Associated Image Processing Algorithm in Dual-projection Systems

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60 YEARS, FOCUS ON

- radiation detector
- industrial nuclear measurement and control
- digital radiography
- reactor radiation measurement

Research Team

- 21 researchers
- 15 master and doctoral students
- 4 professors
- 17 engineer attendants

ICARST 2017
1st International Conference on Applications of Radiation Science and Technology

Courses

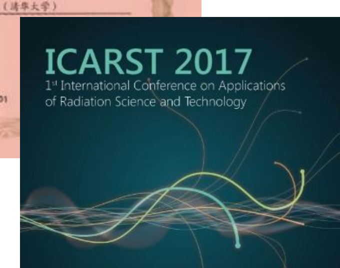
- Ironizing radiation detection
- Radiation information processing
- Nuclear technology application

Articles

- 430 articles (34 by SCI and 142 by EI)

Patented technologies

- Gas ionization X/γ ray radiation detector
- Cobalt-60 digital radiography container inspection system
- A high-precision system for measuring thickness of plate and strip



1.Security Background

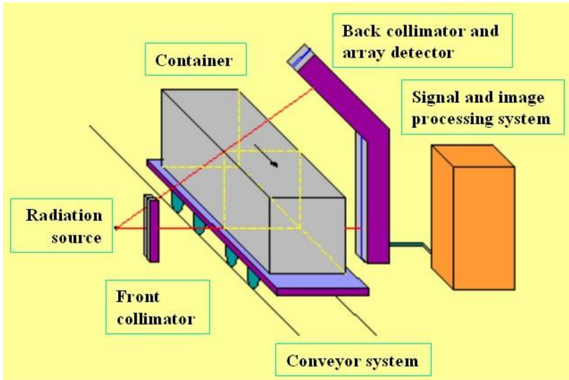
- Anti-smuggling, anti-terrorism
- Nuclear security:
  - prevent bringing explosive into nuclear facility
  - Prevent bringing radioactive materials out of nuclear facility

2004.3.11 Madrid, Spain

Access of Nuclear power plant

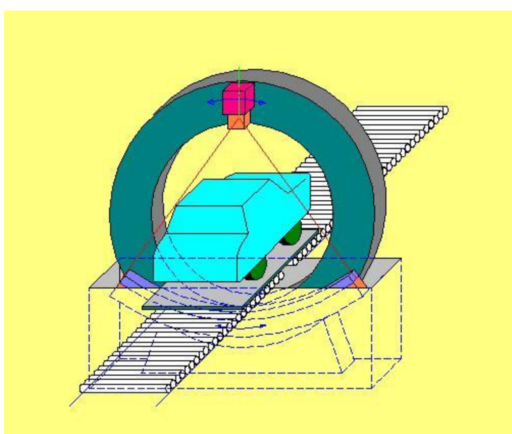
Technology solution

DR



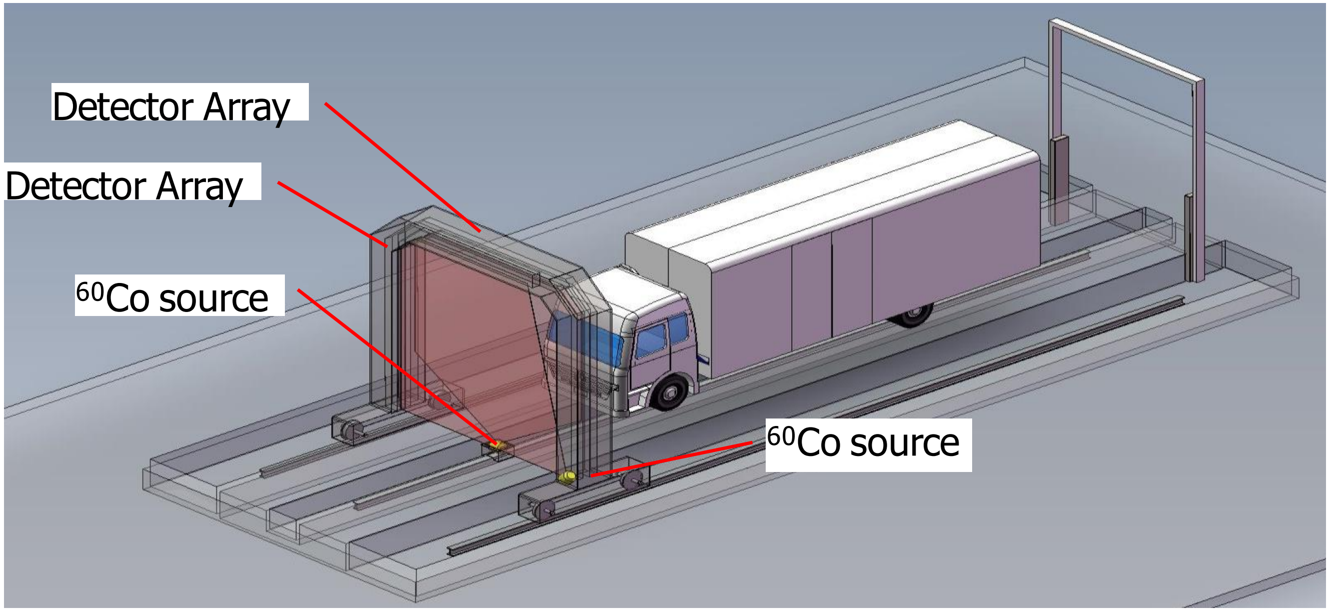
Solution: dual-projection
(economical, high throughput rate)

CT

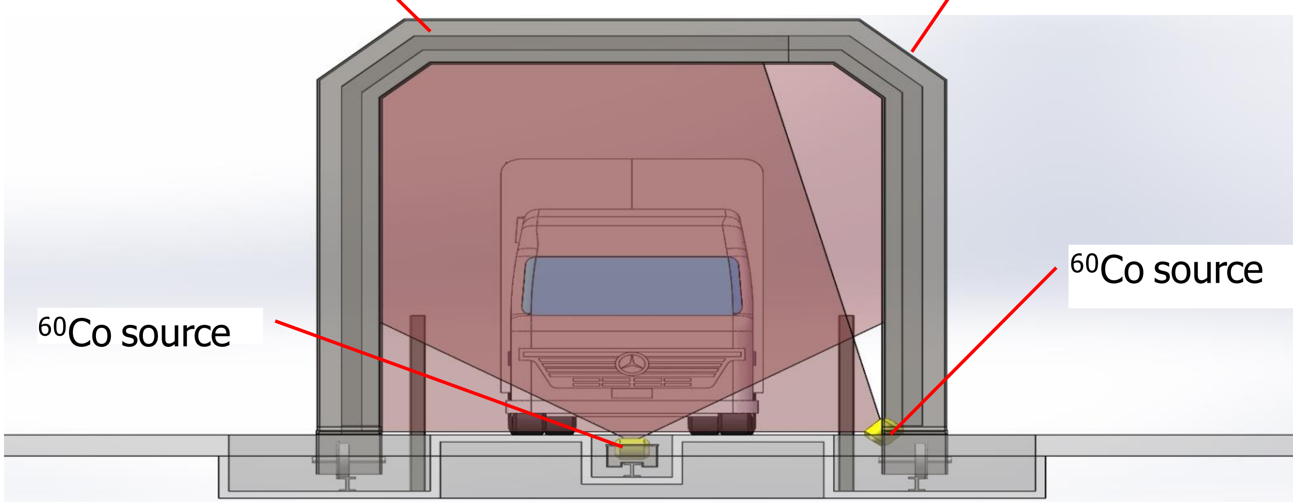


Technical proposal

Overall layout



Front view



Technical proposal

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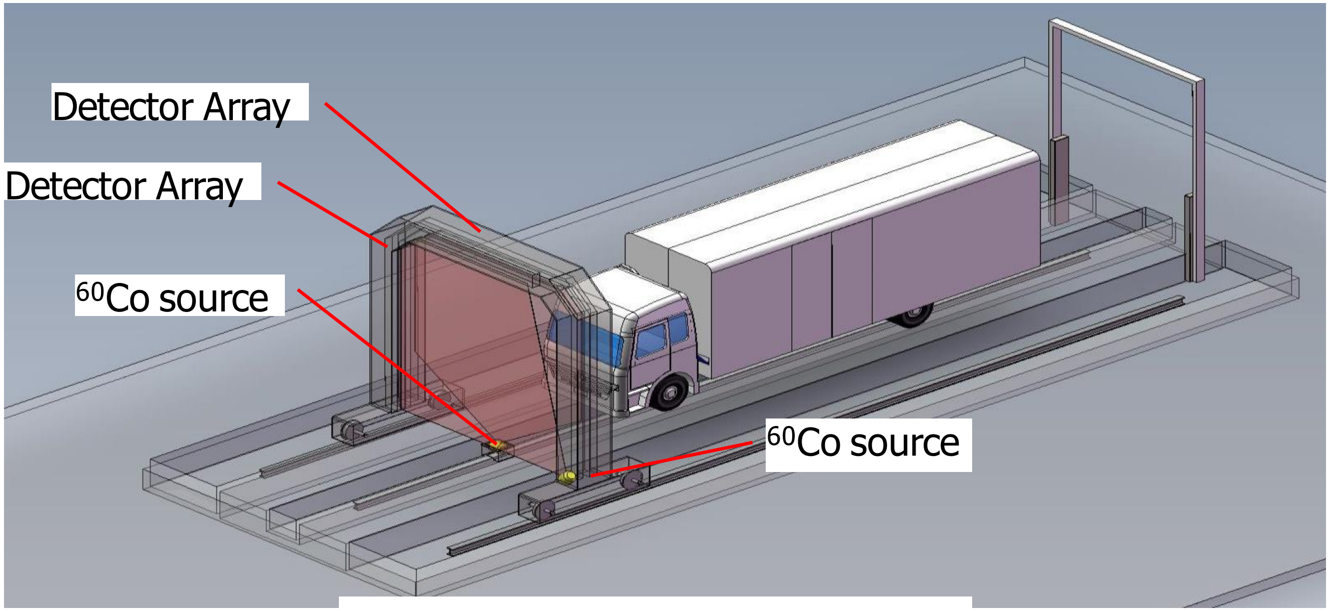
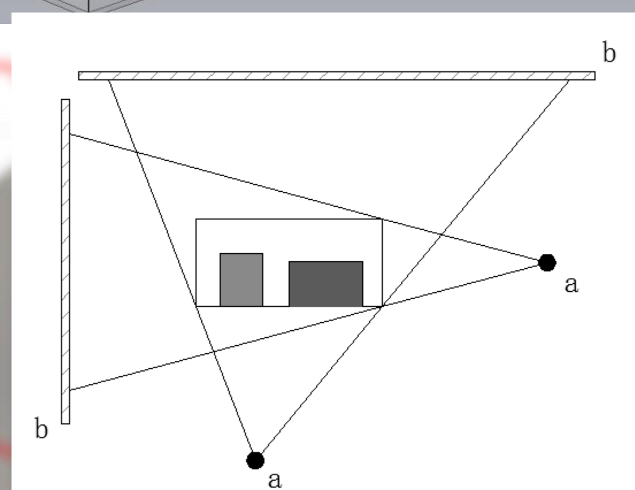


Front view

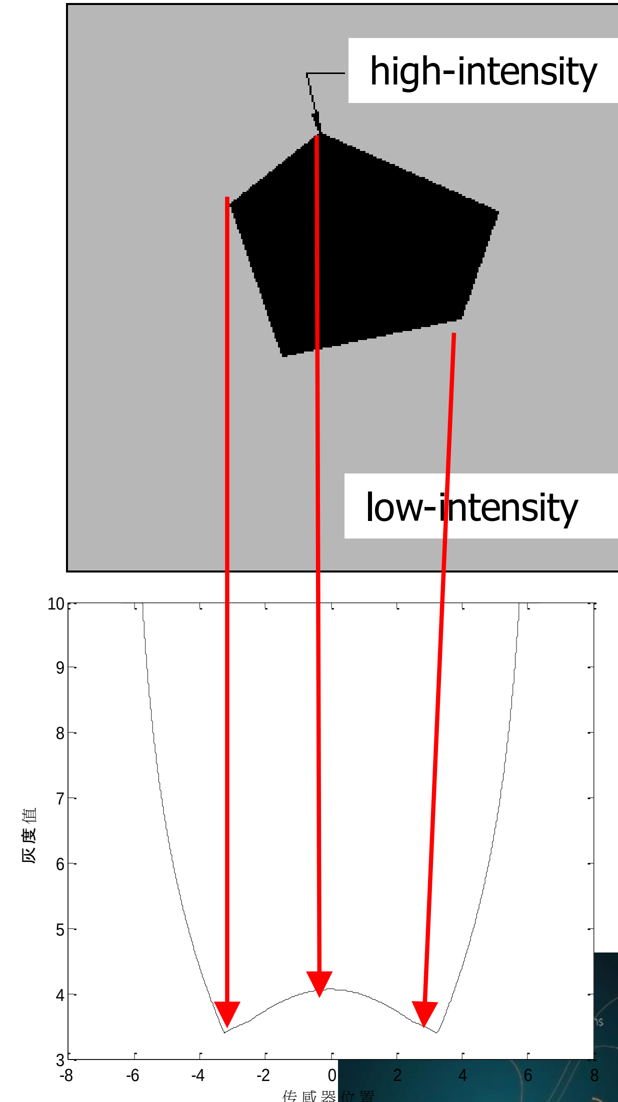


a—Radioactive sources；b—Detectors
Structure of Dual-projection system

2.Algorithm Principle

2.1Analysis of objects and gray scale curves

- Hypothesis:
  - a)high-intensity rounded by low-intensity.
  - b)convex polygon with uniform material.
- Grey scale curves obtained by the device:
  - a)represents physical property information
  - b)vertex of object make inflection of curve
- Principle
  - shape and position of the object can be obtained by analyzing inflections of two curves
  - Object density can be calculated according to shape and position of the object and value of each curve.



2.Algorithm Principle

2.1 Grey scale curve processing method

- step1: Inflections of each curve are found by filtering and derivation on them and mapped to detectors in the system.

- step2: Build Cartesian coordinates , and coordinates of each inflections are mapped . Link the radioactive source and corresponding inflections and obtain M+N lines and M*N intersections.

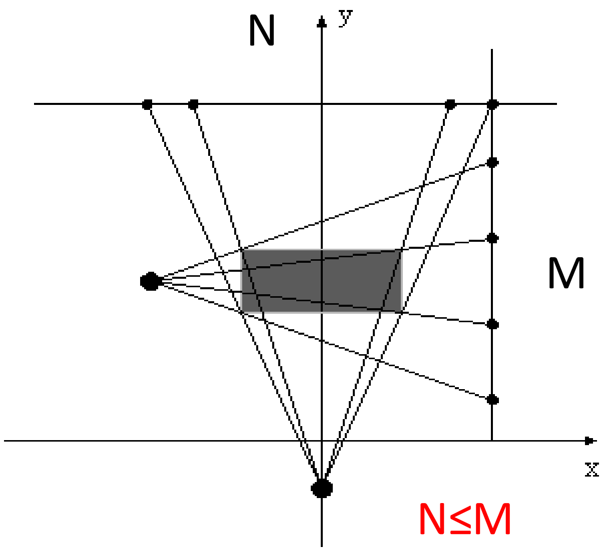


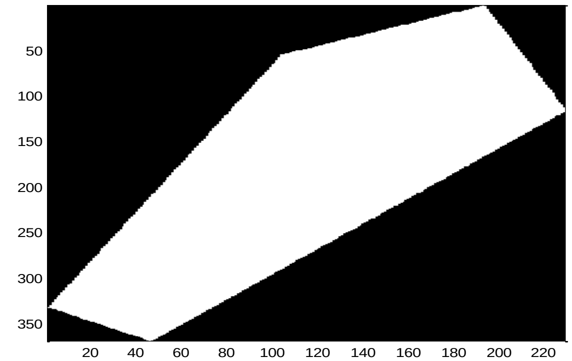
Fig.2. Schematic diagram of processing method

- step3: The vertex of the object must be among the intersections. M<Edges< 2*N. List and link all the groups of the vertex , select the outer contour as the edges of the target.

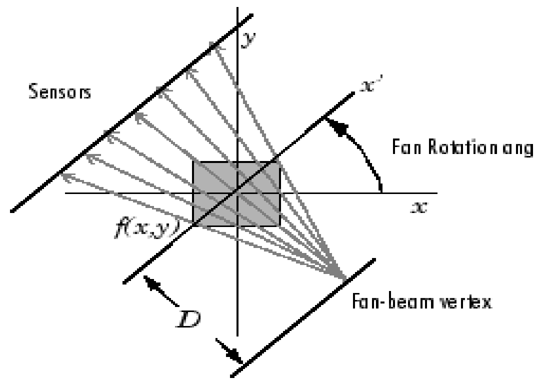
2.Algorithm Principle

2.1 Grey scale curve processing method

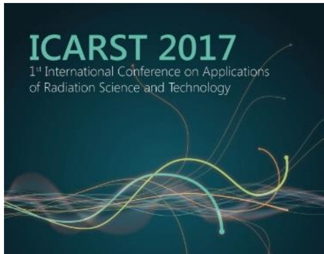
- step4: Transform the object into a Binary Image matrix.



- step5: Put the matrix in the coordinates and perform the back-projection to obtain several grey curves .



- step6: Compare with original curves and for the most coherent one. The corresponding intersections are the vertex of the target object. With the position and shape of the object, density can be calculated through the value of curves and parameters of the device.



3. **Results of Experiments**

3.1 Simulation experiment by Matlab

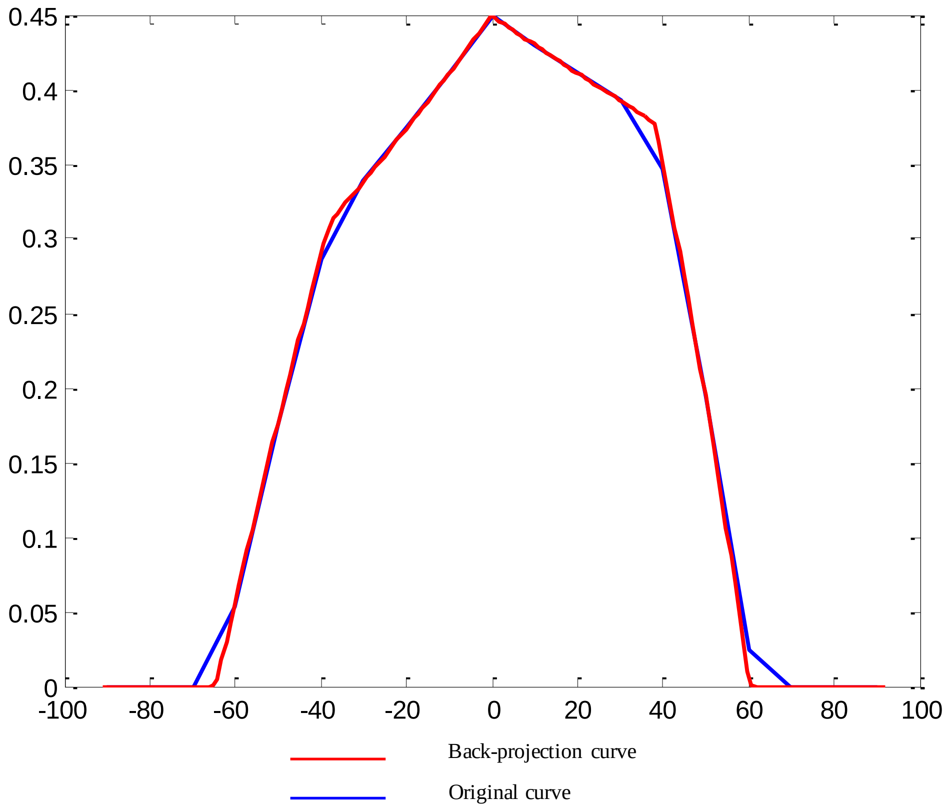
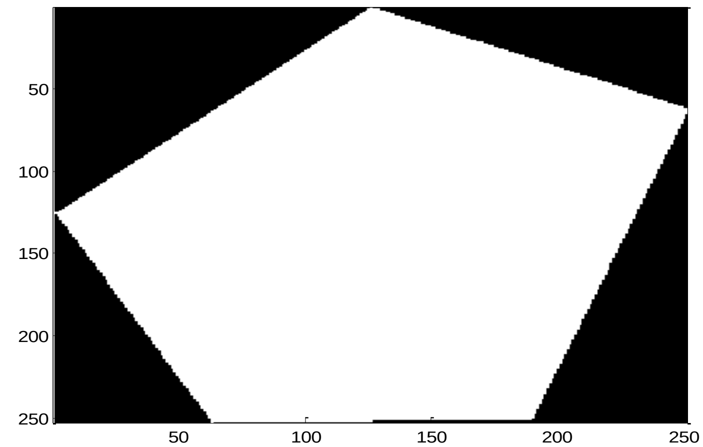
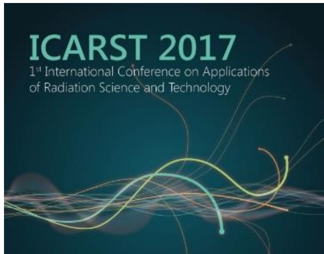


Fig.3. Schematic diagram of processing method



- Device: W=3.5m, H=4m
- Radioactive source: -0.5m
- Size of detectors: 10mm
- Target object: arbitrary pentagon
- Relative error of calculated absorption coefficient is 0.33%.



3. **Results of Experiments**

3.2Realistic experiments with ideal target

- Experiment conditions
  - Target: Standard aluminum blocks with sections of quadrilateral and pentagon
  - Size of detectors: 7mm
  - Radioactive source: Co-60

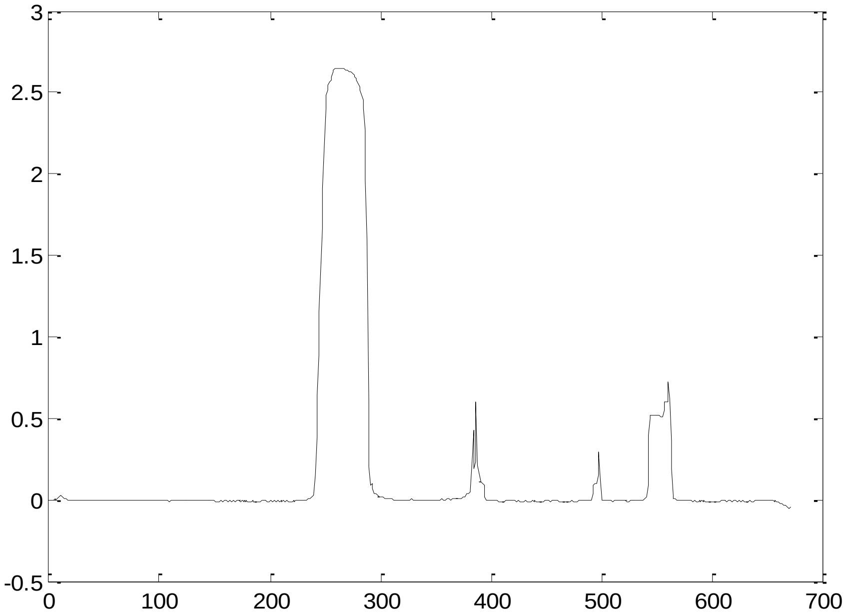


Fig. 4. Grey-scale curves obtained from the experiment

- Targets are measured for the average of 4000 times to improve data quality. (Fig. 4)

- Results
  - Relative error of calculated density: within 3% and 5%.
  - Difference between two experiment results of absorption coefficient: $4e^{-3}$

3. **Results of Experiments**

3.3Realistic experiments with non-ideal targets

- A bucket of water is put in a container along with lots of stuff as the target.
- By selecting interested areas manually, each grey-scale curve in the area is processed by the algorithm which can recover the shape, position and density of every section.

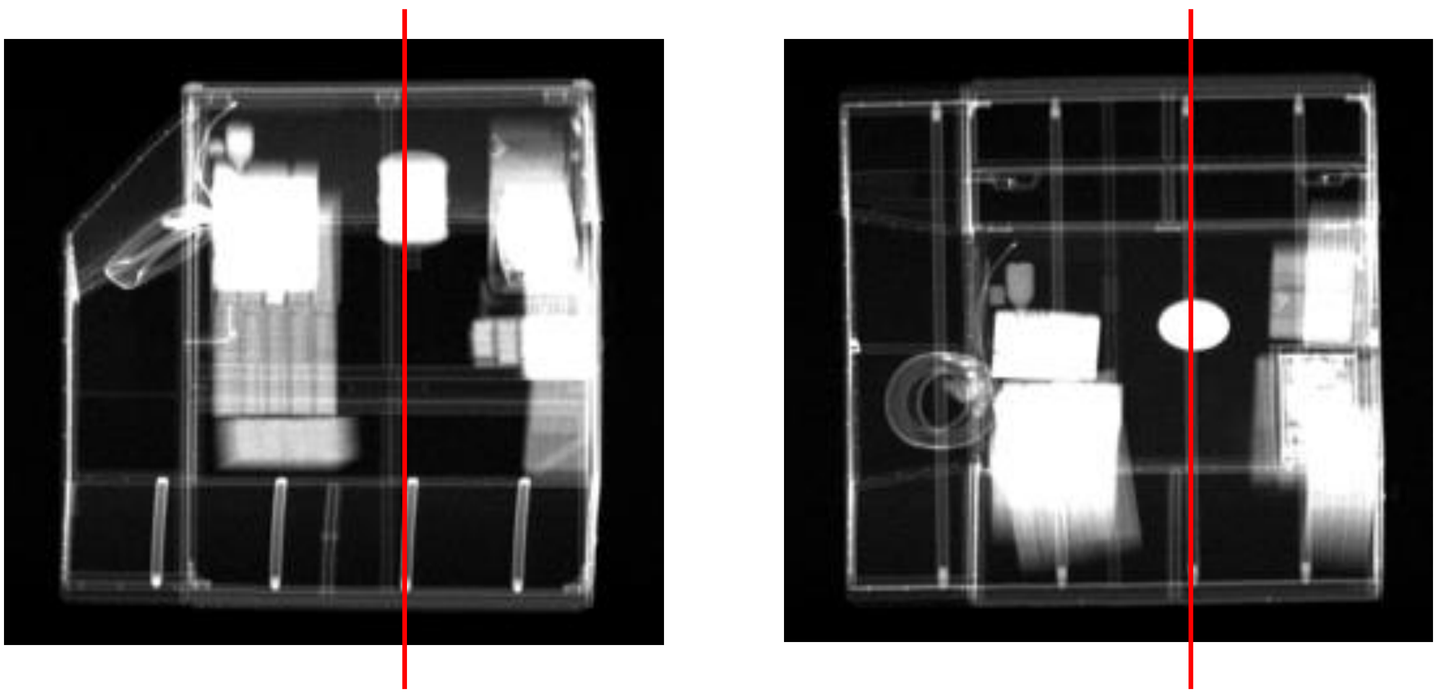


Fig. 5. Radiation images obtained from the device

3. **Results of Experiments**

3.3Realistic experiments with non-ideal targets

- 3D-model of the target object is rebuilt by composing those sections together. Final result of the density is the average of all grey-scale curves whose relative error is 13.5%.

- Subtraction of images is performed to eliminate background to reduce the relative error from 13.5% to 10.4% significantly .

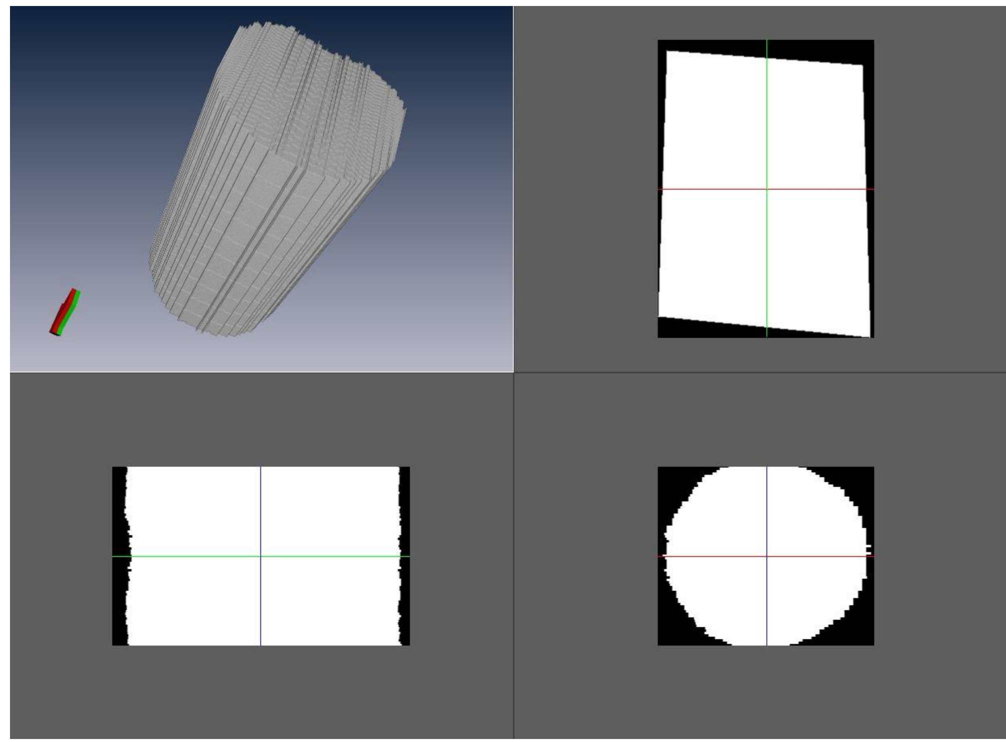


Fig. 6. 3D-model of the target object

3. **Results of Experiments**

3.3Analysis of realistic experiments

- In experiment of aluminum block, the average is measured for several times to reduce relative error. BUT, in experiment of water bucket, the average is measured only once time which causes greater relative error.
- SOLUTION: Increase measuring times to increase the data quality.

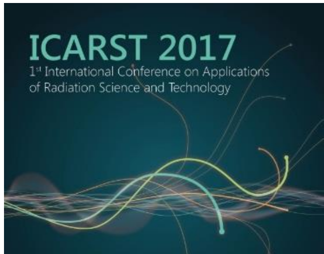
- Experiment of aluminum block: the object is stationary while the water bucket is conveyed on a track which brings mechanical jitter.
- SOLUTION: Move the object slowly.

- Container and stuffs in it bring background noise
- SOLUTION: Subtraction of the image.

- Low intensity of radioactive source and large size of detectors can also bring in relative errors
- SOLUTION: Optimizing the system structure.

4. Conclusion

- A newly developed algorithm for image processing in dual-projection systems is introduced
  - which calculates shape, position, attenuation coefficient and density of target objects rapidly and accurately.
  - Simulation results and realistic experiments confirm its reproducibility and accuracy.
  - By monitoring the target object, 3D model can be reconstructed.
  - Ways to reduce algorithm error are also proposed.
- Shortages of traditional detection systems can be significantly improved by dual-projection systems along with the described algorithm. This system can be widely used in nondestructive detecting applications.



THANK YOU FOR YOUR ATTENTION!