01191 - Computational Cartography and Spatial Modelling

Cartography, Maps, Spatial Modelling and Analysis

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organized by

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The Dagstuhl seminar on computational cartography and spatial modelling is the third in a series of seminars where computer scientists and spatial scientists are brought together. It is the first time that the topic of spatial modelling was added to extend the scope of the seminar. The exchange of ideas and research between computer science and spatial science is essential to advance research in this interdisciplinary area.
The seminar was attended by twenty-six participants from various countries. Most participants were affiliated at universities, but there were also participants from companies and institutions, among which national mapping agencies. The main topics addressed during the seminar were:

- Cartographic methods: automated map labeling and automated map generalization remain crucial issues both in research and software for automated cartography.
- Spatial and spatio-temporal modelling: the definition of formal, conceptual models for time and space which underlie spatial data and its use in geographic information systems.
- Terrain modelling: defining and computing realistic terrain models, and computations on existing digital elevation models.
- Techniques from computational geometry: techniques and topics new in computational geometry that can be of use in geographic information systems.

The surroundings and the atmosphere provided the ideal conditions for a lot of interaction and discussions among the participants. The organisers hope that the seminar will be followed by a fourth on the topic.

Contents

1 STAR-Tree: An Efficient Indexing Scheme for Moving Points

Pankaj K. Agarwal

We present a new technique called, STAR-tree, based on R*-tree for indexing a set of moving points so that various queries, including range queries, time-slice queries, and nearest-neighbor queries, based on their current or future positions. The index provides tradeoffs between storage and query performance and between time spent in updating the index and in answering queries, by combining techniques from computational geometry and spatial databases. We present performance studies that compare our methods with the existing ones under a varying type of data sets and queries. Our experiments show that the index proposed here performs considerably better than the previously known ones.

2 Schematic Maps on Demand

Silvania Avelar

Joint work with Matthias Mueller

Schematic maps are designed to convey only essential features of network routes: geometric accuracy is considered to be less important than linkages, adjacency and relative position. Generating schematic maps on demand can be seen as a geometric constraint problem to be solved algorithmically, in interactive time. In our approach, positions of lines in the original input map are modified to meet geometric and aesthetic criteria defined for the schematic map. We present an algorithm to preserve map topology during this transformation process using simple geometric operations and tests. By preservation of map topology we mean the following three properties: (i) no absence of line crossings that were present in the input map; (ii) no line crossings that were not present in the input map; (iii) cyclic order of outgoing connections around any node agrees with the ordering of connections in the input map. Our algorithm can additionally detect some unwished changes in the sidedness relations among geographic elements. We also discuss some open problems.

3 Elastic Beams for Feature Displacement in Cartographic Maps

Mats Bader

The presentation considers the issue of feature displacement in cartographic generalization. Attempts to display cartographic data at scales smaller than the source scale result in spatial conflicts; map symbols clutter or overlap. Several map generalization operators may be applied to resolve these problems, including displacement. The main goal of displacement is to separate conflicting objects, either by deformation of their outline or by shifting them in their entirety. Cartographic displacement is a contextual operation, dealing with several objects at once, and also affecting the neighborhood of the conflicting features. Local reasoning often fails, since conflicts are not solved, but simply pushed back and forth. Existing sequential displacement algorithms fail to incorporate the required broader view necessary for successful generalization.

In the presentation, we show how cartographic displacement may be interpreted as an optimization problem. The proposed model thereby relies on an interplay of external and internal forces which compete a solution (see also Burghardt, 1997). Internal regularizing forces constrain the displacement of map objects or object structures, while at the same time proximity conflicts give rise to external forces, which try to deform objects and push them away from conflicts. A balance between internal and external forces is iteratively sought – the system energy is minimized.

For the modeling of regularizing structures, the research draws upon elastic beams as used in engineering sciences (see also Hojholt, 2000). For implementation, a Finite Element Method has been used. A goal is to adapt the beam model to demands arising in cartography. The success of the new algorithms depends on the way in which cartographic constraints and cartographic knowledge can be translated into the numerical methods (esp. the handling of junctions).

4 AGENT summary...from my point of view

Mathieu Barrault

Cartographic Generalisation remains a critical issue during the map creation process. Based on the theme, the scale and the legend specifications, there are as many possible generalisations as cartographers. This latter assumption makes the automation of the generalisation task an heavy challenge whose success should contribute to better and faster spreading geographical information. From Dec. 1997 to Nov. 2000, a european project called AGENT, involving Universities of Zurich, Edinbourgh and Grenoble, as well as the French National

Map agency, the IGN, and the english company LaserScan attempted to tackle the automation of the generalisation task through the use of a multi-agent system. Each agent is responsible of a geographical entity and is in charge of finding and applying the best sequence of given generalisation algorithms so as to satisfy as many related cartographic constraints. Two kinds of agents have been defined: Meso-agents are in charge of geographical feature relationships where the micro-agents handle inner behaviour of each geo-feature. AGENT results showed how the multi-agents system deals with roads and buildings (micro-agents) as well as the road network, the city-blocks and towns (meso-agents). Although only a small sub-set of topographic features has been tackled during the project, a whole generic infra-structure has been developed which allow extension of agents behaviours and more over provide a wide flexibility regarding all specifications of the required map (theme, scale, legend,...).

5 A "Seat-of-the-Pants" Displacement Operator

Rupert Brooks

The National Atlas of Canada has a proud cartographic tradition. In the past, many cartographic bases at a variety of scales were kept. Today, framework data is collected as a single more detailed database. Practical exploitation of this data requires automated generalisation techniques.
Recently the National Atlas of Canada produced a 1:4 000 000 scale paper map from framework data at 1:1 000 000 scale. In particular, the hydrology was derived using a partially automated process. The process was "seat-of -the-pants" meaning that it was done very rapidly, and the solutions used were far from optimal. Nevertheless, the map was successfully completed using these techniques for a significant portion of the cartographic process. The displacement operator used is described in detail. At project time it was implemented in a rapid and inefficient way. In collaboration with Carleton University the operator was recently revisited.. It was rewritten to exploit possible performance increases due to hardware, language and parallelisation. A near 60-fold increase has been possible through language and hardware changes. Furthermore, preliminary trials indicate that for datasets which are large enough, significant performance gains are possible using a parallel approach.

6 Schematization of Road Networks

Sergio Cabello

Joint work with M. de Berg, S. van Dijk, M. van Kreveld and T. Strijk

We study the problem of computing schematized versions of network maps, like railroad maps. Every path of the schematized map has two or three links with restricted orientations, and topologically, the schematized map must be equivalent to the input map. Our approach applies to several types of schematizations, and certain additional constraints can be added. In the general case our algorithm takes $O(n \log^3 n)$ time, and when all paths in the input are monotone in some (not necessarily the same) direction, it runs in $O(n \log n)$ time.

7 Resolving inconsistency in multi-granular geographic information sources

Matt Duckham

Granularity in information can lead to inconsistency. Two observations of a feature at different granularities may conflict, even if the feature is wholly accurate and crisp (ie not vague). There are a number of problems to be overcome and strategies which may be adopted when attempting to resolve this inconsistency, for example when integrating multi-granular data sources. This paper explores the development of software targetted at integrating two multi-granular geographic data sets concerning land cover in the UK. The approach used aims to resolve inconsistency based on the inter-relations between spatial and thematic grains in the two data sets. The example is used as a platform to address a number of related issues, including the use of description logics to resolve inconsistency and the extension of the approach to deal with vague as well as granular geographic information.

8 Crusts, Skeletons and Terrain Modelling

Christopher Gold

Good quality terrain models are becoming more and more important, as applications such as runoff modelling are being developed that demand better surface orientation information than is available from traditional interpolation techniques. A consequence is that poor-quality elevation grids must be massaged before they provide useable runoff models.

Rather than using direct data acquisition, this project concentrated on using available contour data, for two reasons. Firstly, despite modern techniques, contour maps are still the most available form of elevation information. Secondly, manual contour tracing has imposed a subjective interpretation of the form of the landscape that is lost with automation, yet which is of considerable value. The maximum slope of the terrain is perpendicular to the contour, and this permits us to visualize the relationships between pairs of contours. With care this may be modelled by triangulation methods, as the spatial relationships can be preserved, although standard grid interpolation methods based on "n nearest neighbours" often have problems.

However, whenever we have relationships between portions of the same elevation contour, such as in peaks, pits or valley heads, our interpretation based on triangle slope is insufficient - we get "flat triangles". In this case we need to re-examine our spatial model. The usual triangulation approach, the Delaunay triangulation, is effective because it is locally stable - a property based on its dual, the Voronoi diagram. These two spatial structures have been much studied by workers in the field of computational geometry - largely in terms of efficient calculation, but also in terms of their properties. In particular, recent work on the automatic reconstruction of curves from point samples, and the generation of medial axis transforms (skeletons) has greatly helped in the visualization of the relationships between sets of boundaries, and families of curves.This provides us with tools to enrich our original contour data for "flat triangles". The insertion of skeleton points in these cases guarantees the elimination of all flat triangles. Additional assumptions about the local uniformity of slopes, either along or across valleys and other features, give us enough information to assign elevation values to these skeleton points.

If required, appropriate interpolation techniques may generate an elevation grid, for visualization purposes, that preserves reasonable slopes at all points on the model - even at the data points themselves - and that are faithful to the input data. We compare several weighted-average methods, and show that the key issues are the selection of the set of neighbours and the estimation of slopes at the data points themselves. The resulting terrain model provides us with a surprisingly realistic model of the surface - that is, one that conforms well with our subjective interpretation of what a real landscape should look like, based on the interpretation of the original contour data.

9 Active Objects and Dynamic Topology for Spatial Data Re-engineering and Rich Data Modelling

Paul Hardy

Many organisations such as national mapping agencies have collected large datasets of spatial data, often by digitising existing map series. However, they are discovering that the current and future demands for spatial datasets and mapping do not match the simple data models and unstructured feature data that they have at present. To create the required rich data models and appropriate mapping using the established GIS and digital mapping software tools has been a major challenge, which has not often been economically viable. However, there are now appearing new software products based on active objects in intelligent spatial object databases, which provide the necessary tools and infrastructure to make these tasks economically possible. This paper overviews the data modelling, dynamic topology, and active object capabilities of a commercial spatial data manipulation product, and shows how they are being used for large-scale spatial data re-engineering to create new national framework datasets and generalised mapping. It also covers some of the challenges remaining, such as conflation of existing datasets to improve quality.

10 Feature-Based Map Generalisation with Delaunay Triangulation

Christopher Jones

Joint work with Peter van der Poorten

A method is presented for generalising multiple cartographic lines using an approach that is sensitive to the shape of line features while guaranteeing the maintenance of topological consistency. A constrained Delaunay triangulation is used to construct a skeleton of the space surrounding the lines and hence represent line features in terms of branches consisting of sets of triangles on both sides of each line. A variety of statistical measures, such as area, length and average width, is used to characterise the shape of the triangulation branches. The measures enable selective elimination of different types of line feature, leading to the possibility of user-specification of the style of generalisation. In our implementation, the triangulation is updated dynamically in the process of labelling line vertices with the values of branch statistics that may be used to eliminate them.

11 Intersecting Red and Blue Line Segments in Optimal Time and Precision

Andrea Mantler

Joint work with Jack Snoeyink

A common geometric problem in geographic information systems and computer graphics is to compute the arrangement of a set of n segments that can be coloured red and blue such that there are no red/red or blue/blue crossings. We present an optimal degree 2 algorithm which finds the intersecting pairs of segments in $O(n \log n + k)$ time and $O(n)$ space, where k is the number of intersection points. The intersections are ordered along each segment, enabling us to compute the arrangement in $O(n \log n + k)$ time as well. Alternately, with a small modification to the algorithm, we can count the intersections in $O(n \log n)$ time and $O(n)$ space.
The slides can be found at
`http://www.cs.unc.edu/~mantler/redblue/dag_pres/index.html`.

12 The ArcGIS TIN Object Model and Its Support for Generalization

Wanning Peng

As an important data structure in computational geometry, Delaunay triangulation has a great potential in supporting automated generalization. This has been proven by many research results. This presentation describes the TIN object model implemented in ESRI's ArcGIS, and demonstrates how it can facilitate automated generalization, through a simple Visual Basic application.
In additional to node, edge, and triangle, the model also supports three higher-level components: TinPoint, TinPolyline and TinPolygon. They are defined as a collection of nodes/ edges/ triangles that share certain (user defined) common properties. The notion of TinPoint, TinPolyline and TinPolygon allows users to describe, embed, query, and manipulate, geometric objects within a TIN structure. It supports spatial queries that are fundamental to many generalization operations, such as, given a minimum required space between objects: a) Can a specific polygon be exaggerated/shrunk/rotated, or moved to a new location, without causing any spatial conflict with existing objects? b) Can this particular vertex of the polygon be deleted, or moved to a new location, without causing any spatial conflict or self-intersection?

The TIN object model was implemented using COM (component object model) technology. This allows the users to access the model, through not only professional programming languages (such as C++), but also scripting languages such as VB and VBA. APIs for manipulating objects (such as deleting, exaggerating, shrinking, rotating, and moving, points, polylines, and polygons; such as deleting, adding, and moving, vertices of a polygon or polyline) are also provided.

13 Automated Relief Representation for Visualisation of Archaeological Monuments and other Anthropogenic Forms

Nicolas Regnauld

Both within the Royal Commission on Ancient and Historic Monuments for Scotland (RCAHMS) and the Ordnance Survey (OS) there are specific requirements to record Historical Monuments (such as ramparts and mounds) and various anthropogenic forms (such as road and rail embankments). The traditional method of relief representation within archaeology employs 'hachures' (a hachure being a hand drawn line along the line of steepest gradient of a slope and in the direction of that slope). Hachuring has proved to be a highly effective form of representation - superior to alternatives such as contours, relief shading and DTMs - but is acknowledged to be extremely time consuming in the context of current IT solutions. Developments in automated cartography and digital databases such as DNF have led to a requirement for an algorithm that automatically generates hachures with the minimum of human input, and the simplest of database requirements. We have developed a method for automatic relief representation required in order to visualise archaeological monuments within a GIS. The program takes as input the isolines defining the top and bottom of the slope and populates the region with hachures whilst addressing a comprehensive set of design issues.

14 Where more geometry could help? What for?

Anne Ruas

The challenge of our information society is to be able to have an easy access to appropriate data, on demand. From a provider point of view (e.g. National Mapping agency) the challenge is first of all to produce geographical data bases with quality constraints that can be summarised as follow: the data should respect the data base specifications and

should be updated. But from these data bases to the satisfaction of user needs, a step is dramatically missing. Data bases are done to answer to a set of different needs, but they never answer to each need. It means that some transformations and integration are necessary. A transformation is a process that changes the data base schema and the data content according to a need, data bases integration groups two or more data bases together. In order to provide these information on demand, we need to automate as well as possible two macro operations: data matching (which is necessary for updating and integration) and data generalisation (which is necessary for providing data with the appropriate level of detail). These macro operations have been studied in GIS research community and more specifically at the cogit laboratory for years. Both of them require a strong analysis of geographical spatial configuration, that uses geometrical analytical measures or indicators.
For data matching, measures are developed in order to compare objects: two objects or two sets of objects. The point is 1- to find automatically from two data sets which objects represent the same geographical information 2- to identify and interpret the differences of representation between correlated objects. For that, it is sometime relevant to change geometrical representation from Cartesian to others one (see Bel Hadj Ali work).
For generalisation, research is performed to enrich the description of geographical objects at a micro (one object), meso (i.e. a group of objects) or macro (a population of objects) level in order to know where, when and how to generalise. Measures are conceived to identify groups, to qualify objects properties (e.g. shape, position, level of detail, differences between two states) as well as relationships between objects (topology, proximity, neighbourhood, density, etc.). Some measures are performed on data structures (such as Delaunay Triangulation, Minimum Spanning Tree, Voronoi Diagram). The method is to identify the property to describe (e.g. line sinuosity), to study the mathematical property and the appropriate geometrical representation, to conceive, code and test the measures (or indicator) and to study their application field (what for, on which data), their sensibility (dy/dx) and their cost (complexity, computational time). For each property, a set of measures can be (and have been) conceived: the point is to know 1- which measure (or indicator) is the best to answer to a given question and 2- how to interpret correctly the value of each measure. For example to qualify the shape of a building, measures can go from simple elongation to an accurate analysis of internal skeleton. The GIS community suffers from a lack of analysis of measure properties and application field that duplicate and slow down progress. The computational geometry community could certainly offers help in order to speed up progress in this domain.

15 Parallel Weighted Shortest Paths in Terrains

Jörg-Rüdiger Sack

Joint work with L. Aleksandrov, M. Lanthier, A. Maheshwari and D. Nussbaum

Shortest path problems are among the fundamental problems studied in computational geometry and have applications in geographical information systems (GIS). Existing algorithms for most of the interesting shortest path problems are either very complex and/or have very large time and space complexities. Hence they are unappealing to practitioners and pose a challenge to theoreticians. This coupled with the fact that the geographic/spatial models are approximations of reality anyway and high-quality paths are favored over optimal paths that are "hard" to compute, approximation algorithms are suitable and necessary. We consider the problem of determining a shortest path through a weighted terrains, i.e., terrains where the cost of travel depends on the nature of the terrain. We have developed a variety of approximation algorithms which are of practical value and theoretical interest.
The main objective of parallelizing a shortest path algorithms is to reduce the algorithm's runtime significantly. This time saving allows larger data sets to be used and more complex calculations to be performed, hence achieving often better solutions (i.e., higher accuracy) in less time than would be possible sequentially. For time-critical computations, parallelism may provide the only solution.
We also present the design, implementation and results of our parallel vector-based GIS, an effort which took approximatively 6 years up to now. (For more information please refer to http://www.scs.carleton.ca/∼gis .)

16 Typification based on Kohonen Feature Nets

Monika Sester

Spatial phenomena need to be analyzed on a level of detail appropriate for the given task. Geographic information systems (GIS) therefore need the possibility to present data at different levels of detail in order to provide a flexible use of the data. This relates both to the presentation and the analysis of the data, and involves generalization techniques.
The paper presents an approach for the automation of a generalization operator, namely typification. Typification is used to present a spatial situation at a reduced scale, using less objects, however under the constraint of preserving the original structure in terms of the type and distribution of the objects.
This presentation proposes an approach for typification of 2D-structures of similar type and size, like a collection of buildings, trees, mines, etc. It is based on Kohonen Feature Nets,

a neural network learning technique. The prominent property of this unsupervised learning method is the fact that the neurons are adapted to a new situation (the attractors), while keeping their spatial ordering - topology. Applying it for typification is straightforward. A subset of the original objects is chosen to represent the new situation. A simple, random selection of objects yields a reduced number of objects – however it will usually not represent the original spatial distribution. This reduced data set is now introduced as the so-called output map; its topology is given by a triangulation of the nodes. In the learning phase, the original objects act as attractors, that drag the neurons of the output map onto them. In the learning iterations, the neurons are iteratively adjusted according to the underlying attractor structure.

17 Part, Complement and Topological Relations

John G. Stell

The spatial world consists of regions and relationships between regions. Examples of such relationships are that two regions are disjoint or that one is a proper part of the other. The formal specification of spatial relations is important in qualitative spatial reasoning and geographical information systems. Various schemes of relationships have been proposed and basic schemes have been extended to deal with vague regions, coarse regions, regions varying over time, and so on. The principal aim of this talk is not to propose further schemes, but to provide a uniform framework within which several existing schemes can be understood, and upon which further schemes can be constructed in a principled manner. This framework is based on the fundamental concepts of part and of complement. By varying these concepts, for example allowing a part-of relation taking values in a lattice of truth values beyond the two-valued Boolean case, we obtain a family of schemes of spatial relations. The viability of this approach to spatial relations as parameterized by the concepts of part and complement is demonstrated by showing how it encompasses the RCC5 and RCC8 schemes as well as the case of 'egg-yolk regions'. The use of the approach for discrete regions is discussed briefly.

18 Smooth Generalization for Continuous Zooming

Marc van Kreveld

Most research efforts on cartographic generalization have focussed on producing a map at a less detailed level than the input map or the input data. Only the final outcome is of interest. In this paper we study how the changes made to a map during generalization can be visualized such that it looks smooth, that is, without sudden changes. This is necessary for continuous zooming during interactive mapping. We identify five visually smooth changes: moving, rotating, morphing, fading and appearing. Each can be useful in generalization. Often, more than one possibility of performing a smooth change is present. We analyze the possibilities and identify various complications that arise.

19 Criteria for better TIN terrain surface representations

Peter van Oosterom

Joint work with Edward Verbree

Computing the Delaunay Triangulation (DT) of a set of 2D points $p_1, ..., p_n$ and then using this triangulation together with the height values $h_1, ..., h_n$ to represent the terrain surface is not optimal. This is also true for the Constrained DT (CDT). The reason is that during the triangulation the third dimension is not taken into account. Note that the problem to reconstruct a surface from a set of points with a height value is very important; e.g. in the case of processing laser altimetry data or more traditionally when computing a surface from a set of contour lines or grid height elevation point.

20 New Developments for a GIS Topology Engine

Jan W. van Roessel

The development of a "Topology Engine" for a GIS is briefly surveyed, and recent additions to the engine are outlined. The engine was first described in paper given during a previous Dagstuhl Conference (Report 252). The dual purpose of the engine is to support real-time editing and to provide the capability for a variety of geo-processing operations, including various types of overlays. A multi-layer overlay processor forms the basis for the topology engine. It reduces all input features to lines segments, cracks and clusters the line segments and then constructs new output features. The outer layer of the engine deals with feature input and output, parentage and attribution and function callbacks. New developments were made in the areas of topological structuring, shape validation, topological relationships, ESRI coverage construction, and various geoprocessing functions. A few specific problems encountered in each of these topics are highlighted.

21 Spatio-temporal Analysis of Moving Point Objects

Robert Weibel

Joint work with Stephan Imfeld and Patrick Laube

Robert Weibel In recent years, data about moving points objects (e.g., GPS or telemetry fixes of animals, persons or vehicles) have become abundant. However, methods for the integrated spatio-temporal analysis of moving point data are still rare and relatively weakly developed. Ultimately, we would like to be able to analyse mobilty patterns over space *and* time of individuals and groups of individuals, subject to environmental conditions (e.g., habitat parameters such as supply of food or shelter; competition, etc.). We present two classes of methods to deal with some of these issues.

The first class of methods, termed *Time Plots* (TP), is designed to analyse mobility patterns of individuals. In TT-plots, distances between points at $t_1 \dots t_n$ are plotted into a symmetrical $n \times n$ matrix. This results in distinct "spatial" patterns that allow to infer recurring paths, movement directions, etc. An interpretation catalog has been compiled that helps with the interpretation of such TT-plot patterns. The method can be extended by using measures other than distance (e.g., direction, speed) or measures between two individuals.

The second class of methods is called *Radial Distance Functions* (RDF) and is designed to analyse the availability (quantity) of environmental parameters in the neighborhood of a point object. Within concentric circles about the point object properties of environmental parameters are measured (e.g., relative area of woodland about a badger sett). leading to a distribution function with respect to increasing distance from the point object. *Temporal RDFs* (TRDF) are then constructed by computing the RDF about consecutive locations $t_1 \dots t_n$.

Possible extensions of the above methods include, among others, statistical analysis of TP and TRDF, pattern recognition for automatic interpretation of these plots, and the integration of TP and TRDF.

22 Pedestrian Guidance Information from City Maps

Stephan Winter

Location-based services are a hot topic in research and development since telecom providers are looking for revenues for their investments in 3G-technology. Ubiquitous access combined with mobility of people creates a new market.

Pedestrian guidance services are a specific kind of location-based services. They are based on positioning techniques for tracking the user, and access to a variety of distributed information

/ service providers, some of them contributing spatial information, some of them contributing content information.

The talk deals with the creation of a graph representing the network of places open for pedestrian navigation in urban environment. Considering different sources and different types of sources it is discussed in detail how a graph can be constructed from two-dimensional spatial objects contained in multi-purpose city maps. Spaces are classified for their accessibility first, then for their shape. Two different kinds of abstracted linearization are presented and compared: center linearization and exit linearization. Both resulting graphs show useful properties for instructing pedestrians; and both are sufficiently abstract from geometric details an autonomous pedestrian is not interested in.

In the outlook the relevance of the graph properties fort the construction of route instructions is discussed, and the problem of tracking along a relatively generalized route is mentioned. Topics like user interface design, user profiling, or individual adaptation of the guidance service are not considered so far.

23 A Survey of Approximation Algorithms for Point Labeling

Alexander Wolff

Maps, graphs and diagrams are usually annotated with textual labels that are essential for understanding the meaning of the graphical objects on display. With the rapid increase of information to be visualized the automation of label placement has become a target of research. Label placement is usually devided into point, line and area labeling according to the objects to be labeled. Point labeling is the field that has the simplest objective functions, the cleanest mathematical formulation and has attracted the greatest research interest, maybe due to its computational complexity.

In my talk I will review the three fundamental objectives of point labeling, namely

1. label-size maximization,
2. label-number maximization, and
3. label-weight maximization.

For each of these objectives I will sketch algorithms for various label shapes, among others

- the oldest approximation algorithm in the label-placement literature for maximizing the size of square labels including some recent extensions,
- an old factor-1/2 and a new factor-2/3 approximation algorithm for maximizing the size of circular labels, two per point, and

- two factor-1/2 approximation algorithms for maximizing the number of sliding axis-parallel rectangular labels of equal height.

Papers on all the above-mentioned algorithms and many more can be found in the Map-Labeling Bibliography that I maintain at
`http://www.math-inf.uni-greifswald.de/map-labeling/bibliography/`.

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