Automatic Postprocessing of Topology Optimization Solutions by using Support Vector Machines

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Outline

• Background & motivation
• Support vector machines
• SVM as metamodels – previous work
• SVM-based postprocessing approach
• In-house toolbox TopoBox
• 2D and 3D examples
• Summary & concluding remarks
Topology optimization of a cutting tool

SVM-based postprocessing
Support vector machines

\[ w \cdot x + b = 0 \]

\[
\begin{aligned}
\min_{(w,b)} & \frac{1}{2}\|w\|^2 \\
\text{s.t.} & 1 - y^i (w \cdot x^i + b) \leq 0
\end{aligned}
\]


The kernel trick

\[
\begin{aligned}
\min_{\lambda} & \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \lambda_i \lambda_j y^i y^j x^i \cdot x^j - \sum_{i=1}^{N} \lambda_i \\
\text{s.t.} & \sum_{i=1}^{N} \lambda_i y^i = 0, \\
& \lambda_i \geq 0, \quad i = 1, \ldots, N.
\end{aligned}
\]

\[
\begin{aligned}
\min_{\lambda} & \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \lambda_i \lambda_j y^i y^j k(x^i, x^j) - \sum_{i=1}^{N} \lambda_i \\
\text{s.t.} & \sum_{i=1}^{N} \lambda_i y^i = 0, \\
& 0 \leq \lambda_i \leq C, \quad i = 1, \ldots, N.
\end{aligned}
\]
### Examples – 2D and 3D dart boards

![2D and 3D dart boards](image)

### Metabox 1.5

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<td>• Newton’s method</td>
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SVM-based limit surface


\[ g_{\text{train}}^{\text{min}} = \begin{cases} 
1 & \text{if } g_i > 0, \\
-1 & \text{otherwise.}
\end{cases} \]

SVM-based approach
TopoBox - inhouse toolbox

Maximizing potential energy

\[ \Pi(\rho, d) = \frac{1}{2} d^T K(\rho) d - F^T d. \]

\[ \begin{align*}
\min_{d} & \quad \Pi(\hat{\rho}, d) \\
\text{s.t.} & \quad C_S d + C_M d - g \leq 0.
\end{align*} \]


Topology optimization with contact constraints

Trade-off curve
Michell’s benchmark


SVM-based postprocessing
Topology optimization of a stamping die

3D benchmark

TO
SVM
3D benchmark

SVM parameters
An automatic postprocessing approach of TO solutions is suggested by using SVM.

The approach is implemented in our in-house toolbox TopoBox.

The approach is implemented for both 2D and 3D geometries.

It is demonstrated that proper stl-files are generated which then are 3D printed.