Algorithmic extraction of 1D curves based on CT scans of fiber reinforced concrete

STUDENT PROJECT

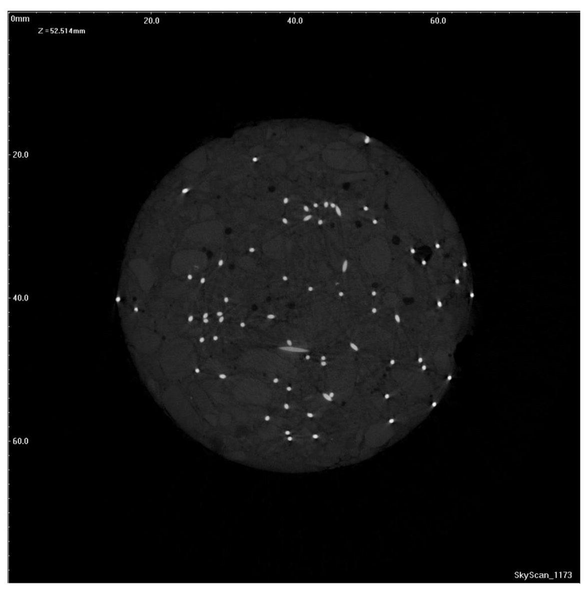
BAU

Jennifer Böltz, Ivo Steinbrecher[1] and Alexander Popp[1]
[1]Institute for Mathematics and Computer-Based Simulation, University of the Bundeswehr Munich, Germany

Universität der Bundeswehr München

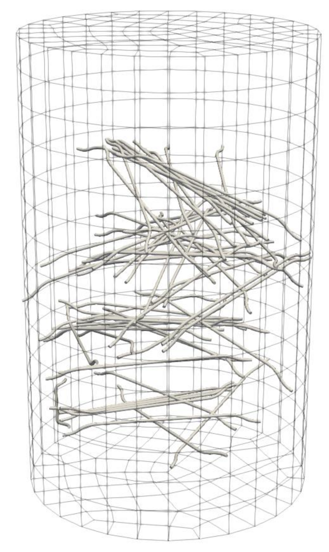
Motivation

Embedding fibers in fiber reinforced concrete brings a lot of advantages to the mechanical properties of the concrete structure.
To simulate the compound structure with a mixed dimensional 1D-3D beam-to-solid coupling, it is necessary to identify the 1D geometry of the fibers within the concrete.
The input for the algorithmic recognition of fibers is image data from a computer tomography (CT) scan of a fiber reinforced concrete specimen.



raw image data

3D model



FEM model

Approach

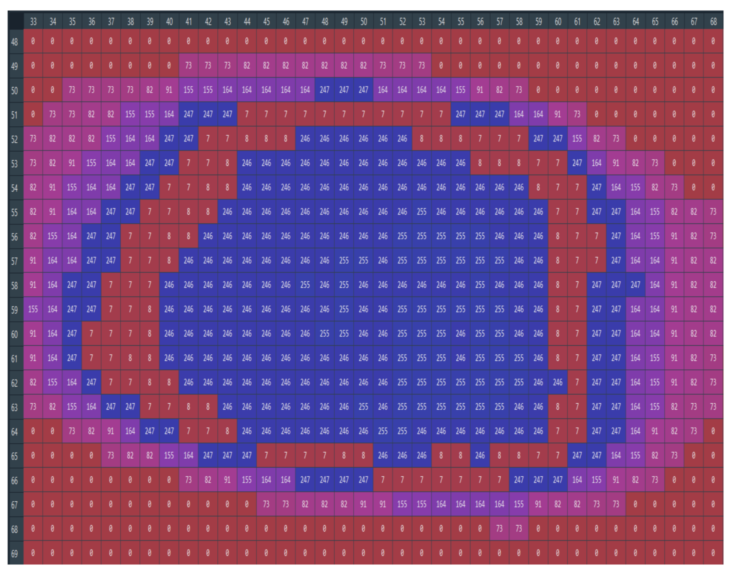
In this project one fiber is identified as a 1D-curve within a set of ten bitmap images from a CT scan of fiber concrete. Therefore, the center of gravity of the fiber cut-area in each image plane will be identified and subsequently approximated by a 3D-curve, i.e., the fiber centerline.

Data Processing

Converting data

After reading the data, the fibers can be found as a set of pixels in a 256- color format. With python the given images can easily be converted into C-based data structures, i.e. arrays.

The color range of the fiber in the 8-bit bitmap goes from values close to zero (dark gray, black) up to the value 256 (white). This characteristic can help with understanding the structure of the fiber and help with distinguishing close fibers from another.

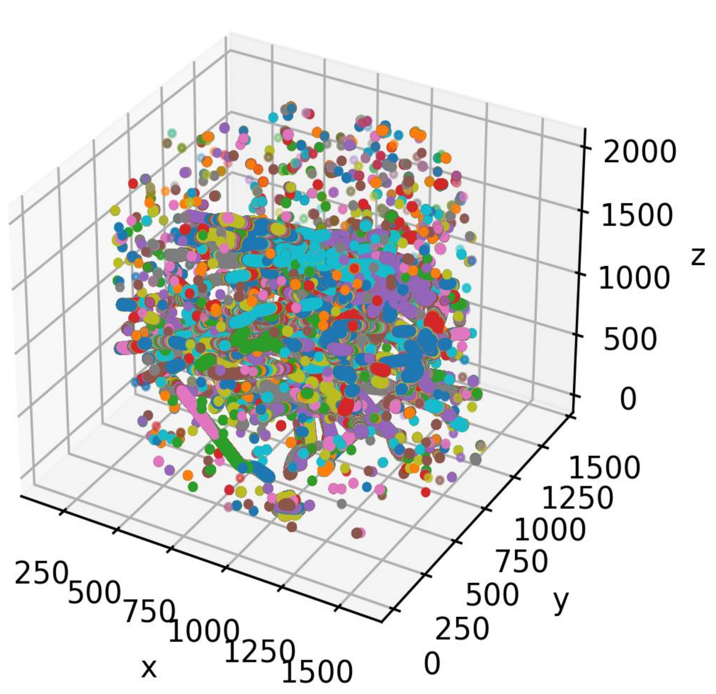


For further data processing the image will be filtered to exclude data not containing relevant information about fibers, e.g. The arrays are converted into *Boolean* format.

Runtime

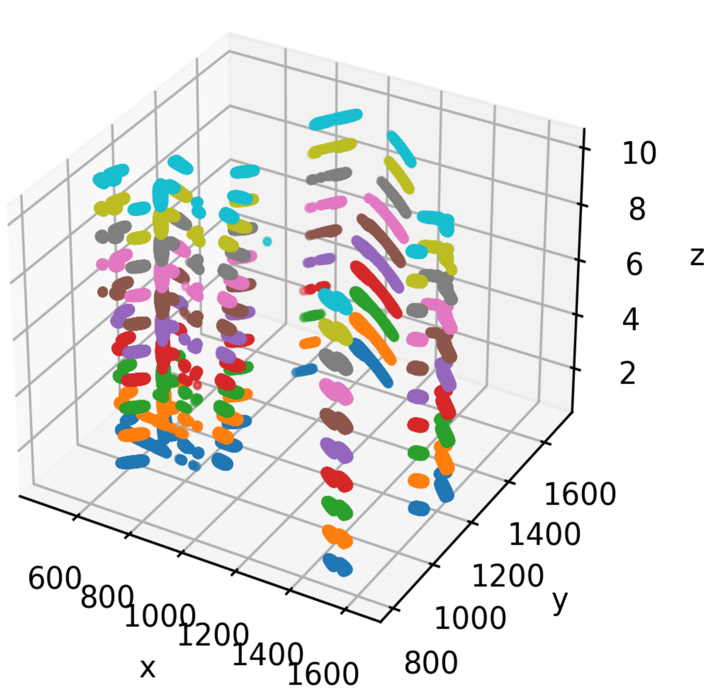
The full data set in 8-bit format requires about 10.5GB of memory. With the converted Boolean format, the memory consumption is reduced to 1.3GB.

Fibers in 2022 CT Scans



Elapsed time 430s

Fibers in 10 CT Scans



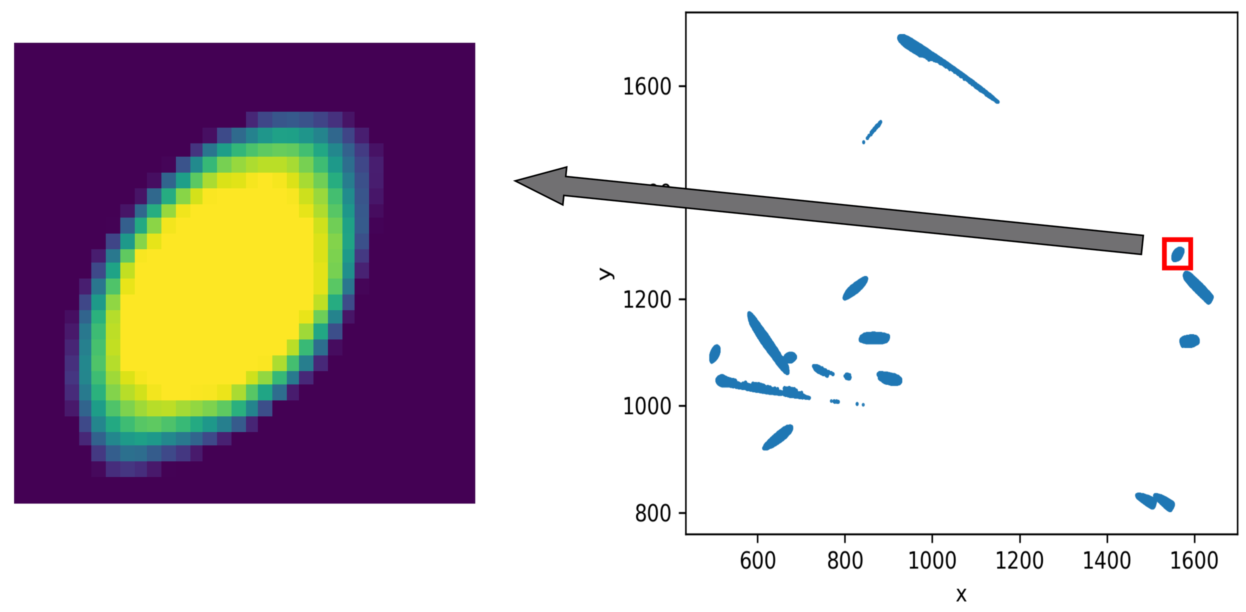
Elapsed time 3.5s

The full CT scan of the fiber concrete specimen consists of 2240 bitmap images with 2240x2240 pixels.

Fiber Identification

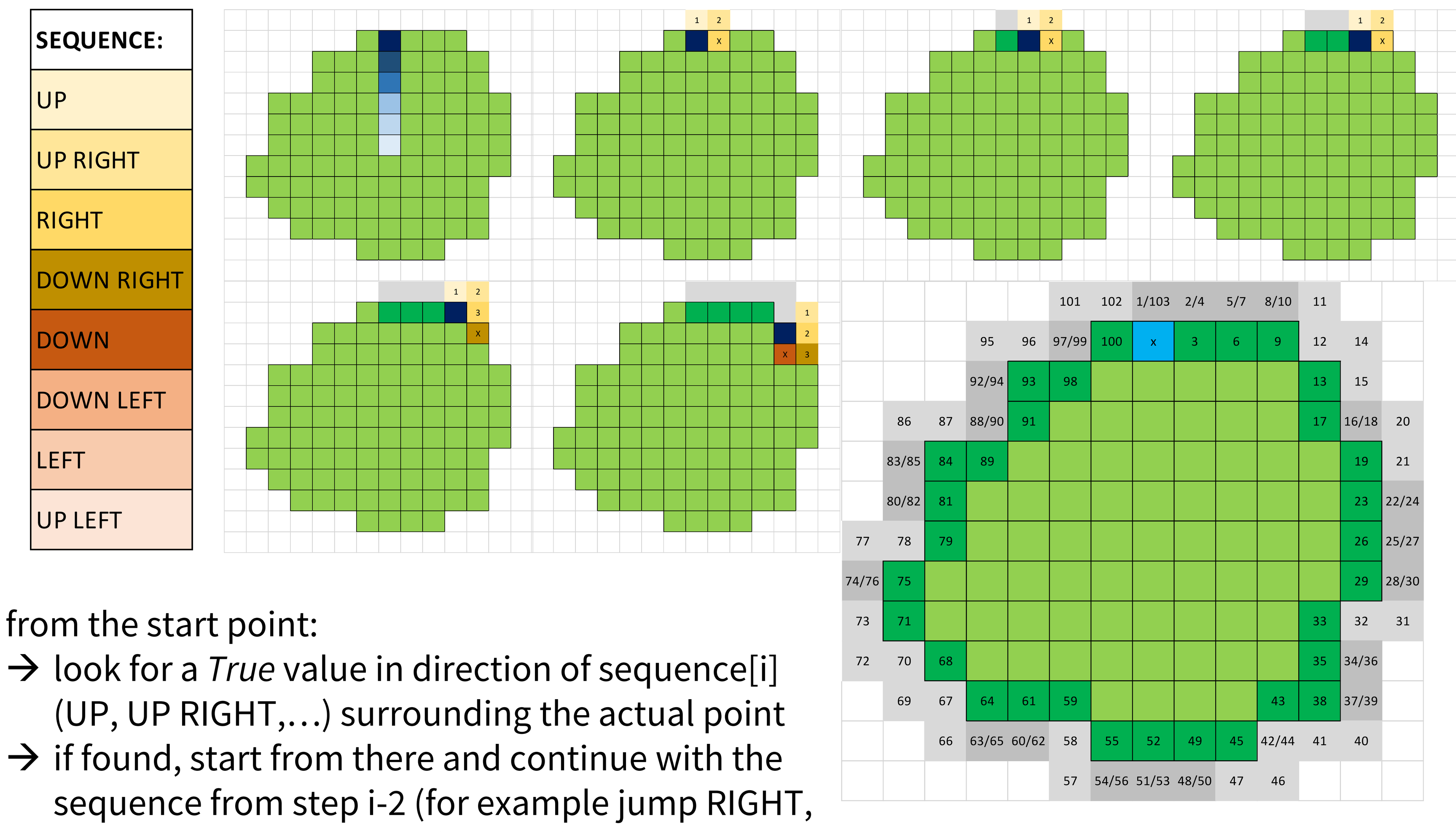
Fiber Areas

In each CT scan different fibers are shown in a plane. These fibers can be cut cross-sectioned or lengthwise, furthermore they can be tangent to other fibers, cross or overlap. Therefore, the different fiber areas need to be delimited.



Algorithm to identify the edge

To identify an area of the image where a fiber lies within, it is necessary to create a function which produces an interval in x and y direction for each single fiber cross-section. For this purpose, an algorithm is implied to obtain the edge of the fiber, only requiring a starting point. The algorithm is shown below. Beginning at a starting point on the outline of the fiber, the algorithm will look counter-clockwise at a low number of pixels to define the circumference of the fiber.



from the start point:
→ look for a *True* value in direction of sequence[i] (UP, UP RIGHT,…) surrounding the actual point
→ if found, start from there and continue with the sequence from step i-2 (for example jump RIGHT, continue with sequence from UP).

Center of Gravity

Calculating the center of gravity of every identified fiber cross-section reduces the data to single coordinates which can then be fitted. The challenge is to find out whether a new fiber starts or ends, or which coordinates on different image planes belong to the same fiber. However, this is a non-trivial task and is subject to further research. In this work a single fiber is reconstructed as a proof of concept. Looking at one single fiber within n images, it is easily possible to use the already calculated center of gravity of the fiber cross-section in image i to identify the fiber area on the next level image plane i+1, where the fiber continues.

Fiber fitted by a third-order polynomial over 10 CT scans