# aRTist – Analytical RT Inspection Simulation Tool

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**Abstract**

The computer simulation of radiography is applicable for different purposes in NDT such as for the qualification of NDT systems, the prediction of its reliability, the optimization of system parameters, feasibility analysis, model-based data interpretation, education and training of NDT/NDE personnel, and others. Within the framework of the integrated project FilmFree the radiographic testing (RT) simulation software developed by BAM is being further developed to meet practical requirements for inspection planning in digital industrial radiology. It combines analytical modelling of the RT inspection process with the CAD-orientated object description applicable to various industrial sectors such as power generation, railways and others.

**Keywords:** Computer Simulation, Radiography, Computed Tomography, Ray Tracing

## 1. Introduction

A software tool for numerical simulation is presented, which generates realistic radiographs on the basis of virtual part representations and well-defined radiological parameters.

In the scope of the European project FilmFree [1], which focuses on the development of digital radiographic techniques, the development and application of numerical models is ranked with high importance. The aim in this context is to furnish a simulation tool witch fulfils practical industrial requirements and can be applied for inspection planning.

In addition simulation of non-destructive testing is applied in development and optimization of particular testing techniques including automatic analysis of testing results.

## 2. Modelling of radiography

Modelling of radiographic testing procedures requires the consideration of various theoretical and practical aspects. The theoretical aspect focuses on the choice of appropriate physical approximations to implement a fast simulation program with sufficient and problem adjusted accuracy. For industrial application particularly imported are suitable interfaces for handling of virtual part representations. The presented simulation program uses an analytical process model, efficient ray tracing algorithms, industry standard boundary representations, and a graphical user interface with 3D visualisation to meet this requirements.

### 2.1 Model of X-ray penetration process

The X-ray projection process can be subdivided into three independent parts: the X-ray generation, the interaction between the radiation and the part material, and the imaging process.

The initial X-ray beam model considers the extent of the beam and its energy spectrum because of the energy dependence of the interaction between X-ray beam and penetrated material. A raster of point sources defines the focal spot in its size and radiation density distribution. Energy spectra can be defined by a measured data, or are tabulated like line spectra of gamma sources for instance. An internal Module can calculate X-ray spectra on the basis of interaction cross sections for Bremsstrahlung generation [2], also.

The radiation-material interaction with its stochastic processes of absorption and scattering (and pair production for higher energies) can be described by the Bolzmann transport equation. A detailed solution (e.g. using Monte Carlo methods) for arbitrary part geometry is difficult and computing time intensive and thus not suitable in this case. The ray tracing model used here [3] is based on the attenuation law:

$$I(\vec{r}, E) = \int_{source} \frac{I_0(\vec{r}'', E)}{|\vec{r} - \vec{r}''|^2} e^{-\int_0^{|\vec{r}''|} \mu(\vec{r} - \vec{r}', E) \, dr'} \, d^2 r'' \quad (1)$$

The influence of scattered photons and internal sources is considered by the build-up factor or analytical scattering models for single cases.

In a ray casting procedure the imaging process is simulated by tracing beams from all source points to every detector pixel. Transmission functions like the characteristic film curves for different types of film classes are used to describe the properties of different detectors. The inner unsharpness is simulated by Gaussian filtering. Noise is added to the synthetic image in consideration of its gray value dependency.
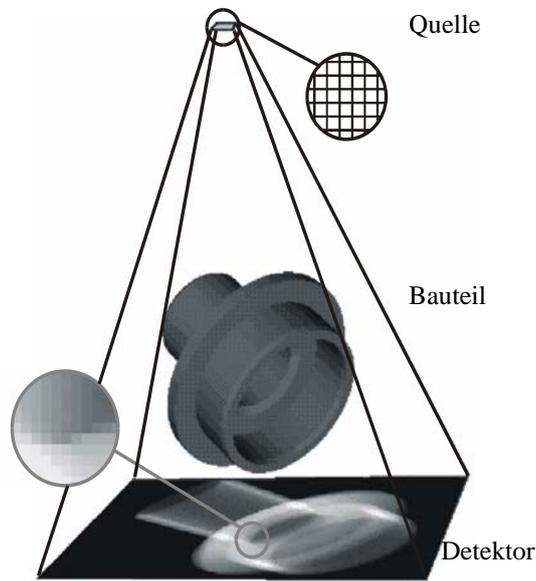


Figure 1. Geometrical model for RT simulation.

## 2.2 Geometrical model

The computer simulation models the real inspection scenario by defining a virtual setup. As described above, source and film consist of raster points on a finite extended plane. Besides source and film the geometrical computer model of the experimental setup has

to support the representation of the test sample geometry (see Figure 1, 2). One or more geometrical part representations can be freely arranged in virtual space.

Parts were modelled by boundary representations, witch separate areas of homogeneous material. Used are facetted (triangulated) boundary descriptions. Curved boundaries are approximated by an appropriate number of plane facets. For data exchange of this facetted part descriptions the STL format [4] is used, which is a de-facto standard in the CAD domain.

To determine the attenuation of radiation the length of homogeneous material sections on the linear connections between source and detector points have to be calculated. By making use of the always linear spreading of the primary radiation a special ray tracer [3] has been developed, witch allows the treatment of realistic scenes (huge number of triangles) at practical (short) run times.

Several, interactive arrangable part representations can easily be managed in the virtual 3D scene. Overlap of geometries in the scene and combination by Boolean operators leads to variable defect descriptions independent from the surrounding host material of the defect.
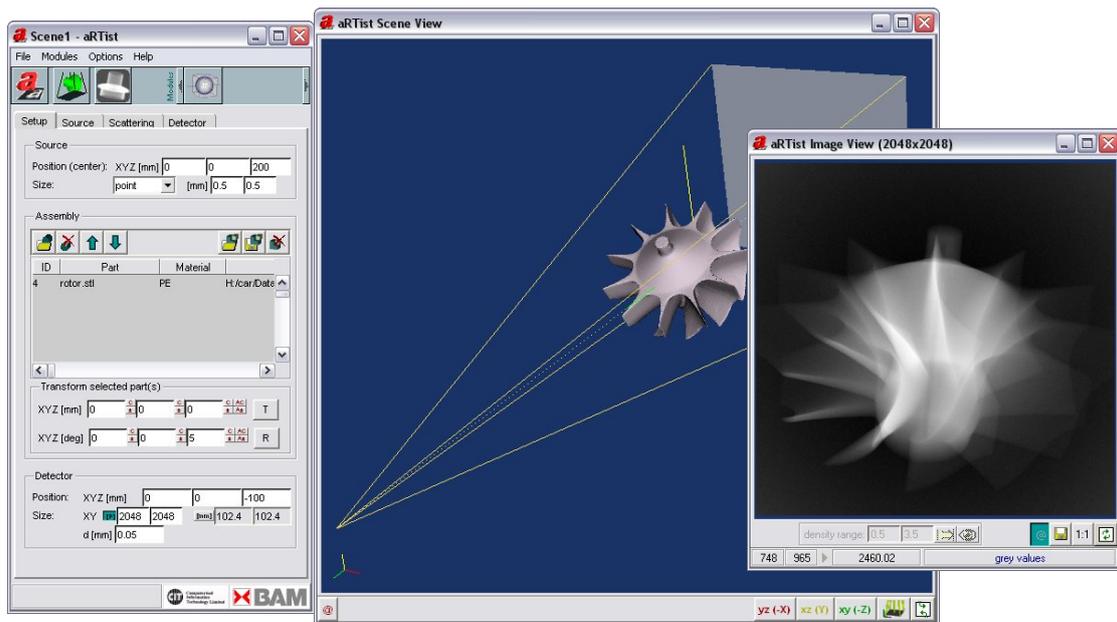


Figure 2. Graphical user interface of aRTist simulation program.

## 3. Simulation with aRTist

The discussed model is realised within the program "aRTist" (analytical RT inspection simulation tool). With aRTist a radiographic testing procedure can be numerical simulated using a standard personal computer. Besides the demands of special scientific problems, witch has been studied in related projects, the program development was driven by practical requirements for industrial application, as there are general usability, realistic scenarios, and fast execution.

The graphical user interface is based on three program windows. The main window gives a structured access to the parameters which are defining the radiographic scenario

and is used to control the simulation. A second window shows the three-dimensional scene of the virtual radiographic setup which can be interactively viewed from all directions. An image viewer completes the interface by showing the synthetic exposures.

Figure 2 depicts a simulation scenario in the program interface. This example illustrates the inspection of a rotor. The representation of the part consists of more than hundred thousand triangles. Also shown in Figure 2 is the synthetic radiography of this part. This image has been calculated assuming a prefilterd 120 kV X-ray spectra and a flat panel detector of 2048 x 2048 pixels. The calculation time was about 35 sec on a standard 3.2 GHz-Pentium-PC. While the program can handle several million triangles as well, other setups are less complex in part geometry than this example and the computation time for a single projection averages a few seconds only. The calculation time depends very much on the scenario and particularly increases with the number of pixels.

The practical application of the simulation depends on the availability of corresponding part representations. Within the program it is possible to generate geometrical primitives like cuboids, ellipsoids, and cylinders. Other part geometries can be provided in STL format. Sources of realistic object descriptions may be CAD data, or measurement data from e.g. laser scanners, structured light digitizers, or even CT. Figure 3 shows examples of part representations of various origins. Material types are always assigned to the part geometries from an extensible materials list within the program.

Figure 4 illustrates the main steps of radiographic simulation with the aRTist program. For the composition of the virtual setup geometrical representations of the considered parts are needed. In this case the outer surface of a longitudinal seam was digitised by optical scanning. The setup was completed with penetrameter models provided with the program. After setting source and detector parameters the actual simulation of the exposure can be performed. This results in the corresponding synthetic radiograph.
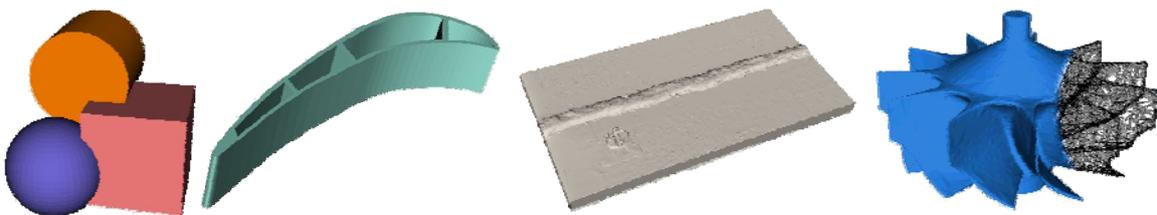


Figure 3. Examples of part representations of different origin: internal generation of parametric primitives, CAD, 3D surface scanning by strip projection, CT (from left to right).

## 3. Summary

A practical simulation tool producing radiographic images from virtual parts was developed. Arbitrary part representations in STL format can be arranged in a virtual radiographic setup. By choosing radiographic parameters realistic radiographic images can be calculated.

Within the scope of the FilmFree project the simulation program will be further developed and it will be tested by different partners. This work focuses on the description of digital detectors and the improvement of the user interface.
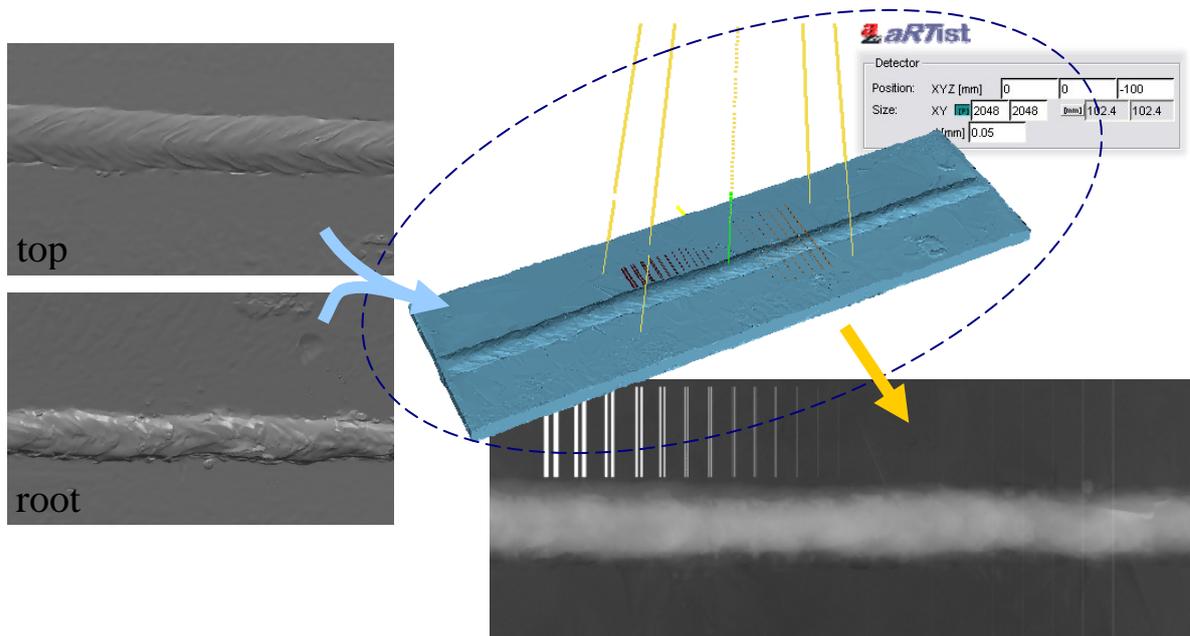
Figure 4. Computer simulation of radiographic testing. From part representation to synthetic radiograph by virtual testing setup.

## References

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