I. Research activities and results

1. Robust multilevel preconditioners for anisotropic problems with discontinuous coefficients.

Semi-coarsening approach is a proper choice for construction of efficient preconditioners for anisotropic problems discretized with bilinear finite elements.

Optimal order algebraic multilevel iteration (AMLI) preconditioners based on recursive application of two-level finite element (FE) methods and polynomial stabilization have been introduced and analyzed from O. Axelsson and P.S. Vassilevski in the nineties. The construction follows the natural hierarchical splitting using the fact that the finite element spaces corresponding to two successive mesh refinements are nested. Uniform estimates for the constant $\gamma$ in the strengthened Cauchy-Bunyakowski-Schwarz (CBS) inequality are very important for the derivation of optimal order methods. The value of the upper bound for $\gamma \in (0, 1)$ is a part of the construction of the multilevel extension of the related two-level method. Composite algebraic two-level and multilevel preconditioning algorithms for second order anisotropic elliptic boundary value problems are constructed. Here we allow big jumps in the coefficients and varying the direction of dominating anisotropy from one element to another in the coarse triangulation. The discretization is done by trilinear conforming finite elements where the semi-coarsening mesh refinement strategy is applied. A new uniform estimates for the related CBS constants are derived. The additive preconditioning strategy for the system with the pivot block in the hierarchical two-level splitting is proposed, where the related sub-problems have a two dimensional structure.

Fluid-structure interaction is a challenging problem with many important applications. One such application is a simulation of a flow through 3D structures and especially the blood flow through intracranial aneurysms.

For better understanding of the nature of the problem he is working on finite element solution of axisymmetric flow problem arising in blood flow simulation. On this problem he is working together with a master student from Sofia University.

Specialized software for computer modeling of the fluid structure interaction problems was installed on the available in IICT high performance cluster and the first tests of the performance are encouraging.


Composite materials significantly enlarge the possibilities of design and functionality of the single component materials. The homogenized properties of the composite material can be determined by numerical upscaling. Then the extensive computer simulations can be performed on the macro scale i.e. the whole detail can be simulated using the upscaled material parameters.

He did series of CT scans of different composite materials provided to us from colleagues from academia and from industrial partners. This is a first step of the study which will be followed by extraction and segmentation of proper reference volume elements to perform the numerical homogenization.

4. Work with Smart Lab Equipment

The main focus was to learn how to work with the industrial Computer Tomograph. To produce a reasonable data that can be used for analysis and simulations one has to practice with different materials and with different scanning regimes. The next step is the reconstruction of 3D volume from the obtained series of “row” 2D radiograph images. To
produce a “good” reconstruction different parameters/options in the software has to be set for
the different objects/materials. The third step in the study is to perform the analysis with the
specialized software. Here again different algorithms for segmentation, smoothing, and defect
detection are available.

He is working on pilot projects with various industrial and academic partners. The companies
from casting industry are interested in non-destructive testing and defect detection of their
castings in order to adjust and develop the casting process and to increase the quality of their
production. Machine engineering companies are interested to control the quality of the parts
delivered from their subcontractors in order to guarantee the quality of the final product.
He has also established (started) projects with academic partners working in the areas of
composite materials, geo-materials, and metal alloys study.

II. Participations and presentations at scientific events

- 95th European Study Group with Industry, 23-27 September, Sofia, Bulgaria,
  http://esgi95.fmi.uni-sofia.bg/

- Seminar on Computational Mathematics, Institute of Mathematics and Informatics,
  Bulgarian Academy of Sciences, 12 December 2013, talk: “Optimal order multilevel
  methods for numerical solution of anisotropic scalar elliptic problems in polyhedral
  domains”

- Seminar on Industrial Mathematics, IICT-BAS, 19 December 2013, Sofia, Bulgaria,
talk: “Computer simulation of Wood Polymer Composite materials”,

- 8th Annual Meeting of the Bulgarian Section of SIAM, 18-19 December 2013, Sofia,
• Seminar on Mathematical modeling and Numerical Analysis, Faculty of Mathematics and Informatics, Sofia University “St. Kliment Ohridski”, 19 March, talk: “Non-destructive testing and microstructure of materials“


III. Publications


IV. Plans for future work

• Further development of multilevel algorithms based on a hierarchical basis splitting and recursively stabilized two-level additive or multiplicative preconditioners. Both, conforming and non-conforming FEM approximations will be considered. We are mostly interested to construction and analysis of robust methods when the coefficient jumps which are aligned with the interfaces of the initial mesh. In this case the focus will be on locking-free algorithms for parameter dependent problems including strong mesh and/or coefficient anisotropy.

• Continuation of the research in the area of numerical homogenization of composite and porous materials. We observe serious interest for collaboration from our colleagues from material sciences who are ready to produce for us different test specimens that we will study and will compare and validate results with other methods when it’s possible.

• 3D scanning, digitalization, and visualization of archaeological artefacts.

• Collaboration with colleagues from fluid dynamics and usage of other Smart Lab devices (High speed camera and Laser particle sizer). The research will be focused in the area of practical studies of capillary jet instability for jets containing micro and nano particles.

• Continuation of establishing connections with industry as a basis for future collaboration. Dr. I. Georgiev is a contact person for the newly announced 104th European Study Group with Industry, 23-27 September 2014, http://parallel.bas.bg/ESGI104/.

31 March 2014

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