4.5.7. STATISTICAL GROUP-THEORETICAL METHODS OF IMAGE PROCESSING FOR NON-DESTRUCTIVE TESTING

Baranov V.A., Introscopy Institute by Tomsk Politechnic University, Tomsk, Russia;
Ewert U., Bundesanstalt für Materialforschung und – prüfung (BAM), Berlin, Germany

The main destination of image processing (IP) in non-destructive testing (NDT) is the revelation of representative "semantic structures" in test-object, for example the exposure of *defect map* of this object.. In doing so, many insignificant and even undesirable details of initial image (so-called "semantic noise") can be lost. Procedures of IP can be subdivided into *analytical* ones in which *direct problems* are solved and *synthetical* ones in which *inverse* and as a rule *ill-posed problems* are solved. "Analytical" *computerized diagnostics* (CD) calculates some characteristics of test-object which though gave useful information but were only "fragments of whole", whereas "synthetic" CD represent the semantic structure as whole. Advantages of synthetic or "holistic" representation of information on objects for their testing and control in comparison to representation in the form of a set of aspects are evident and huge. In particular, it was convincingly shown in development of *computerized tomography* (CT) and "synthetic" CD which has arisen after it, with wider possibilities than in prototypal CT. As to "analytical" CD, its intensive development began at once after occurence of the first electronic computer. The majority of existing now CD systems (not only in NDT but also in many other areas, for example in *computerized psychology*) remain still to be "analytical" ones.

The solution of synthetical ill-posed problemes demands the aprioristic information. The most natural way to this is the purposeful and regular use of basic holistic properties of test-object at a stage of reconstruction [3, 4, 2]. For this intention an unified mathematical apparatus was developed, which allows systematize the generating of hypotheses (i.e. synthetic aprioristic assumptions) as well as their testing. Especially, such fundamental holistic property of object is its *self-similarity* incl. the similarity between "whole" and "parts" was used. What is more, it is a *morphological* property which gives well into mathematization. A group-theoretical approach [3, 4, 2] was used for classification of different semantic structures in initial image, in the same manner as F. Klein applied in XIX century the group-theoretical ideology to comparative analysis of different geometries (*Das Erlanger Programm*, 1872). The essentially new step in the proposed approach was the landing "bridge" between mathematical statistics and group theory. Invariant properties of "semantic structures" (so-called *structural invariants* or invariants of automorphisms of the "key group" which is responsible for this structure) were considered systematically as *statistical hypotheses* and there were developed adequate mathematical techniques for their evaluation. In the case of space filtering the key group is the group of *local symmetry* which is introduced as *type characteristics* of the structure and acts in the framework of "geometry in small" [3, 4]. It is a *Lie group*, in degenerated cases is a finite group. Different non-linear and statistical in nature multiple *measures of similarity* between "wholes" (as well as *measures of diversity*) are introduced. They can be interpreted as *generalized backprojections* [1]. The mathematical approach to *morphological resonance* is considered and on this basis methods of *morphological analysis* of different structures (for example, images) are proposed. Procedures of *situational pattern recognition* which allow to unmask constituents of semantic structure are elaborated.

In the developed IP a key group is used for construction of synthetic *group-theoretical statistical filters*., essentialy more powerful than traditional "analytical" ones. This, in turn, allows to perform *morphing* or aimed reconstruction of test-object. The result of morphing is well-adjusted to human interpretation and manipulation, can be easily "translated" into the language of human imaginative thinking. Of course, it is quite adequate to inquiries of modern NDT.

On the basis of this approch already dozens of practically important problems were solved. Some of these solutions [2] are supposed to be considered in this lecture.

References:

1. **Baranov V.A.** A Variational Approach to Non-Linear Backprojection / "Computerized Tomography", coll. of papers, Editor-in-Chief: M.M. Lavrent'ev, Utrecht, the Netherlands, 1995. – P. 82–97.

2. **Ewert U., Baranov V., Borchard K.** Cross-sectional imaging of building elements by new non-linear tomosynthesis technique using imaging plates and ^{60}Co radiation" / invited paper in "NDT & E International", 1997 Elsevier Science Ltd., Vol. 30, N 4. – P. 243 – 248.

3. **Baranov V., Ewert U.** A group theoretical approach to ill-posed problems" / Book of abstract to 3-d international scientific conference "Computer Methods and Inverse Problems in NDT and Diagnostics" (CM NDT – 2001), Moscow, 2002. – P. 11–12.

Baranov V., Ewert U., Redmer B. Tomographical visualisation of zones of crack formation in components of nuclear power stations, Bulletin of the Tomsk Polytechnik University, 2008, Vol. 312, N 2. – P. 299–311.