Thank you for your application for the position “Efficient Algorithms for Visual Data Analysis” at the scientific visualization group at Linköping University. Based on all applications we generated a shortlist of possible candidates which also includes you and hope that you are still interested in the position.

As the position is announced in the area of algorithms for topological data analysis in visualization the candidate must have the necessary background in programming and algorithms, mathematical interest, and at least some knowledge about visualization.

To be able to evaluate your knowledge we kindly ask you to try to solve the following tasks which will serve as a criterion in our selection process. It is not required that you complete all tasks perfectly, see how far you will get.

Your answer will serve as the basis for a discussion during an interview.

# Task 1: Visual Data analysis

Pick some data of your choice and generate some visualization of it in a tool of your choice. Briefly explain the data and the visualization decision.

Note: There are many open-source visualization tools available. Two examples of tools that we are frequently using in our research are Inviwo (https://inviwo.org/) and Paraview (https://www.paraview.org), however, any other tool is also welcome.

# Task 2: Mathematical concepts for visual data analysis

In scientific visualization, we work extensively with *scalar fields* that are scalar functions usually defined on 2D and 3D domains. Let in the following be a 2-dimensional a scalar field.

1. A frequent visualization method for 2-dimensional scalar fields is i**socontours** (also called isolines). How are such lines mathematically defined?
2. Another core concept in *topological analysis* of scalar fields is finding all local **minima, maxima** and **saddles** (or **critical points,** in general) in scalar functions. Take a look at the illustration below for visual explanation of these special points in 2D scalar field. For analytical functions they can be detected and classified by performing *derivative tests,* i.e., looking at first and second derivatives.

A diagram of a graph

Description automatically generated with medium confidence

Consider the following scalar field: defined over the domain . Note: these are *open intervals*, so, the boundary of the square is not included.

* 1. How do the ‘derivative tests’ look like for ?
  2. How many critical points does have in the domain ?
  3. Can you give a general expression for all the critical points of for the domain i.e. ?

1. Finally, a concept from topological data analysis that builds on the above-mentioned ideas of iso-contours and critical points is the **contour tree**. Try to find out what a contour tree is and explain the concept briefly.

# Task 3: Programming task

In the attached file “2d\_scalar\_field.csv” you are given a 2D scalar function sampled on a grid. In each row, information about the coordinates of the sample point along with the function value (𝑆) at the point are provided.

Write a program in a programming language of your choice to:

1. compute iso-contours for the given data set. You can take the csv file and the isovalue as the command line arguments. Try extracting iso-contours for the following three isovalues .
2. find the local minima, local maxima, and saddle points in the data set.

It’s up to you how you want to organise your code and the platform you want to target (Linux, Windows, and MacOS are all acceptable). The above two programming tasks can be done in separate scripts or a single one. Make sure you attach a README file explaining how we can run your code.