Universität Stuttgart
Fakultät für Bau- und Umweltingenieurwissenschaften

Tolga Usta

Evaluation of Various Averaging and Interpolation Methods for Scalar and Tensorial Finite Element Data Mapping

Motivation

The continuous finite element(FE) data transfer from simulation to simulation increases the accuracy of the results during the product development. However, assembly models which are constructed by many sub-models with very detailed mesh structures are costly to solve. Therefore, transfering the FE data, such as stress tensor and effective plastic strain, to an optimal mesh structure is necessary to reduce computational effort. The mapping tool and certain data averaging and interpolation formulations are required for both tensors and scalars.

Solution

- Extend scalar data averaging and interpolation formulations to be able to transfer tensorial data

$$\bar{f}(\mathrm{R}) = \begin{cases} \Big[\sum\limits_{\mathrm{E}_i\in\mathbb{P}} (\bar{d}_i)^2 \mathbf{v}_i\Big] \Big/ \Big[\sum\limits_{\mathrm{E}_i\in\mathbb{P}} (\bar{d}_i)^2\Big], & \text{if } d_i \neq 0 \text{ for all } \mathrm{E}_i \\ \mathbf{v}_i, & \text{if } d_i = 0 \text{ for some } \mathrm{E}_i \end{cases}$$

$$\bar{f}(\sigma^j_{t,kl}) = \begin{cases} \Big[\sum\limits_{\mathrm{S}_i\in\mathbb{P}} (\bar{d}_i)^2 \sigma^i_{s,kl}\Big] \Big/ \Big[\sum\limits_{\mathrm{S}_i\in\mathbb{P}} (\bar{d}_i)^2\Big], & \text{if } d_i \neq 0 \text{ for all } \mathrm{S}_i \\ \sigma^i_{s,kl}, & \text{if } d_i = 0 \text{ for some } \mathrm{S}_i \end{cases}$$

Shepard's formulation for scalar data (top) and application of Shepard's function to tensorial data (bottom)

- Modify invariant-based diffusion tensor interpolation methods in medical imaging applications to interpolate tensorial FE data.
- Use FE shape functions to interpolate the data on the projection of the target point which lies on the patch.

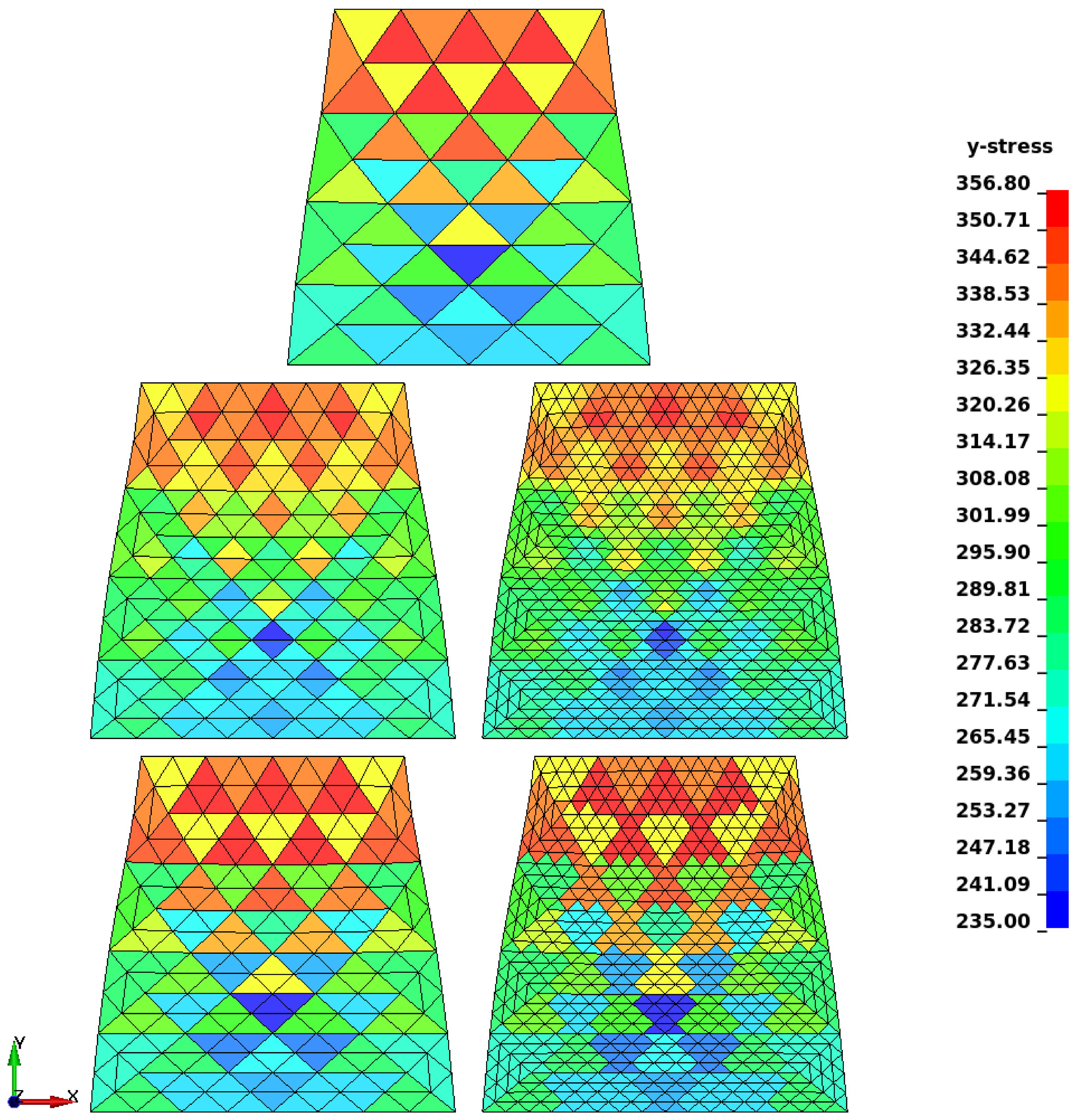
$$\boldsymbol{\sigma}^{\mathrm{G}}_j = \sum_{i=1}^{n} \mathrm{N}_i(\xi_j,\eta_j)\boldsymbol{\sigma}_i$$

Results

	Absolute Dissipated Total Energy Error [%]	Absolute Return Displacement Error [%]
64 Element Source Mesh	1.96	0.04
Closest Point Map	2.74	0.03
C-Invariant Set Map	0.81	0.88
256 Element Target Mesh	-	-
	Absolute Dissipated Total Energy Error [%]	**Absolute Return Displacement Error [%]**
64 Element Source Mesh	2.87	0.05
Closest Point Map	3.40	0.11
C-Invariant Set Map	1.38	1.08
1024 Element Target Mesh	-	-

Absolute errors of the selected mapping procedures which are done using fully integrated 3-node triangle elements

Numerical Example



The FE data mapping from 64 element source mesh (top) to 256 element target meshes (left) and 1024 element target mesh (right) using C-set invariant-based mapping formulation (middle) and closest point search formulation (bottom)

References

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Supervisors: M.Sc. Tobias Willmann
Dipl.-Ing. Christian Liebold [DYNAmore GmbH]

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