Evaluation Questionnaire

MObjects - A Novel Method for the Visualization and Interactive Exploration of Defects in Industrial XCT Data

1. Introduction

With this evaluation questionnaire we intend to get feedback to our software prototype for the interactive exploration and visualization of defects in industrial CT data. Your feedback will be part of an application/design paper submission for SciVis 2013.

In our work we introduce mean objects (MObjects). A MObject represents the summation of a set of individual objects in a dataset. To create a MObject, the centroids of all individual objects are aligned. After summing up the individual objects, the resulting MObject is visualized, in order to distinguish largely coinciding regions from underrepresented regions. A set of MObjects is called mean object set (MObject Set). They are used to explore the parameter space of the calculated MObjects.

In this questionnaire we will focus on the evaluation of the following tasks:

- MObject Visualization (Task 1)
- Local MObject Visualization (Task 2)
- MObjects Exploration (Task 3)

2. Previous work

Non-destructive testing methods:

Q 2.1	Have you ever worked with computed tomography data?	Yes ☐ No ☐
Q 2.2	If yes, how many years of experience do you have using computed tomography?	_____ years
Q 2.3	Have you ever used active thermography?	Yes ☐ No ☐
Q 2.4	If yes, how many years of experience do you have using active thermography?	_____ years
Q 2.5	Have you ever used ultrasonic testing?	Yes ☐ No ☐
Q 2.6	If yes, how many years of experience do you have using ultrasonic testing?	_____ years

Materials:

	(1 – no experience, 2 hardly any, 3 – moderate, 4 – plenty of, 5 – high level of experience)	1 2 3 4 5
Q 2.7	Are you experienced with carbon fiber reinforced polymers?	☐ ☐ ☐ ☐ ☐
Q 2.8	How many years of experience do you have with carbon fiber reinforced polymers?	_____ years
Q 2.9	Are you experienced with light metals?	☐ ☐ ☐ ☐ ☐
Q 2.10	How many years of experience do you have with light metals?	_____ years
Q 2.11	Are you experienced with steel?	☐ ☐ ☐ ☐ ☐
Q 2.12	How many years of experience do you have with steel?	_____ years

3. MObject Visualization (Task 1):

In our work, we introduce mean objects (MObjects). A MObject represents the summation of a set of individual objects in a dataset. To create a MObject, the centroids of all individual objects are aligned. After summing up the individual objects, the resulting MObject may be visualized, in order to distinguish largely coinciding regions from underrepresented regions.

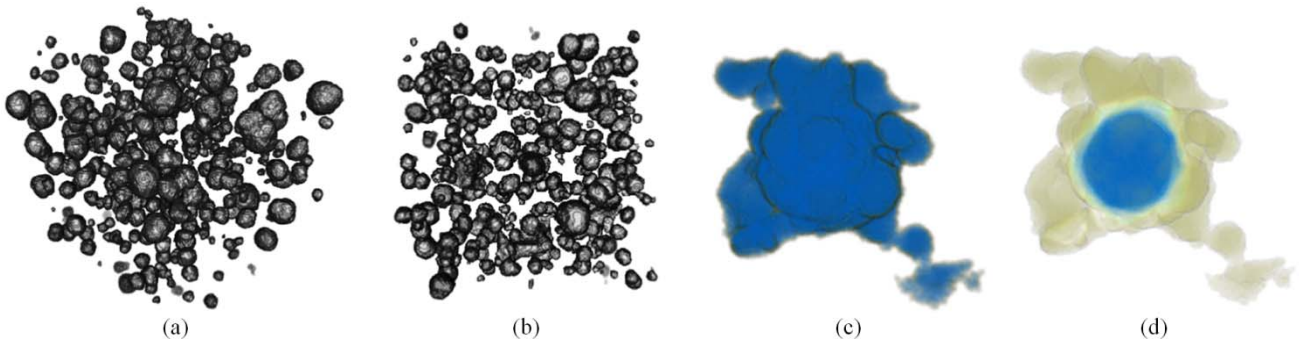

Figure 1: 3D Renderings of individual objects in (a) isometric view, (b) xy view. (c, d) 3D Rendering of MObject visualization generated from the input of image (a) using 2 different transfer function settings.

	(1 – poor, 2 – fair, 3 – average, 4 – very good, 5 – excellent)	1 2 3 4 5
Q 3.1	Can you identify deviating (not nodular) structures in Figure 1 (a)?	☐☐☐☐☐
Q 3.2	Can you identify deviating (not nodular) structures in Figure 1 (b)?	☐☐☐☐☐
Q 3.3	Can you identify deviating (not nodular) structures in Figure 1 (c)?	☐☐☐☐☐
Q 3.4	Can you identify deviating (not nodular) structures in Figure 1 (d)?	☐☐☐☐☐

Remarks concerning the mean objects visualization (benefits / drawbacks):

4. Local MObjects Visualization (Task 2):

For a fast homogeneity overview of the specimen we divide the dataset in regular sub-volumes. We now refer to them as cells. Figure 2 shows the partitioning of a CFRP dataset with segmented pores in cells.

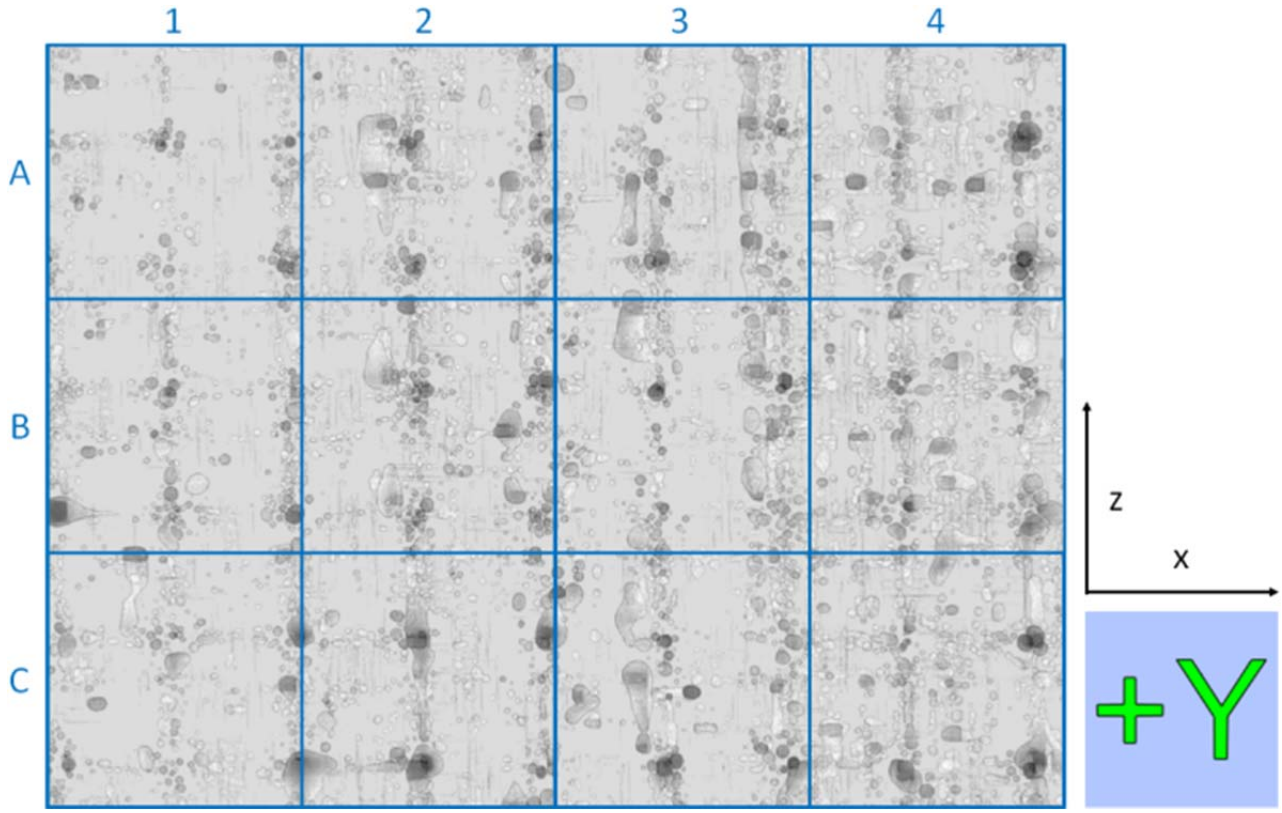

Figure 2: Visualization of segmented pores in a CFRP dataset.

Q 4.1	Which cell in Figure 2 has the lowest deviation of the average pore volume?	_____
Q 4.2	Which cell in Figure 2 has the highest positive deviation of the average pore volume?	_____
Q 4.3	Which cell in Figure 2 has the highest negative deviation of the average pore volume?	_____
Q 4.4	Which cell in Figure 2 has the lowest deviation of the average pore shape factor?	_____
Q 4.5	Which cell in Figure 2 has the highest positive deviation of the average pore shape factor?	_____
Q 4.6	Which cell in Figure 2 has the highest negative deviation of the average pore shape factor?	_____
Q 4.7	Which cell in Figure 2 has the lowest deviation of the average pore dimension in x direction?	_____
Q 4.8	Which cell in Figure 2 has the highest positive deviation of the average pore dimension in x direction?	_____
Q 4.9	Which cell in Figure 2 has the highest negative deviation of the average pore dimension in x direction?	_____
Q 4.10	Which cell in Figure 2 has the lowest deviation of the average pore dimension in y direction?	_____
Q 4.11	Which cell in Figure 2 has the highest positive deviation of the average pore dimension in y direction?	_____
Q 4.12	Which cell in Figure 2 has the highest negative deviation of the average pore dimension in y direction?	_____
Q 4.13	Which cell in Figure 2 has the lowest deviation of the average pore dimension in z direction?	_____
Q 4.14	Which cell in Figure 2 has the highest positive deviation of the average pore dimension in z direction?	_____
Q 4.15	Which cell in Figure 2 has the highest negative deviation of the average pore dimension in z direction?	_____

For each cell a local MObject is calculated. In this calculation an individual pore belongs to the cell, in which the center of the pore is located. Figure 3 shows the local MObjects visualization using the segmented pores dataset from Figure 2.

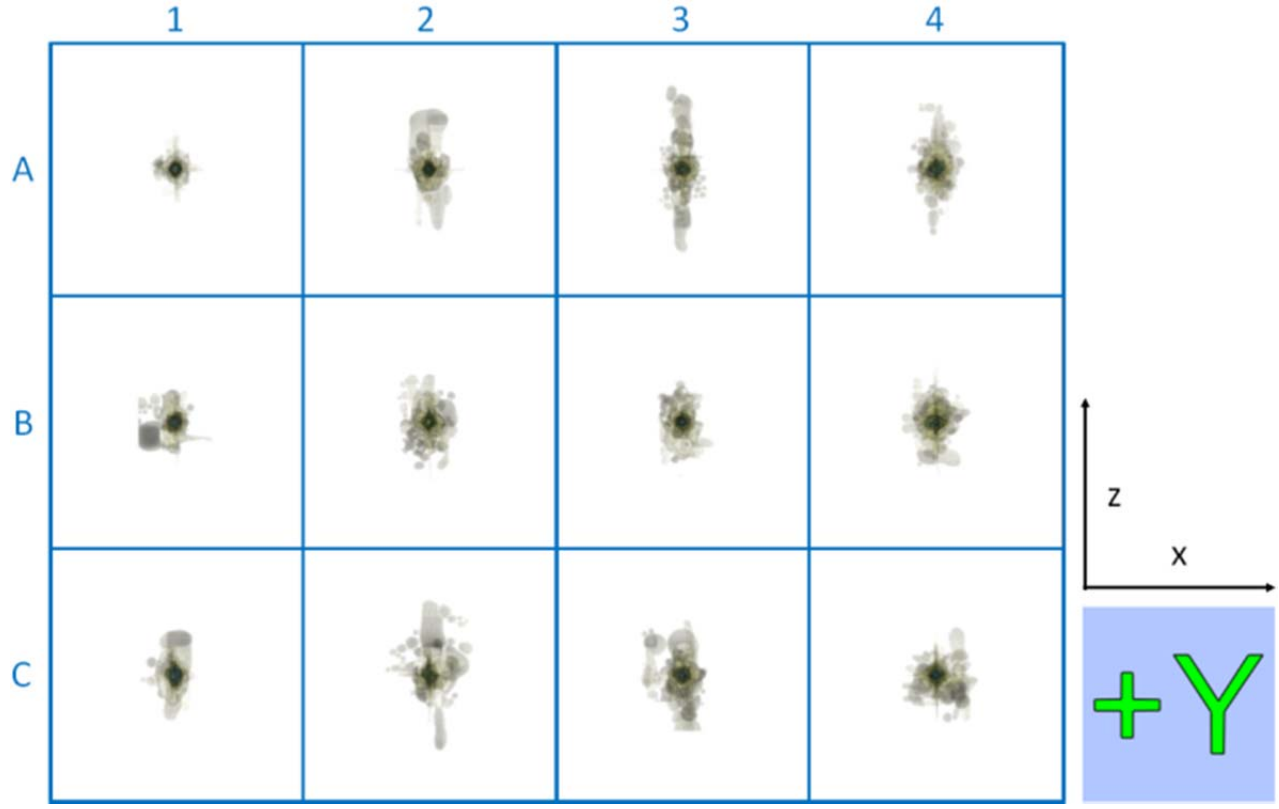

Figure 3: Local MObjects visualization of the CFRP dataset from Figure 2.

Q 4.16	Which MObject in Figure 3 represents the lowest average pore volume in the dataset?	_____
Q 4.17	Which MObject in Figure 3 represents the highest average pore volume in the dataset?	_____
Q 4.18	Which MObject in Figure 3 represents the lowest average pore shape factor in the dataset?	_____
Q 4.19	Which MObject in Figure 3 represents the highest average pore shape factor in the dataset?	_____
Q 4.20	Which MObject in Figure 3 represents the lowest average pore dimension in x direction in the dataset?	_____
Q 4.21	Which MObject in Figure 3 represents the highest average pore dimension in x direction in the dataset?	_____
Q 4.22	Which MObject in Figure 3 represents the lowest average pore dimension in z direction in the dataset?	_____
Q 4.23	Which MObject in Figure 3 represents the highest average pore dimension in z direction in the dataset?	_____

Q 4.24	Which MObject in Figure 3 has the lowest pore volume homogeneity in its cell?	_____
Q 4.25	Which MObject in Figure 3 has the highest pore volume homogeneity in its cell?	_____
Q 4.26	Which MObject in Figure 3 has the lowest pore shape factor homogeneity in its cell?	_____
Q 4.27	Which MObject in Figure 3 has the highest pore shape factor homogeneity in its cell?	_____
Q 4.28	Which MObject in Figure 3 has the lowest homogeneity regarding the pore dimension in x direction in its cell?	_____
Q 4.29	Which MObject in Figure 3 has the highest homogeneity regarding the pore dimension in x direction in its cell?	_____
Q 4.30	Which MObject in Figure 3 has the lowest homogeneity regarding the pore dimension in z direction in its cell?	_____
Q 4.31	Which MObject in Figure 3 has the highest homogeneity regarding the pore dimension in z direction in its cell?	_____

Figure 4 shows a color-coded cell visualization. Each cell is colored regarding its deviation of the average individual pore properties volume, shape factor, dimensions in x, y and z direction.

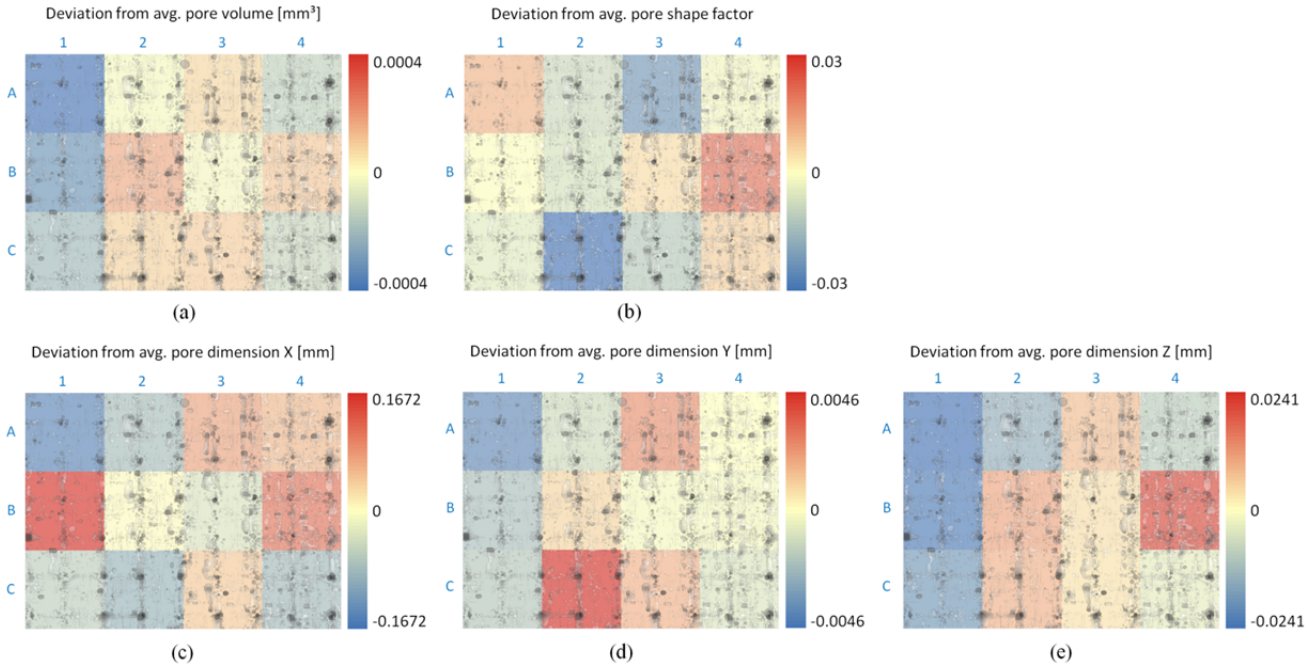

Figure 4: Color-coded visualization of the deviation of the average pore (a) volume, (b) shape factor, (c) dimension in x direction, (d) dimension in x direction and (e) dimension in z direction.

Q 4.32 Which cell in Figure 4 (a) has the lowest deviation of the average pore volume?	_____
Q 4.33 Which cell in Figure 4 (a) has the highest positive deviation of the average pore volume?	_____
Q 4.34 Which cell in Figure 4 (a) has the highest negative deviation of the average pore volume?	_____
Q 4.35 Which cell in Figure 4 (b) has the lowest deviation of the average pore shape factor?	_____
Q 4.36 Which cell in Figure 4 (b) has the highest positive deviation of the average pore shape factor?	_____
Q 4.37 Which cell in Figure 4 (b) has the highest negative deviation of the average pore shape factor?	_____
Q 4.38 Which cell in Figure 4 (c) has the lowest deviation of the average pore dimension in x direction?	_____
Q 4.39 Which cell in Figure 4 (c) has the highest positive deviation of the average pore dimension in x direction?	_____
Q 4.40 Which cell in Figure 4 (c) has the highest negative deviation of the average pore dimension in x direction?	_____
Q 4.41 Which cell in Figure 4 (d) has the lowest deviation of the average pore dimension in y direction?	_____
Q 4.42 Which cell in Figure 4 (d) has the highest positive deviation of the average pore dimension in y direction?	_____
Q 4.43 Which cell in Figure 4 (d) has the highest negative deviation of the average pore dimension in y direction?	_____
Q 4.44 Which cell in Figure 4 (e) has the lowest deviation of the average pore dimension in z direction?	_____
Q 4.45 Which cell in Figure 4 (e) has the highest positive deviation of the average pore dimension in z direction?	_____
Q 4.46 Which cell in Figure 4 (e) has the highest negative deviation of the average pore dimension in z direction?	_____

Figure 5 compares the before evaluated visualizations of individual pores, local MObjects and the color-coded cells.

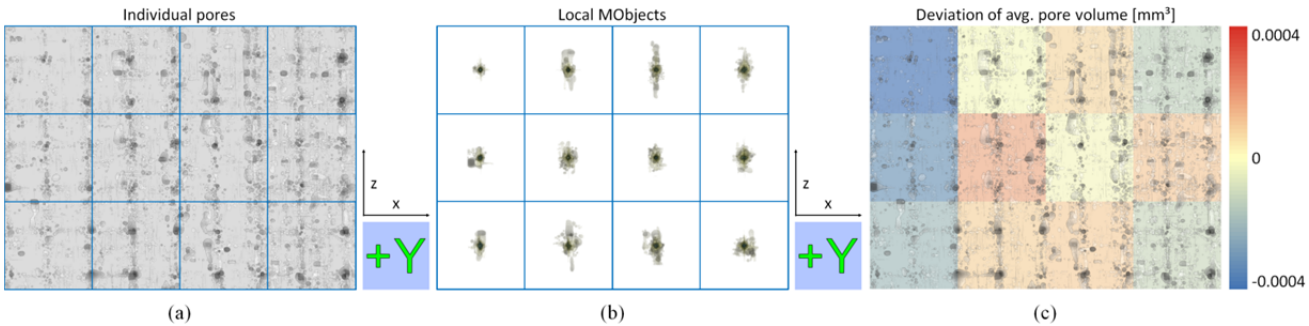

Figure 5: (a) Visualization of (a) segmented pores (b) local MObjects and (c) the color-coded cell visualization.

(1 – poor, 2 – fair, 3 – average, 4 – very good, 5 – excellent)	1	2	3	4	5
Q 4.47 Can you identify the pore homogeneity of the whole dataset in Figure 5 (a)?	☐	☐	☐	☐	☐
Q 4.48 Can you identify the pore homogeneity in the individual cells in Figure 5 (a)?	☐	☐	☐	☐	☐
Q 4.49 Can you identify the pore homogeneity of the whole dataset in Figure 5 (b)?	☐	☐	☐	☐	☐
Q 4.50 Can you identify the pore homogeneity in the individual cells in Figure 5 (b)?	☐	☐	☐	☐	☐
Q 4.51 Can you identify the pore homogeneity of the whole dataset in Figure 5 (c)?	☐	☐	☐	☐	☐
Q 4.52 Can you identify the pore homogeneity in the individual cells in Figure 5 (c)?	☐	☐	☐	☐	☐

Remarks concerning the local MObjects visualization (benefits / drawbacks):

5. MObjects Exploration (Task 3):

For the interactive exploration of the MObjects, MObject Sets are calculated by clustering the individual objects regarding their calculated properties, e.g. volume, dimensions or shape factors.

	(1 – not interested, 2 – hardly interested, 3 – little interested, 4 – interested, 5 – very interested)	1 2 3 4 5
Q 4.1	Are you interested in nodular objects?	☐☐☐☐☐
Q 4.2	Are you interested in long and thin objects?	☐☐☐☐☐
Q 4.3	Are you interested in crack-shaped objects?	☐☐☐☐☐
Q 4.4	Are you interested in classifications based on the volume of the individual objects?	☐☐☐☐☐
Q 4.5	Are you interested in classifications based on the dimensions of the individual objects?	☐☐☐☐☐
Q 4.6	Are you interested in classifications based on the shape factors of the individual objects?	☐☐☐☐☐
Q 4.7	Into how many sub-classes would you split the individual objects regarding the volume?	_____ classes
Q 4.8	Into how many sub-classes would you split the individual objects regarding the dimensions?	_____ classes
Q 4.9	Into how many sub-classes would you split the individual objects regarding the shape factors?	_____ classes

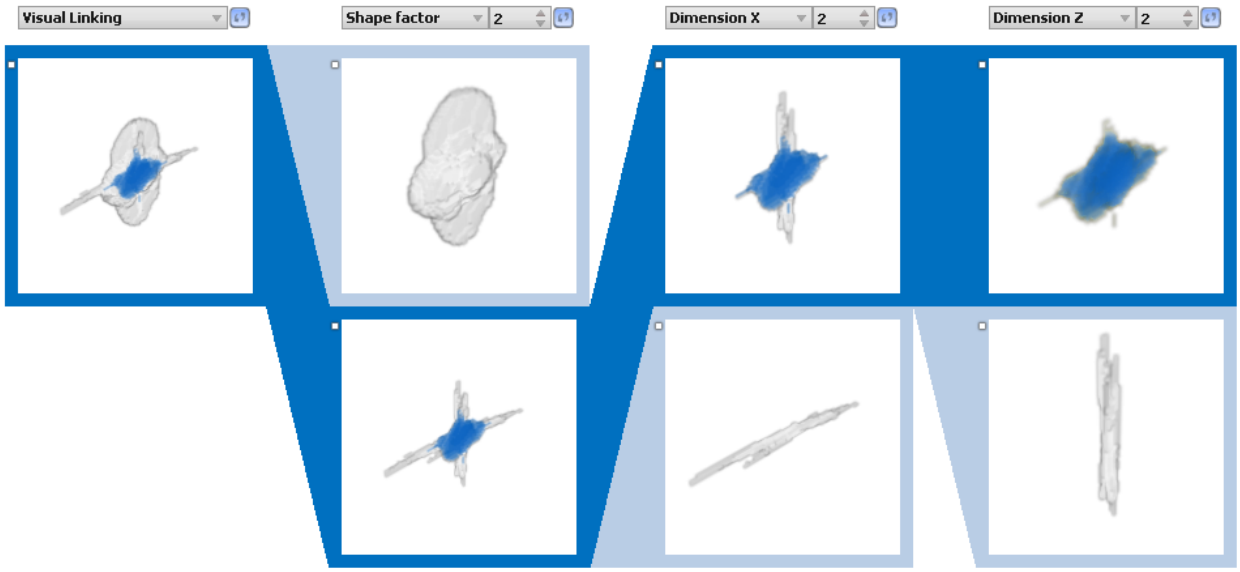

Figure 6: MObject Set visualization showing the selected path and the visual linking approach of the rendered MObjects.

	(1 – poor, 2 – fair, 3 – average, 4 – very good, 5 – excellent)	1 2 3 4 5
Q 4.10	Can you identify the selected path of the interactive exploration in Figure 6?	☐☐☐☐☐
Q 4.11	Can you identify the different scaling of the MObjects through visual linking in Figure 6?	☐☐☐☐☐

Remarks concerning the mean objects exploration (benefits / drawbacks):

We have tested our visualization with a dataset of a carbon fiber reinforced polymer specimen, showing a MObject of the whole dataset (see Figure 7) as well as some exported MObjects after the interactive exploration of the dataset (see Figure 8).

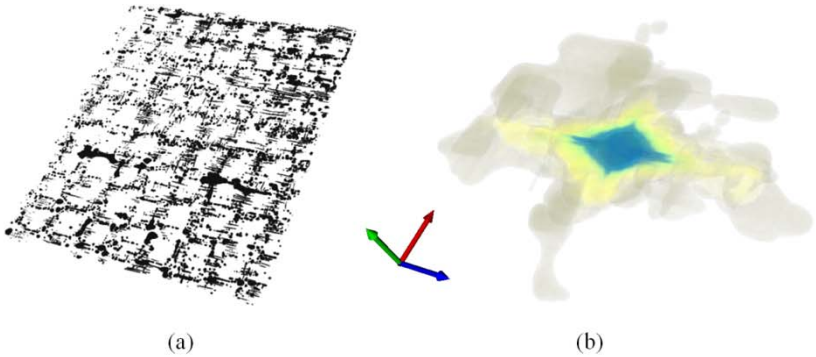

Figure 7: (a) Rendering of individual objects (pores) of a CFRP dataset. (b) Mean object (MObject) visualization of the individual objects from (a).

	(1 – poor, 2 – fair, 3 – average, 4 – very good, 5 – excellent)	1 2 3 4 5
Q 5.1	Can you identify nodular pores in Figure 7 (a)?	☐☐☐☐☐
Q 5.2	Can you identify long and thin pores in Figure 7 (a)?	☐☐☐☐☐
Q 5.3	Can you identify crack-shaped pores in Figure 7 (a)?	☐☐☐☐☐
Q 5.4	Can you identify nodular pores in Figure 7 (b)?	☐☐☐☐☐
Q 5.5	Can you identify long and thin pores in Figure 7 (b)?	☐☐☐☐☐
Q 5.6	Can you identify crack-shaped pores in Figure 7 (b)?	☐☐☐☐☐

Figure 8: Rendering of mean objects (MObjects) of a CFRP dataset.

	(1 – poor, 2 – fair, 3 – average, 4 – very good, 5 – excellent)	1 2 3 4 5
Q 5.7	Do the mean objects in Figure 8 represent the typical pore structures in a CFRP dataset?	☐☐☐☐☐

Remarks concerning representative mean objects (benefits / drawbacks):