization as a Tool for Analysing Time-Varying and Non-Linear Systems". Jimmy Johansson David Lindgren Matthew Cooper Lennart Ljung. 16th IFAC World Congress, 2005. IEEE Computer Society. Number of citations: 2

3. Books

"Data Mining" Kai Puolamäki, Alessio Bertone, Roberto Theron, Otto Huisman, Jimmy Johansson, Silvia Miksch, Panagiotis Papapetrou and Salvo Rinzivillo. (Book chapter). Mastering The Information Age – Solving Problems with Visual Analytics, Eurographics Association, 2010. Number of citations: 84

"Efficient Information Visualization of Multivariate and Time-Varying Data". Jimmy Johansson. PhD thesis, Linköping University, Sweden, 2008. Number of citations: 4

4. Top five most cited publications

“Revealing Structure within Clustered Parallel Coordinate Displays”. Jimmy Johansson, Patric Ljung, Mikael Jern and Matthew Cooper. IEEE Symposium on Information Visualization, pages 125-132, 2005. IEEE Computer Society. Number of citations: 106

“Data Mining” Kai Puolamäki, Alessio Bertone, Roberto Theron, Otto Huisman, Jimmy Johansson, Silvia Miksch, Panagiotis Papapetrou and Salvo Rinzivillo. (Book chapter). Mastering The Information Age – Solving Problems with Visual Analytics, Eurographics Association, 2010. Number of citations: 84

“Interactive Dimensionality Reduction Through User-defined Combinations of Quality Metrics”. Sara Johansson and Jimmy Johansson. IEEE Transactions on Visualization and Computer Graphics, volume 15, number 6, pages 993–1000, 2009. Number of citations: 31

“3-Dimensional Display for Clustered Multi-Relational Parallel Coordinates”. Jimmy Johansson, Matthew Cooper and Mikael Jern. IEEE Information Visualisation, IV05, pages 188-193, 2005. IEEE Computer Society. Number of citations: 28

“The GAV Toolkit for Multiple Linked Views”. Mikael Jern, Sara Johansson, Jimmy Johansson, Johan Franzén. IEEE Coordinated & Multiple Views in Exploratory Visualization, pages 85–97, 2007. EEE Computer Society. Number of citations: 28

Publications by Katerina Vrotsou

Citation numbers taken from Google scholar on 2013-04-03.

1. **Peer-reviewed articles (2005-2013)**

* Katerina Vrotsou, Anders Ynnerman, and Matthew Cooper. "Are we what we do? Exploring group behaviour through user-defined event-sequence similarity." Information Visualization, Published online before print March 6, 2013.

Katerina Vrotsou, Gennady Andrienko, and Natalia Andrienko. "Interactive visual analysis of event-based movement data extracted from phone call records." In Geoinformationssysteme, edited by Koch, Kutzner, and Eder, 1-10. Munich, Germany: Wichmann, 2012.

* Katerina Vrotsou, and Camilla Forsell. "A Qualitative Study of Similarity Measures in Event-Based Data." In Human Interface and the Management of Information. Interacting with Information, edited by Michael Smith and Gavriel Salvendy, 6771:170-179. Springer Berlin / Heidelberg, 2011. Number of citations: 2

Katerina Vrotsou, Natalia Andrienko, Gennady Andrienko, and Piotr Jankowski. "Exploring City Structure from Georeferenced Photos Using Graph Centrality Measures." In Machine Learning and Knowledge Discovery in Databases, edited by Dimitrios Gunopulos, Thomas Hofmann, Donato Malerba, and Michalis Vazirgiannis, 6913:654-657. Springer-Verlag, 2011. Number of citations: 2

Katerina Vrotsou, Camilla Forsell and Matthew Cooper. "2D and 3D representations for feature recognition in time geographical data". Information Visualization, Volume 9, no. 4, December, 2010. Pages 263-276. Number of citations: 5

* Katerina Vrotsou, Jimmy Johansson and Matthew Cooper. "ActiviTree: Interactive Visual Exploration of Event-Based Data Using Graph Similarity". IEEE Transactions on Visualization and Computer Graphics, Volume 15, no.6, November/December, 2009. Pages 945-952. Number of citations: 18

* Katerina Vrotsou, Kajsa Ellegård and Matthew Cooper. "Exploring time diaries using semi-automated activity pattern extraction". electronic International Journal of Time Use Research, Volume 6, no.1, 2009. Pages 1-25. Number of citations: 12

2. **Peer-reviewed conference contributions (2005-2013)**

Iulian Peca, Georg Fuchs, Katerina Vrotsou, Natalia Andrienko, and Gennady Andrienko. "Scalable Cluster Analysis of Spatial Events." To appear in EuroVA, 2012. Number of citations: 1

Katerina Vrotsou, Haolin Zhi, Iulian Peca, Gennady Andrienko, and Natalia Andrienko. "Interactive Exploration of Events and Presence of People in Space and Time through KD-Photomap." To appear in AVI'12: Advanced Visual Interfaces Conference, 2012.

* Kajsa Ellegård, Joakim Widén, and Katerina Vrotsou. "Appliances Facilitating Everyday Life - Electricity Use Derived from Daily Activities." In World Renewable Energy Congress (WREC 2011), 1031-1038. Linköping, Sweden, 2011.

Kajsa Ellegård, Katerina Vrotsou, and Joakim Widén. "VISUAL-TimePAcTS/energy use - a software application for visualizing energy use from activities performed." In Proceedings of the 3rd International Scientific Conference on Energy Systems with IT, 2010. Number of citations: 4

Katerina Vrotsou, Anders Ynnerman, and Matthew Cooper. "Seeing Beyond Statistics: Visual Exploration of Productivity on a Construction Site." In Proceedings of International Conference on Visualisation in Built and Rural Environments, 37-42. London, UK: IEEE Computer Society, 2008. Number of citations: 3

Katerina Vrotsou, Kajsa Ellegård, and Matthew Cooper. "Everyday Life Discoveries: Mining and Visualizing Activity Patterns in Social Science Diary Data." In Proceedings of the 11th International Conference Information Visualization, 130-138. Zürich, Switzerland, 2007. Number of citations: 17

Katerina Vrotsou, Kajsa Ellegård, and Matthew Cooper. "Exploring Time Diaries Using Semi-Automated Activity Pattern Extraction." In 29th Conference of International Association for Time Use Research (IATUR), Washington DC, USA, 2007. Number of citations: 5

3. **Review articles, book chapters, books**

Doctoral Thesis
Katerina Vrotsou. "Everyday mining: Exploring sequences in event-based data". Doctoral thesis.

Linköping University, 2010. http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-58311. Number of citations: 8

4. **Patents**

5. **Open access computer programs that you have developed**

6. **Popular science articles/presentations**

Iulian Peca, Haolin Zhi, Katerina Vrotsou, Natalia Andrienko, and Gennady Andrienko. "KD-Photomap: Exploring Photographs in Space and Time." In IEEE Symposium on Visual Analytics Science and Technology (poster), 289-290. Providence, RI, USA, 2011. Number of citations: 3

* Kajsa Ellegård, and Katerina Vrotsou. "Capturing patterns of everyday life - presentation of the visualization method VISUAL-TimePAcTS." In 28th Conference of International Association for Time Use Research (IATUR). Copenhagen, Denmark, 2006. Number of citations: 15

5 most cited publications

18 Katerina Vrotsou, Jimmy Johansson and Matthew Cooper. "ActiviTree: Interactive Visual Exploration of Event-Based Data Using Graph Similarity". IEEE Transactions on Visualization and Computer Graphics, Volume 15, no.6, November/December, 2009. Pages 945-952.

17 Katerina Vrotsou, Kajsa Ellegård, and Matthew Cooper. "Everyday Life Discoveries: Mining and Visualizing Activity Patterns in Social Science Diary Data." In Proceedings of the 11th International Conference Information Visualization, 130-138. Zürich, Switzerland, 2007.

15 Kajsa Ellegård, and Katerina Vrotsou. "Capturing patterns of everyday life - presentation of the visualization method VISUAL-TimePAcTS." In 28th Conference of International Association for Time Use Research (IATUR). Copenhagen, Denmark, 2006.

12 Katerina Vrotsou, Kajsa Ellegård and Matthew Cooper. "Exploring time diaries using semi-automated activity pattern extraction". electronic International Journal of Time Use Research, Volume 6, no.1, 2009. Pages 1-25.

8 Katerina Vrotsou. "Everyday mining: Exploring sequences in event-based data". Doctoral thesis. Linköping University, 2010. http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-58311.

Publications by Matthew Cooper

Citation numbers taken from Google scholar on 2013-04-11
h-index 15 (107,67,34,32,28,28,25,23,21,20,19,18,17,17,16)

Peer-reviewed journal articles (2005-2013)

* Katerina Vrotsou, Anders Ynnerman, Matthew Cooper. "Are we what we do? Exploring group behaviour through user-defined event-sequence similarity." To appear in Information Visualization Journal, 2013.

* Katerina Vrotsou, Camilla Forsell and Matthew Cooper. "2D and 3D representations for feature recognition in time geographical data". Information Visualization December 21, 2010. Volume 9, no. 4 Pages 263-276. Number of citations: 5

* Katerina Vrotsou, Jimmy Johansson and Matthew Cooper. "ActiviTree: Interactive Visual Exploration of Event-Based Data Using Graph Similarity". IEEE Transactions on Visualization and Computer Graphics, Volume 15, no.6, November/December, 2009. Pages 945-952. Number of citations: 18

* Katerina Vrotsou, Kajsa Ellegård and Matthew Cooper. "Exploring time diaries using semi-automated activity pattern extraction". International Journal of Time Use Research, Volume 6, no.1, 2009. Pages 1-25. Number of citations: 12

Nguyen Thong Dang, Monica Tavanti, Ivan Rankin and Matthew Cooper. "A comparison of different input devices for a 3D environment". International Journal of Industrial Ergonomics, **39** (May 2009) pp.554-563. Number of citations: 20

Karljohan Lundin Palmerius, Matthew Cooper and Anders Ynnerman, "Haptic Rendering of Dynamic Volumetric Data", IEEE Transactions on Visualization and Computer Graphics, **14**(2):263-276, March 2008. Number of citations: 11

Jimmy Johansson and Matthew Cooper. "A Screen Space Quality Method for Data Abstraction". Computer. Graphics Forum, volume 27, number 3, pages 1039–1046, 2008. Number of citations: 11

* Jimmy Johansson, Camilla Forsell, Mats Lind and Matthew Cooper. "Perceiving Patterns in Parallel Coordinates: Determining Thresholds for Identification of Relationships". Information Visualization, volume 7, number 2, 2008, pages 152–162. Number of citations: 16

Karljohan Lundin, Matthew Cooper, Anders Persson, Daniel Evestedt and Anders Ynnerman. "Enabling design and interactive selection of haptic modes." Virtual Reality, Volume 11, Number 1 (March, 2007), pages 1-13, Springer London. Number of citations: 25

"Revealing Structure in Visualizations of Dense 2D and 3D Parallel Coordinates". Jimmy Johansson, Patric Ljung, Mikael Jern and Matthew Cooper. Information Visualization, 2007, volume 5, number 2, pages 125–136, 2006. Number of citations: 23

Matthew Cooper and Kajsa Ellegård, “Complexity in daily life - 3D-visualization showing activity patterns in their contexts”. In the electronic International Journal of Time Use Research, Volume 1, August 2004. Number of citations: 26

Peer-reviewed conference publications since (2005-2013)

Umut Kocak, Karljohan Palmerius and Matthew Cooper. “Anisotropic Virtual Coupling with Energy-Based Deflection for Palpating Inhomogeneous Compliant Objects.” To appear in proceedings of World Haptics 2013. Daejeon, South Korea, April 2013.

Christine Mikkelsen, Jimmy Johansson an Matthew Cooper. “Visualization of Power System Data on Situation Overview Displays.” In proceedings of the 16th International Conference on Information Visualization, Montpelier, France, July 2012. pp.188-197.

Camilla Forsell and Matthew Cooper. “A Guide to Reporting Scientific Evaluation in Visualization”. In Proceedings of Advanced Visual Interfaces (AVI) 2012, Capri, Italy, May 2012.

Umut Kocak, Karljohan Lundin Palmerius, Camilla Forsell, Matthew Cooper. “The Effect of the Stiffness Gradient on the Just Noticeable Difference Between Surface Regions”. To Appear in the proceedings of Eurohaptics 2012, Tampere, Finland, June 2012, Springer Berlin/Heidelberg. pp.282-292.

Umut Koçak, Karljohan Lundin Palmerius and Matthew Cooper “An Error Analysis Model for Adaptive Deformation Simulation”, in Proceedings of ACHI Conference, Valencia, February 2012.

Umut Koçak, Karljohan Lundin Palmerius, Camilla Forsell, Anders Ynnerman and Matthew Cooper. “Analysis of the JND of Stiffness in Three Modes of Comparison”, in Proceedings of the HAID Conference, Kyoto, Japan, August 2011. Number of citations: 1

Magnus Axholt, Martin Skoglund, Stephen O'Connell, Matthew Cooper, Stephen Ellis, Anders Ynnerman, “Parameter Estimation Variance of the Single Point Active Alignment Method in Optical See-Through Head Mounted Display Calibration”, Proceedings of the IEEE Virtual Reality Conference, 27-24, 2011. Number of citations: 2

Staffan Klashed, Per Hemingsson, Carter Emmart, Matthew Cooper, Anders Ynnerman, “Uniview – Visualizing the Universe”. In Eurographics 2010 - Areas Papers, May 2010.

Magnus Axholt, Martin Skoglund, Stephen Peterson, Matthew Cooper, Thomas Schön, Fredrik Gustafsson, Anders Ynnerman, Stephen Ellis. “Optical See-Through Head Mounted Display: Direct Linear Transformation Calibration Robustness in the Presence of User Alignment Noise”. In Proceedings of the Human Factors and Ergonomics Society 54th Annual Meeting, 2010. Number of citations: 2

Stephen D. Peterson, Magnus Axholt, Matthew Cooper, Stephen R. Ellis, "Detection Thresholds for Label Motion in Visually Cluttered Displays", In proceedings of the IEEE Virtual Reality Conference, 2010.

Monica Tavanti and Matthew Cooper. “Looking for the 3D Picture: The Spatio-temporal Realm of Student Controllers”. In proceedings of the Human Computer Interaction and Interfacing conference, San Diego, California, USA. July 2009. Published by Springer Verlag in Volume 5619 of Human Centred Design. Pages 1070-1079. Number of citations: 4

Mats Lind, Jimmy Johansson and Matthew Cooper. “Many-to-Many Relational Parallel Coordinates Displays”. In Proceedings of the 13th IEEE International Conference on Information Visualisation, Barcelona, Spain, July 2009. Number of citations: 5

Stephen D. Peterson, Magnus Axholt, Matthew Cooper, Stephen R. Ellis. “Evaluation of Alternative Label Placement Techniques in Dynamic Virtual Environments”. In proceedings of the International Symposium on Smart Graphics, Salamanca, Spain. July 2009. Number of citations: 2

Stephen D. Peterson, Magnus Axholt, Matthew Cooper, Stephen R. Ellis. “Visual Clutter Management in Augmented Reality: Effects of Three Label Separation Methods on Spatial Judgments”. In proceedings of the IEEE Symposium on 3D User Interfaces 2009, Lafayette, Louisiana, U.S.A., March 2009. Number of citations: 5

Petter Bivall Persson, Gunnar Höst, Matthew Cooper, Lena Tibell and Anders Ynnerman. “Improved Feature Detection over Large Force Ranges Using History Dependent Transfer Functions”. In proceedings of the Third Joint Eurohaptics Conference and Symposium on Haptic Interfaces for Virtual Environments and Teleoperator Systems, IEEE-WorldHaptics 2009, Salt Lake City, Utah, USA. pp.476-481. Number of citations: 2

Umut Koçak, Karljohan Palmerius and Matthew Cooper. “Dynamic Deformation Using Adaptable, Linked Asynchronous FEM Regions”. In proceedings of the Spring Conference on Computer Graphics, pp.213-220, Budmerice, Slovak Republic, April, 2009. Number of citations: 3

Karljohan Lundin Palmerius and Matthew Cooper and Anders Ynnerman. “Flow Field Visualization Using Vector Field Perpendicular Surfaces”. In proceedings of the Spring Conference on Computer Graphics, pp.35-42, Budmerice, Slovak Republic, April, 2009. Number of citations: 4

Katerina Vrotsou, Anders Ynnerman, and Matthew Cooper. “Seeing Beyond Statistics: Visual Exploration of Productivity on a Construction Site.” In Proceedings of International Conference Visualization in Built and Rural Environments (BuiltViz 08), 37-42. London, UK: IEEE Computer Society, 2008. Number of citations: 3

“A comparison of different input devices for a 3D environment.” Nguyen Thong Dang, Monica Tavanti, Ivan Rankin, Matthew Cooper. In proceedings of the European Conference on Cognitive Ergonomics 2007. London,UK. pp 153-160. ACM Press, 2007. Number of citations: 8

“Depth Cues and Density in Temporal Parallel Coordinates.” Jimmy Johansson, Patric Ljung, Matthew Cooper. In proceedings of the Eurographics/IEEE-VGTC Symposium on

Visualization. Norrköping, Sweden. pp. 35-42. Eurographics Association, 2007. Number of citations: 12

"Designing and Evaluating a Haptic System for Biomolecular Education." Petter B Persson, Matthew Cooper, Lena Tibell, Shaaron Ainsworth, Anders Ynnerman, Bengt-Harald Jonsson. In proceedings of IEEE Virtual Reality Conference 2007. Charlotte, North Carolina, USA. pp. 171 - 178. IEEE Computer Society Press, 2007. Number of citations: 28

"Everyday Life Discoveries: Mining and Visualizing Activity Patterns in Social Science Diary Data." Katerina Vrotsou, Kajsa Ellegård, Matthew Cooper. In proceedings of the IEEE International Conference on Information Visualisation, Zürich, Switzerland. pp. 130 - 138. 2007. Number of citations: 17

"Exploring Time Diaries Using Semi-Automated Activity Pattern Extraction." Katerina Vrotsou, Kajsa Ellegård, Matthew Cooper IATUR - XXIX Annual Conference 2007. Washington DC, USA. Number of citations: 5

"Evaluating the Effectiveness of Haptic Visualization in Biomolecular Education - Feeling Molecular Specificity in a Docking Task." Petter B Persson, Lena Tibell, Matthew Cooper, Anders Ynnerman, Bengt-Harald Jonsson. 12th IOSTE Symposium, Penang, Malaysia. pp. 745 – 752. Universiti Science Malaysia, 2006. Number of citations: 4

"Enabling Haptic Interaction with Volumetric MRI Data Through Knowledge-based Tissue Separation". Karljohan Lundin, Claes Lundström, Matthew Cooper, Anders Ynnerman. In proceedings of Volume Graphics 2006. Boston, Massachusetts, USA. pp. 75 – 78. Eurographics Association, 2006. Number of citations: 5

"Interactive Resolution of Conflicts in a 3D Stereoscopic Environment for Air Traffic Control". Marcus Lange, Thong Dang and Matthew Cooper. In proceedings of the 4th IEEE International Conference on Computer Sciences - RIVF'06, Ho Chi Minh City, Viet Nam, February 12-16, 2006. Number of citations: 5

"The Orthogonal Constraints Problem with the Constraint Approach to Proxy-based Volume Haptics and a Solution". Karljohan Lundin, Matthew Cooper and Anders Ynnerman. In Proceedings of SIGRAD Conference 2005, Lund, Sweden, pp. 45-49. Number of citations: 6

"Revealing Structure within Clustered Parallel Coordinate Displays". Jimmy Johansson, Patric Ljung, Mikael Jern and Matthew Cooper. In proceedings of the 11th IEEE Symposium on Information Visualization, pages 125-132, Minneapolis, MN, USA, 2005. Number of citations: 107

"3-Dimensional Display for Clustered Multi-Relational Parallel Coordinates". Jimmy Johansson, Matthew Cooper and Mikael Jern. In proceedings of the 9th IEEE International Conference on Information Visualisation, pages 188-193, 2005. Number of citations: 28

"Visual Data Analysis using Tracked Statistical Measures within Parallel Coordinate Representations". Daniel Ericson, Jimmy Johansson and Matthew Cooper. In proceedings of

the 3rd IEEE International Conference on Coordinated & Multiple Views in Exploratory Visualization, pages 42-53, London, 2005. Number of citations: 14

"Interactive and Immersive 3D Visualization for Air Traffic Control". Marc Bourgois, Matthew Cooper, Vu Duong, Jonas Hjalmarsson, Marcus Lange, and Anders Ynnerman. In Proceedings of the 6th USA-Europe ATM R&D Seminar, Baltimore, Maryland, U.S.A. June 2005. Number of citations: 17

"Interactive Visualization as a Tool for Analysing Time-Varying and Non-Linear Systems". Jimmy Johansson David Lindgren Matthew Cooper Lennart Ljung. In proceedings of the 16th IEEE IFAC World Congress, 2005. Number of citations: 2

K. Lundin, Mattias Sillén, Matthew Cooper, and Anders Ynnerman. "Haptic Visualization of Computational Fluid Dynamics Data Using Reactive Forces". In Proceedings of Visualization and Data Analysis 2005. SPIE, SPIE-IS&T Electronic Imaging, January 2005. Number of citations: 21

Other Conference Contributions (2005-2013)

Matthew Cooper, Alexander Fridlund, Miroslav Andel, Claudiu Bojan, Jean-Luc Hardy, "Educational Benefits of 3D displays in Early Controller Training", Proceedings of the 27th International Congress of the Aeronautical Sciences (ICAS2010), Nice, France, 2010.

"Visuella och haptiska modeller för underlättad förståelse för molekylers struktur och interaktioner." Petter B Persson, Matthew Cooper, Lena Tibell. In proceedings of Universitetspedagogiska konferensen vid Linköpings Universitet. 2006. pp. 43 – 47. Linköping, 2007.

"Reasoning through Touch? Using Haptics in Life Science Education." Petter B. Persson, Lena Tibell, Matthew Cooper, Shaaron Ainsworth. In proceedings of the EARLI 12th Biennial Conference for Research on Learning and Instruction. Budapest, Hungary, 2007.

"Use of Chemical Force Feedback for Multisensory Insights into Ligand Docking." Petter B Persson, Matthew Cooper, Anders Ynnerman, Bengt-Harald Jonsson, Lena Tibell. In proceedings of the VII European Symposium of The Protein Society – From Proteins to Proteome. Stockholm/Uppsala, Sweden, 2007. pp. 151 - 151.

"Experience the Aperceptual through Virtual Reality! Tactile and Visual VR Representations as Cognitive Tools in Molecular Life Science" Lena Tibell, Petter B Persson, Matthew Cooper, Anders Ynnerman, Bengt-Harald Jonsson. In proceedings of ESERA 2007. Malmö, Sweden.

"Using Force Feedback Virtual Reality Technology as a Tactile Gateway to Understanding of Biomolecular Interactions." Petter B Persson, Lena Tibell, Matthew Cooper. 9th JURE conference of EARLI, 2006. Tartu, Estonia.

"Interactive Visual Exploration of Time-Use Data". Katerina Vrotsou, Matthew Cooper. Short paper in IEEE International Conference on Information Visualisation, 2006. London. pp. 93 – 94. IEEE Computer Society. Number of citations: 2

Technical Reports

Colin Venters and Matthew Cooper. "A review of content-based image retrieval systems." JISC Technology Applications Programme (JTAP) Technical report. Number 054. June 2000. Number of citations: 67.

Book Contributions

"An Introduction and Guide to Evaluation of Visualization Techniques through User Studies." Camilla Forsell and Matthew Cooper. To appear in "Handbook of Human Centric Visualization." Springer. July 2013.

"Visualization with AVS/Express", Matthew D. Cooper, W. Terrence Hewitt, Yien Kwok, George W. Leaver, Joanna M. Leng, Paul G. Lever, Mary J. McDerby, James S. Perrin, Mark Riding, I. Ari Sadarjoen, Tobias M. Schiebeck, Colin C. Venters. In: Johnson C, Hansen C, editors of *The Visualization Handbook*. Academic Press, 2004. ISBN: 0-12-387582-x. Publication date: 2004-07-25.

Invited Talks

Invited Speaker at "Challenges in Visualizing Network Enabled Capability", University of Leeds, April 2009.

Invited Speaker at the 6th IEEE Virtual Reality International Conference, Held in Laval, France. May 2004.

5 Most Cited Peer-Reviewed Publications

107 "Revealing Structure within Clustered Parallel Coordinate Displays". Jimmy Johansson, Patric Ljung, Mikael Jern and Matthew Cooper. In proceedings of the 11th IEEE Symposium on Information Visualization, pages 125-132, Minneapolis, MN, USA, 2005.

32 "Effect of Hydration on the Barrier to internal Rotation in Formamide. Quantum Mechanical Calculations Including Explicit Solvent and Continuum Models." J. S. Craw, J. M. Guest, M. D. Cooper, N. A. Burton and I. H. Hillier, Journal of Physical Chemistry 100 (1996) 6304-6309.

34 Matthew Cooper and Kajsa Ellegård, "Complexity in daily life - 3D-visualization showing activity patterns in their contexts". In the electronic International Journal of Time Use Research, Volume 1, August 2004.

28 "3-Dimensional Display for Clustered Multi-Relational Parallel Coordinates". Jimmy Johansson, Matthew Cooper and Mikael Jern. In proceedings of the 9th IEEE International Conference on Information Visualisation, pages 188-193, 2005.

28 "Designing and Evaluating a Haptic System for Biomolecular Education." Petter B Persson, Matthew Cooper, Lena Tibell, Shaaron Ainsworth, Anders Ynnerman, Bengt-Harald Jonsson. In proceedings of IEEE Virtual Reality Conference 2007. Charlotte, North Carolina, USA. pp. 171 - 178. IEEE Computer Society Press, 2007.

VETENSKAPSRÅDET
THE SWEDISH RESEARCH COUNCIL

Kod
þÿ2013 42910 104025

Name of applicant
Johansson, Jimmy

Date of birth
þÿ760717 1977

Title of research programme

Appendix N

Budget and research resources

Vetenskapsrådet, Box 1035, SE-101 38 Stockholm, tel. +46 (0)8 546 44 000, vetenskapsradet@vr.se

N BUDGET

N.1 RESEARCH STAFF

Dr. Jimmy Johansson is the PI of the project and will together with Dr. Katerina Vrotsou and Dr. Matt Cooper research techniques for detecting and exploring change in high-dimensional temporal data. Dr. Johansson and Dr. Vrotsou will each devote 30% of their time and Dr. Cooper will devote 15% of his time to the project. A PhD student will be recruited to work on all areas of the project. The PhD student will work 90% on the project and we expect to get funding for a teaching assistant-ship covering 10% of the salary costs.

Research Staff	Salary	%	Y1	Y2	Y3	Y4
Jimmy Johansson	40100	30%	349	358	367	376
Katerina Vrotsou	38500	30%	336	345	353	362
Matthew Cooper	52000	15%	222	228	234	240
New PhD Student	25700	90%	699	716	734	753
Sum of salary (tkr)			1606	1647	1688	1731

N.2 EQUIPMENT

The proposed project will have full access to the resources of the Norrköping Visualization Centre – C. This will allow us to promote visualization through various activities supporting exchange and collaboration between academia, industry and society.

In our research lab we have access to a Tobii TX300 eye-tracker which will be used in one of the sub-projects. We have also access to large stereoscopic displays which will be used for developing and experimenting with 3D visual representations for exploring complex change.

In order to develop prototype applications we will purchase a personal computer, equipped with a high-specification graphics card.

N.3 TRAVEL

The scientific outcomes of the project will be disseminated through the common channels for academic contributions using publications in suitable academic journals and international conferences. We anticipate that the student and parts of the research staff will be required to travel to at least two international conferences per year to present papers and the travel budget has been designed with that in mind.

N.4 COSTS FOR EQUIPMENT AND TRAVEL

Here we list the costs not related to research staff salary. Travel costs include indirect costs of 40%. The cost for the computer is written off over three years.

Costs for equipment and travel	Y1	Y2	Y3	Y4
Travel	126	126	126	126
Computer (30 tkr)	10	10	10	0
Total cost (tkr)	136	136	136	126

N.5 OTHER PROJECT RESOURCES

This project concerns a new research idea and no other related projects exist or are applied for to Vetenskapsrådet.

VETENSKAPSRÅDET
THE SWEDISH RESEARCH COUNCIL

Kod
2013-42910-104025-66

Dnr
2013 -

Name of applicant
Johansson, Jimmy

Date of birth
760717-1977

Reg date
2013-04-11 14:49:39

Project title
A user-centered information visualization framework for detecting and exploring change in high-dimensional temporal data

NT

Research grants NT April 11, 2013
Project Grant Junior Researchers
*Nat-Tek generellt
Linköpings universitet

NT-2, NT-14

Appendix S

Signatures

2014	2015	2016	2017	2018	
1742	1783	1824	1857		2014-01-01 -- 2017-12-31

Applicant | **Date**

Head of department at host University | **Clarifi cation of signature** | **Telephone**

A signature on the application is required not only from the applicant but also from the authorised representative of the administrating organisation/institution or equivalent (normally the head of the department or establishment where the research is to be conducted). The signature confirms that the department can accommodate the proposed research, position or equipment; that the costing in the application is approved for the department's part, that any proposed experimentation on human or animal subjects has been reported, and that the applicant has reported any secondary occupations and commercial ties (s)he may have, and nothing inconsistent with good research practice has thereby emerged. The applicant must have discussed these conditions with the representative of the administrating organisation/institution or equivalent before the latter approves and signs the application.

NOTE the exceptions!
Please note that a different procedure applies for the following types of grants:

- Infrastructure- Operation Grants
- Infrastructure- Grants for Expensive Equipment
- Infrastructure- Grants for Large Databases
- Framework Grant SIMSAM

For these types of grants the vice-chancellor, instead of the head of department, must sign Appendix S. Thereby (s)he confirms the commitments of the administrative organization. The details are specified in the Call for Proposals, published at www.vr.se.

Vetenskapsrådets noteringar
Kod

2013-42910-104025-66

Vetenskapsrådet, Box 1035, SE-101 38 Stockholm, tel. +46 (0)8 546 44 000, vetenskapsradet@vr.se