

# Simulation of Complex Scan Paths for 3D Reconstruction

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**Abstract.** X-ray computed tomography (CT) is a volumetric (3D) imaging diagnostic method, well established in the medical field, and in industrial NDE as well. Developments in industrial CT aim to extend the applicability to complex structures, which do not allow the access of all directions. This are e.g. limited view, data and angle CT applications. New reconstruction algorithms are required on one side, and the accuracy has to be improved on the other side. Numerical simulation can support such developments by providing well defined data sets for the testing of reconstruction algorithms. This approach of virtual CT is realized within the radiographic simulator aRTist, developed by BAM. The poster shows the possibilities of this tool to consider complex scan paths. Simulated data sets have been reconstructed by an versatile backprojection algorithm.

## Introduction

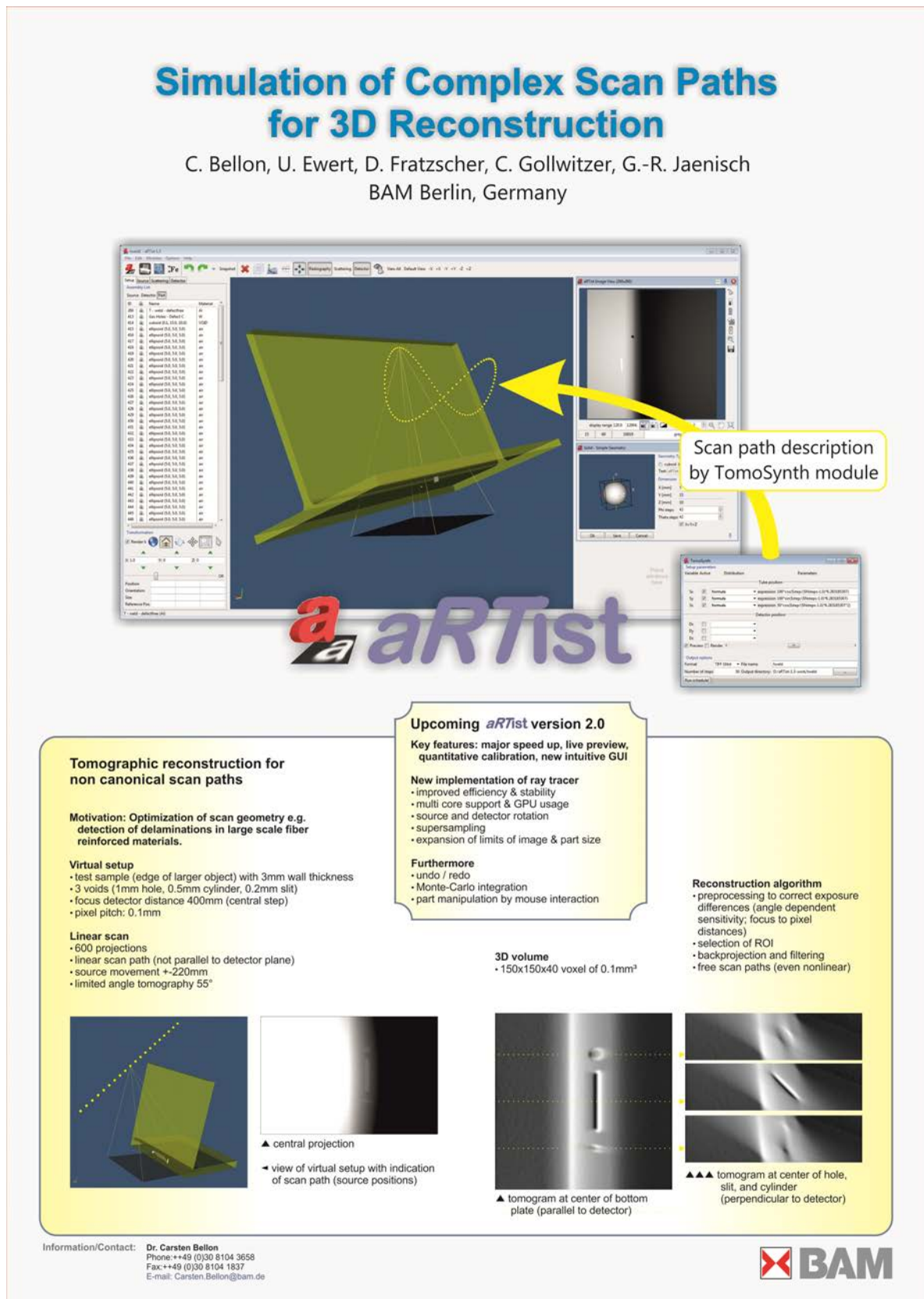
A concept on virtual radiographic scans for 3D reconstruction has been developed featuring the aRTist software and backprojection-based reconstruction method. The radiographic simulator aRTist has been newly updated with a major speed up and further improvements from the underlying models to the graphical user interface. Additionally the “TomoSynth” module has been accomplished, which allows to interactively arrange and perform scans on complex paths for 3D reconstruction as illustrated at the upper part of the poster (Fig. 1). The lower part of the poster (Fig. 1) demonstrates a reconstruction of a freely chosen linear scan path not parallel to the detector plane. A reconstruction of the more complex scanning geometry mentioned above is shown in Figures 3 and 4.

## The TomoSynth module

The TomoSynth module provides the interface defining and executing a series of simulation runs with a controlled parameter variation. Besides source and detector position other parameters can be activated for virtual manipulation.

Distribution functions control the exact way how a variable is varied from image to image. Two kinds of distributions are considered, deterministic and random ones. A deterministic distribution describes, how to compute the value for a given image number step for a total of  $N_{steps}$  images. Here, step varies from 0 ...  $N_{steps}-1$ . A random distribution assigns a (pseudo-)random number with a given probability density to the associated variable. The pseudorandom numbers are generated by hashing sequence numbers with a fixed random seed and therefore are reproducible.

For a monotonic increase or decrease, linearly and logarithmically spaced steps can be selected using the distributions linear and logarithmic, respectively.  
When `circle_x` and `circle_y` are selected for source position variables `sx` and `sy` of



**Fig. 1.** Poster on complex scan paths in RT simulation for 3D reconstruction.

an object, the object moves on a circle in the x-y-plane with its centre at the original position. Here, the circle is not closed, i.e. the first and last positions are different. The angular spacing between subsequent positions is equal and equal to the spacing between the last and the first position.

Similarly, `arc_x` and `arc_y` define the x- and y- component of an arc, when used as a position shift to an object or tube/detector position. In contrast to the circle, the starting angle `angle1` and the final angle `angle2` are both included in the set of positions. For both circle and arc distributions, the radii in both dimensions must agree to get an undeformed circle or circular arc, respectively. If the radii do differ, the result is an ellipse or elliptical arc. The sign of the radius defines the direction of the rotation, where positive radius values indicate a right handed rotation.

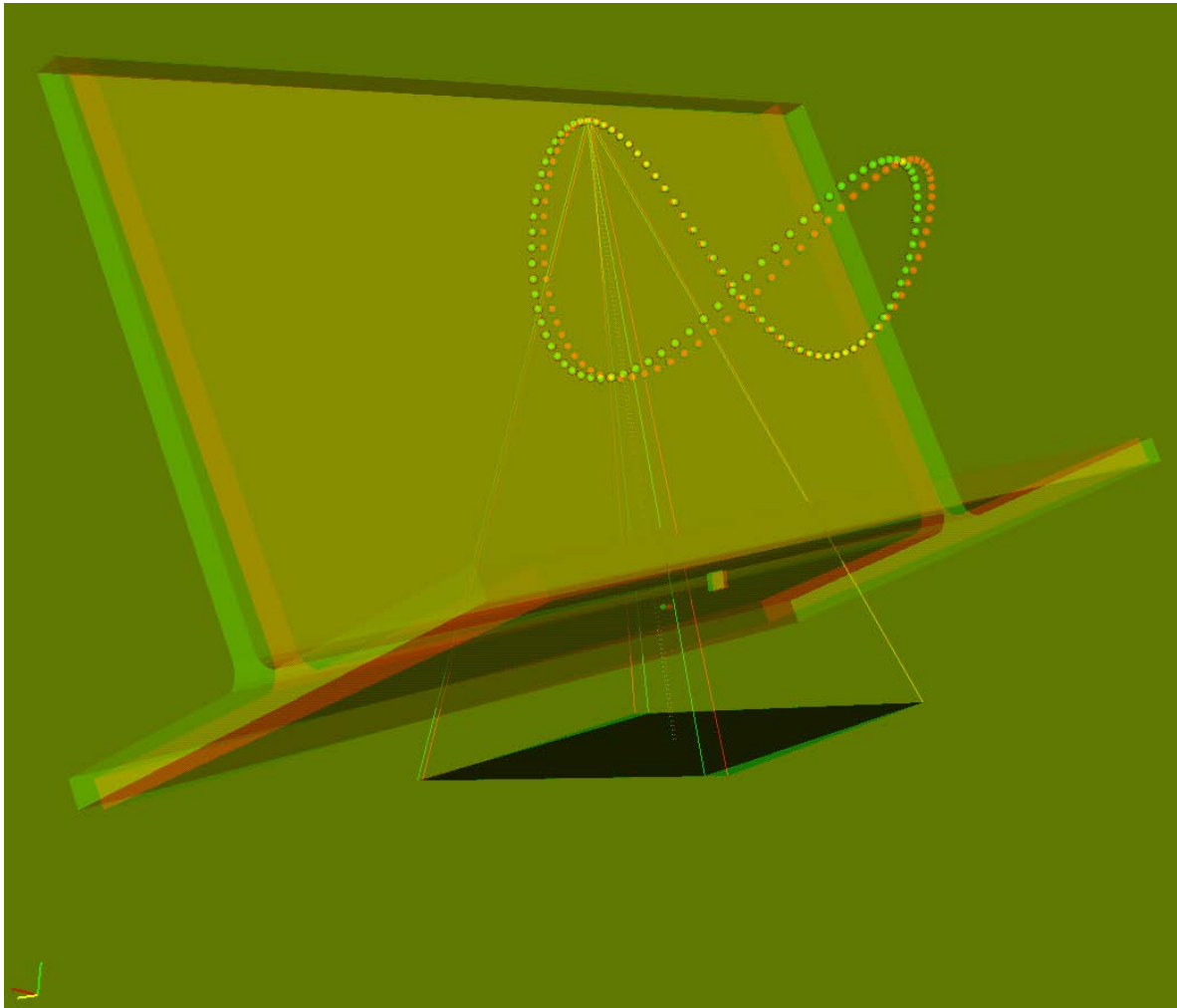
Finally, an arbitrary mathematical formula can be entered to define a deterministic distribution as done in the presented example of Figure 2. Here the source position ( $S_x$ ,  $S_y$ ,  $S_z$ ) variation is defined as:

$S_x$  formula:  $100 \cdot \cos(\$step / (\$Nsteps - 1.0) \cdot 2 \cdot \$PI)$

$S_y$  formula:  $100 \cdot \sin(\$step / (\$Nsteps - 1.0) \cdot 2 \cdot \$PI)$

$S_z$  formula:  $60 \cdot \cos(\$step / (\$Nsteps - 1.0) \cdot 4 \cdot \$PI)$ ,

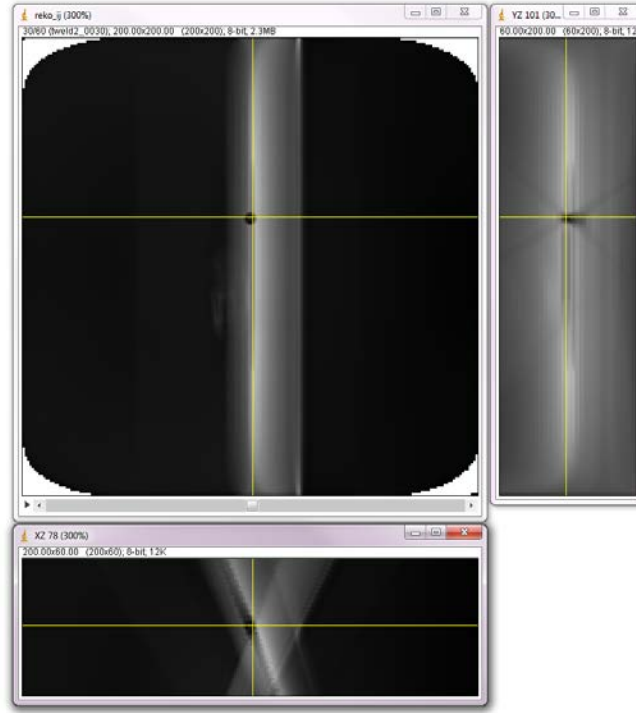
describing a closed circular path with sinusoidal out of plane distortion (with shape of the number eight in a side view).



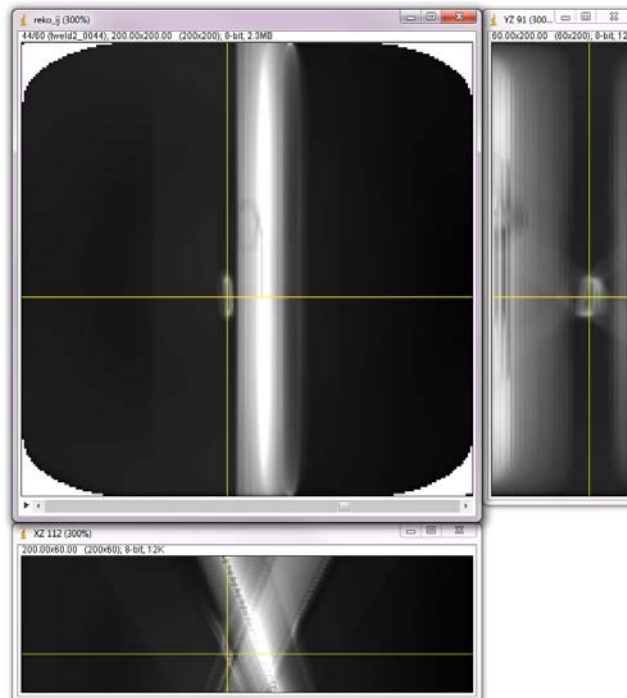
**Fig. 2.** Scene view of virtual setup and scan path as in Fig. 1 (above). This figure is a 3D view for use with red/green eyeglasses.

### 3D reconstruction

BAM developed a highly flexible backprojection-based reconstruction algorithm. For the poster (Fig. 1) a CT-scan with a linear movement of the X-ray tube in an angle of  $45^\circ$  to the detector plane has been simulated by aRTist and the reconstruction results are shown. Figures 3 and 4 show the reconstruction of the complex scan path described earlier. The two inner features are presented separately.



**Fig. 3.** Reconstruction of high absorbing sphere within simulated volume according Fig. 2.



**Fig. 4.** Reconstruction of empty narrow box within simulated volume according Fig. 2.