Finite Element Model Updating (FEMU)

Practice Guide and Open-Source Software

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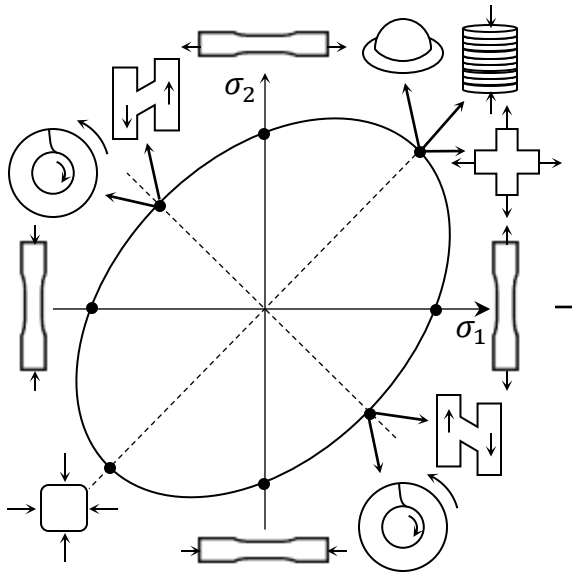
Finite Element Model Updating (FEMU)

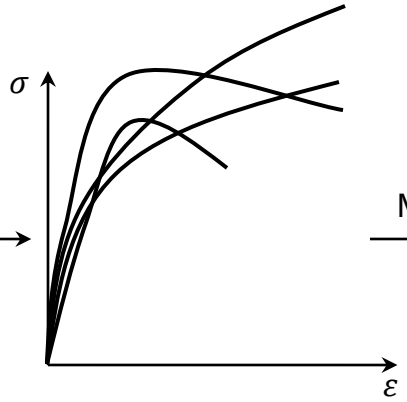
Overview

Material Testing 2.0

Material Testing 1.0



Conventional test

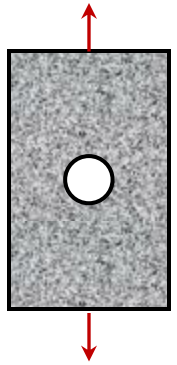


Statically determinate

Model fitting

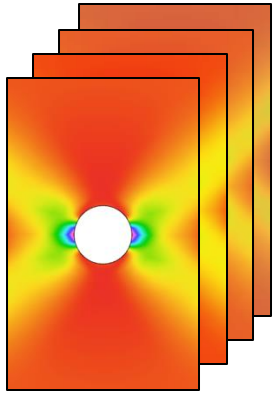
Model parameters via multiple data-poor material tests

Material Testing 2.0



Non-conventional test

Full-field measurement

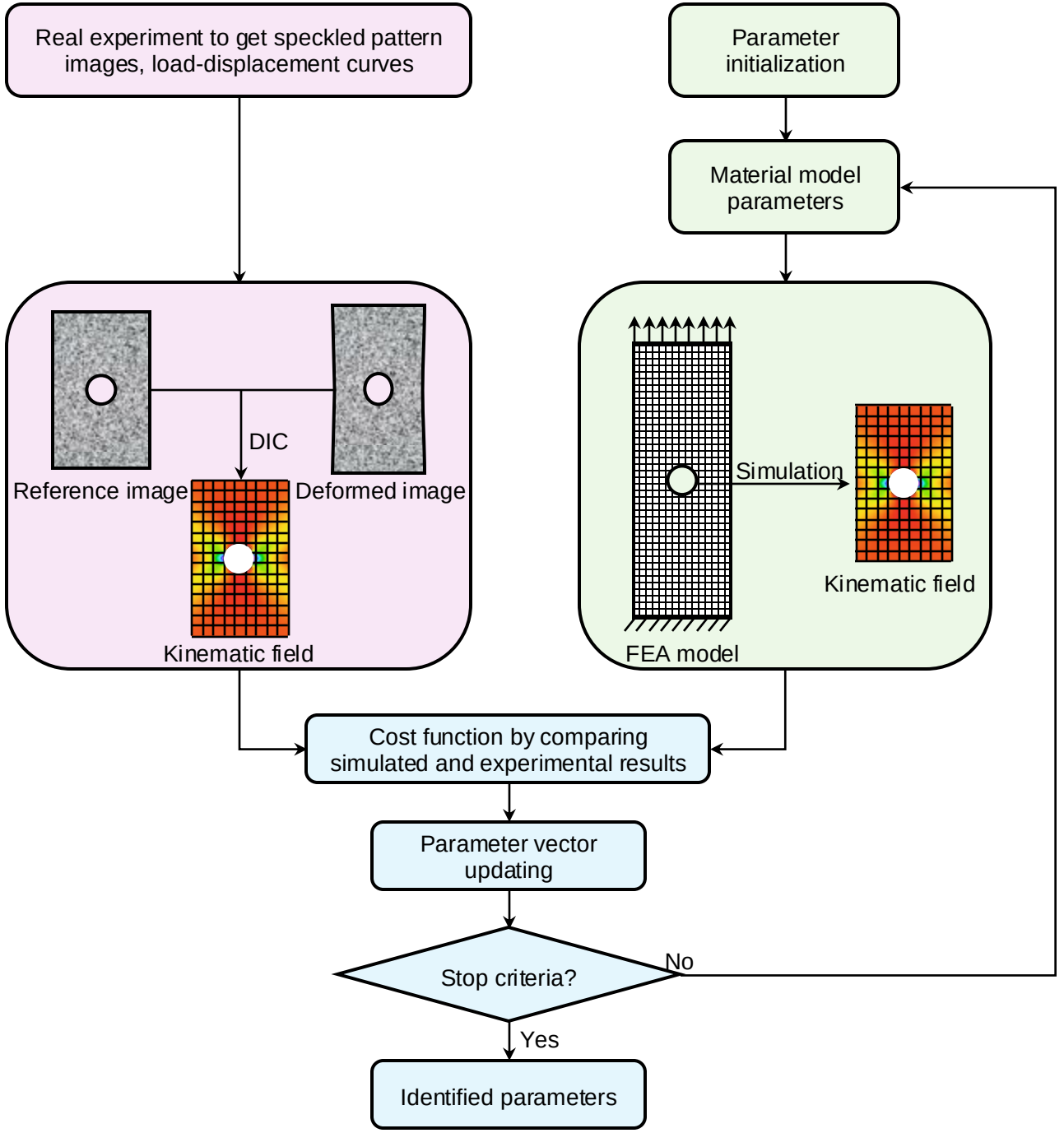


Statically indeterminate

Iterative identification

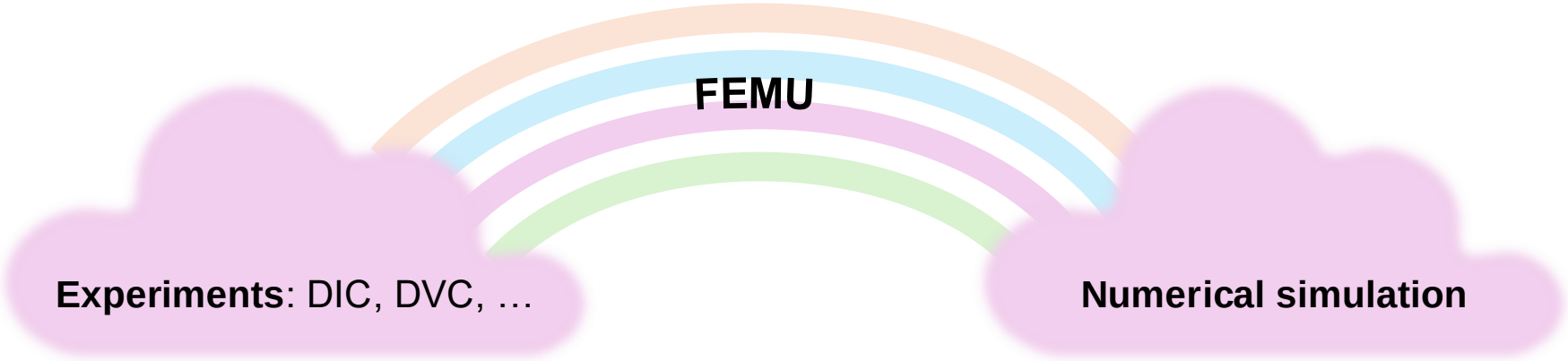
Multiple parameters from few data-rich material tests

FEMU

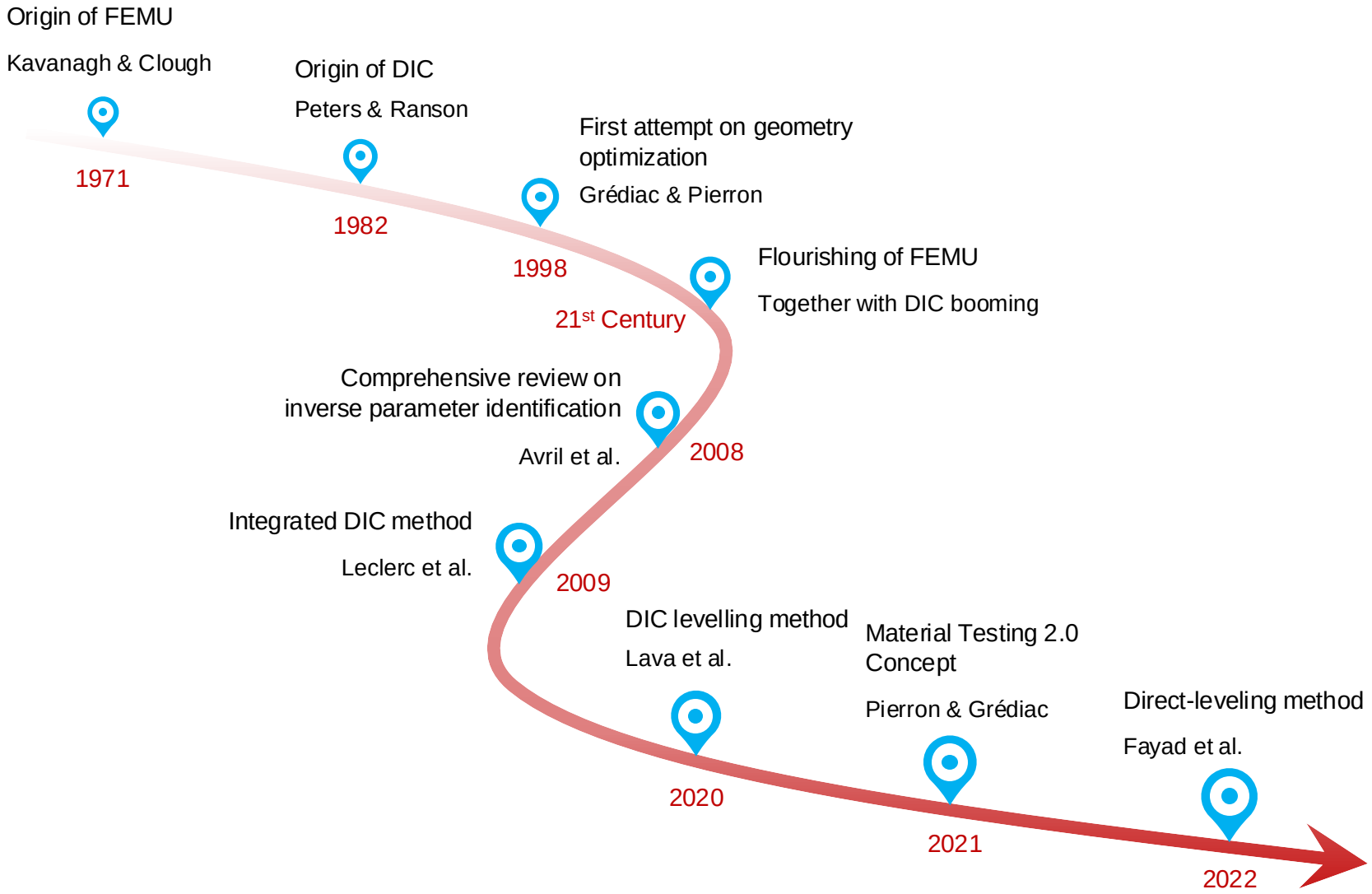

Real experiment to get speckled pattern images, load-displacement curves
Parameter initialization
Material model parameters
DIC
Reference image
Deformed image
Kinematic field
Simulation
Kinematic field
FEA model
Cost function by comparing simulated and experimental results
Parameter vector updating
Stop criteria?
No
Yes
Identified parameters

FEMU

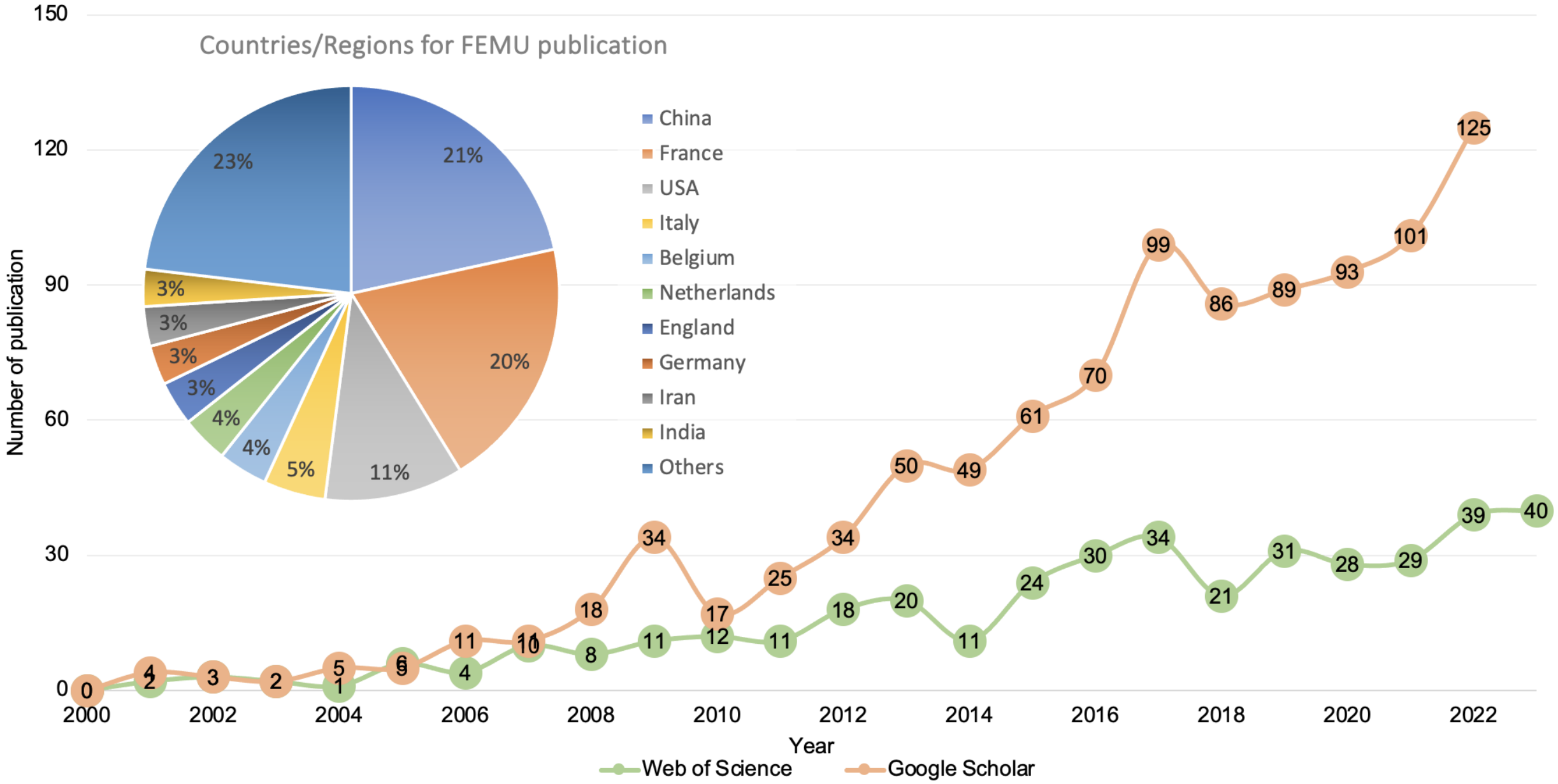
- Full exploitation of multi-physics experimental data
- Efficient and accurate derivation of multi-physics material parameters
- Material model discovery, selection, validation, and refinement



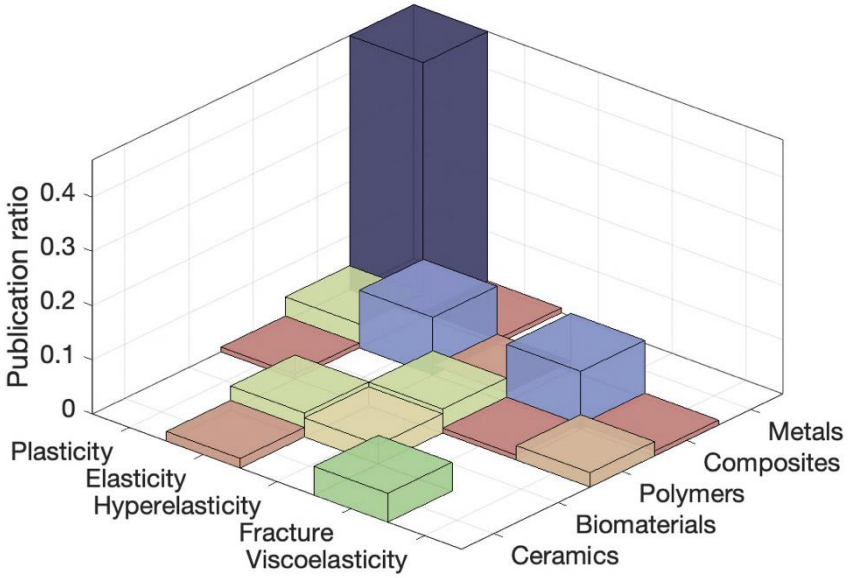
FEMU-Overview

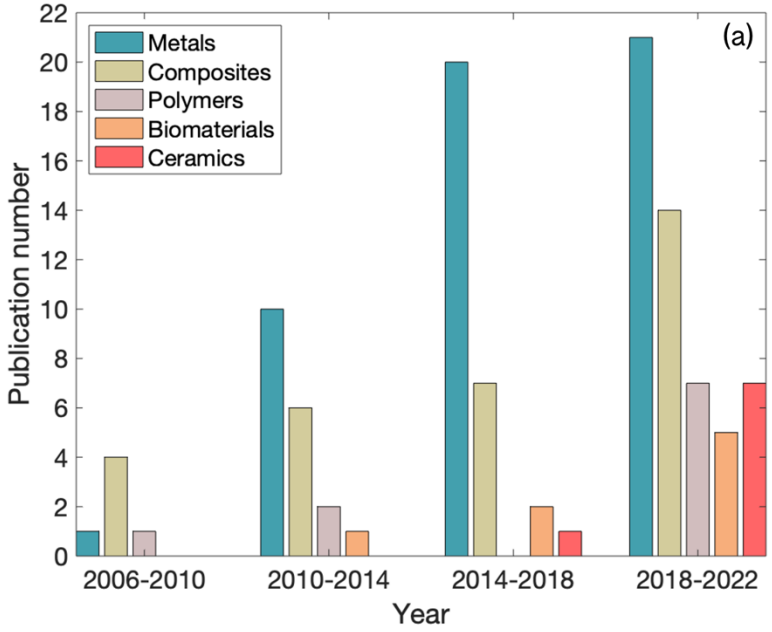


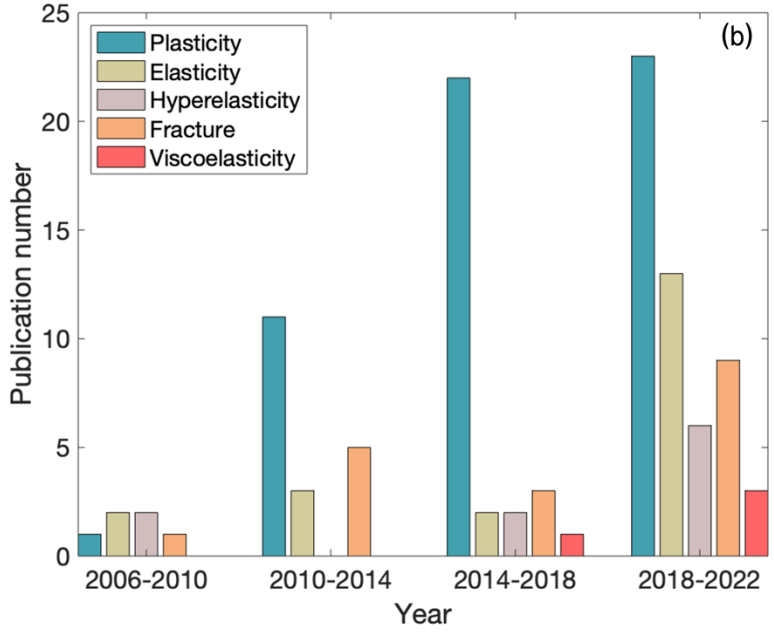
FEMU-Overview



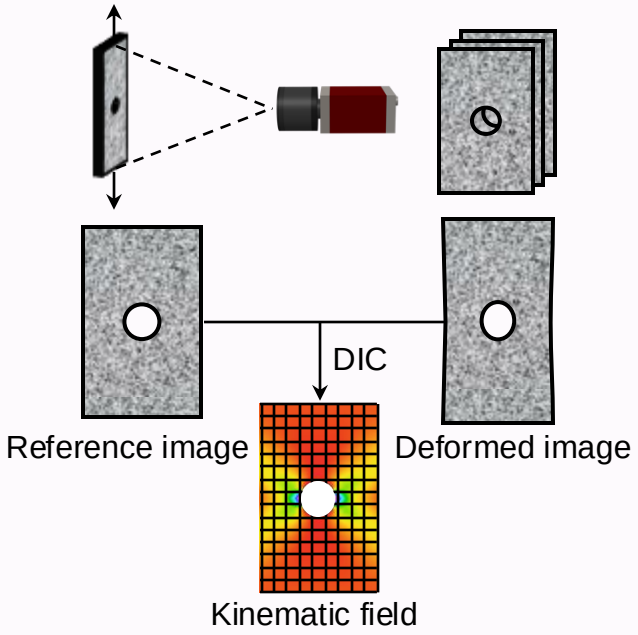
FEMU-Applications





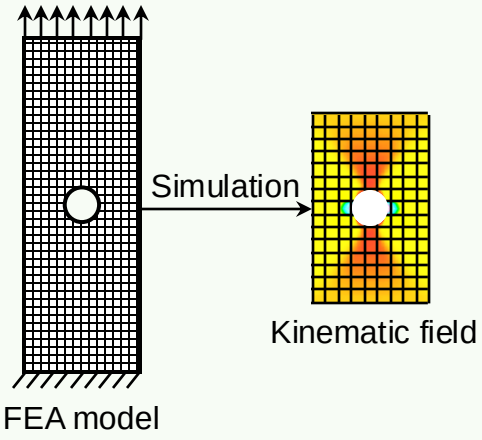


FEMU: Three pillars



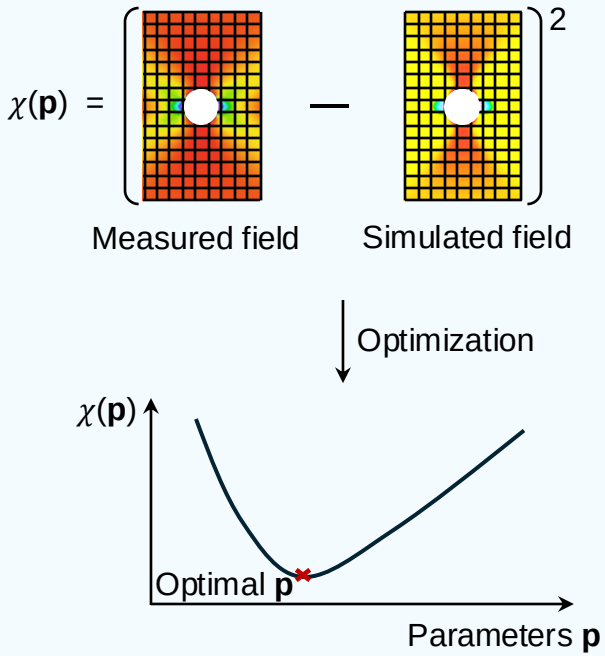
Experiments

- Test design and loading conditions: sample geometry design, load path;
- Measurements: subset size, shape function, speckle pattern, DIC algorithm, imaging technique, etc.;
- Experimental implementation: sample manufacture, sample misalignment, equipment synchronization.



Numerical simulation

- Constitutive material model selection;
- Accurate boundary condition;
- Mesh quality control: mesh type, mesh size, etc.;
- Solver selection: static analysis, dynamic analysis, etc.;



Identification strategy and optimization

- Cost function selection; physical quantity selection, data amount;
- Sensitivity analysis;
- Data fusion: coordinate transformation; data interpolation, filter mismatch;
- Iterative parameter optimization: algorithms, strategies, stop criteria, initial guess;

FEMU: Objectives

➢ Motivation:

- FEMU faces challenges in computational efficiency, uncertainty quantification, and overall robustness,
- Good practice requires a certain level of expertise.
- Lack of education in the use of FEMU.

➢ Citation

Bin Chen, Bojan Starman, Miroslav Halilovič, Lars A.Berglund, Sam Coppieters, *Finite Element Model Updating for Material Model Calibration: A Review and Practice Guide*. (Archives of Computational Methods in Engineering)

Finite Element Model Updating (FEMU)

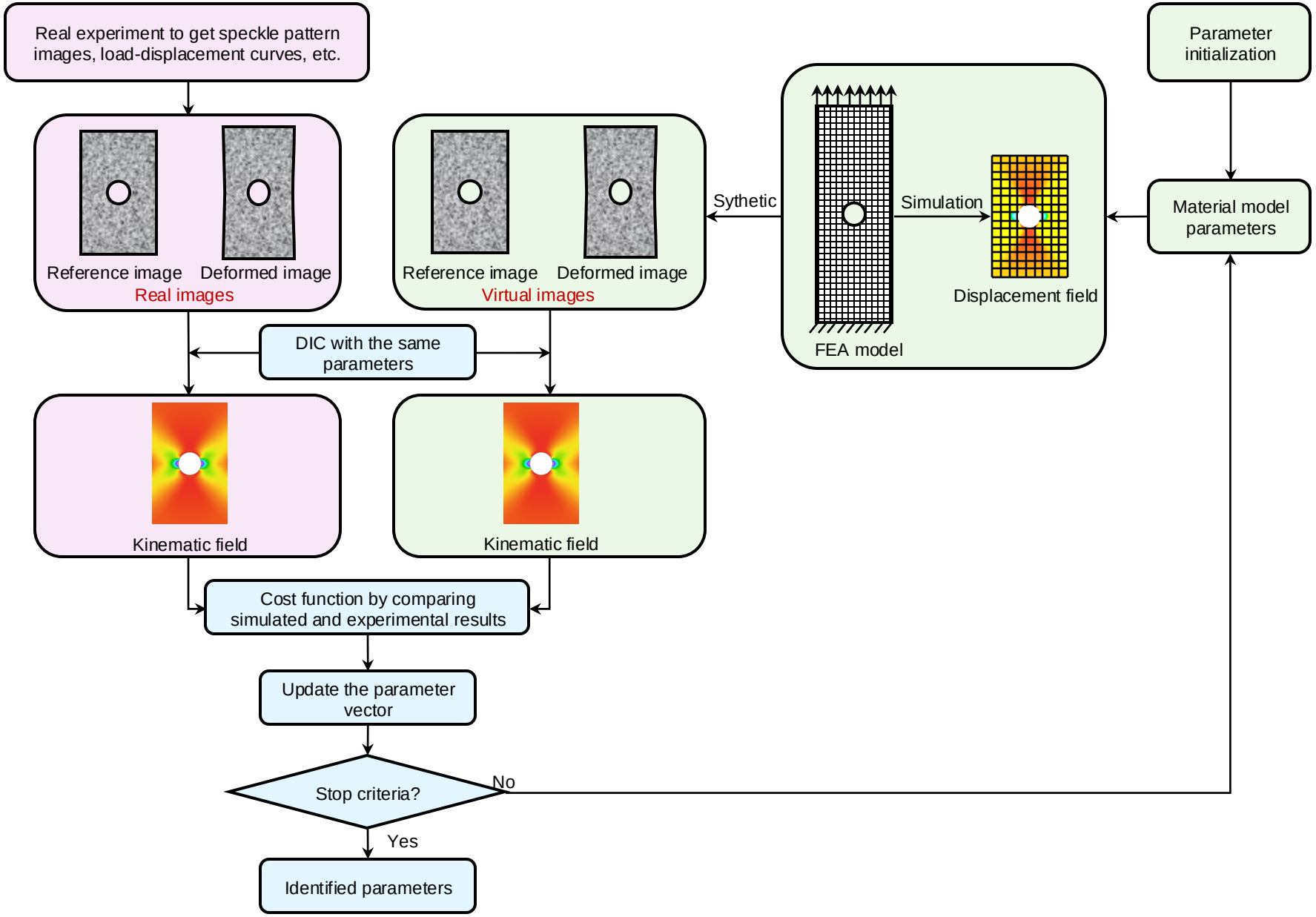
Frameworks

FEMU frameworks

- Classical FEMU
- Leveling-based FEMU
  - Direct-leveling method
  - DIC-leveling method
- Integrated DIC

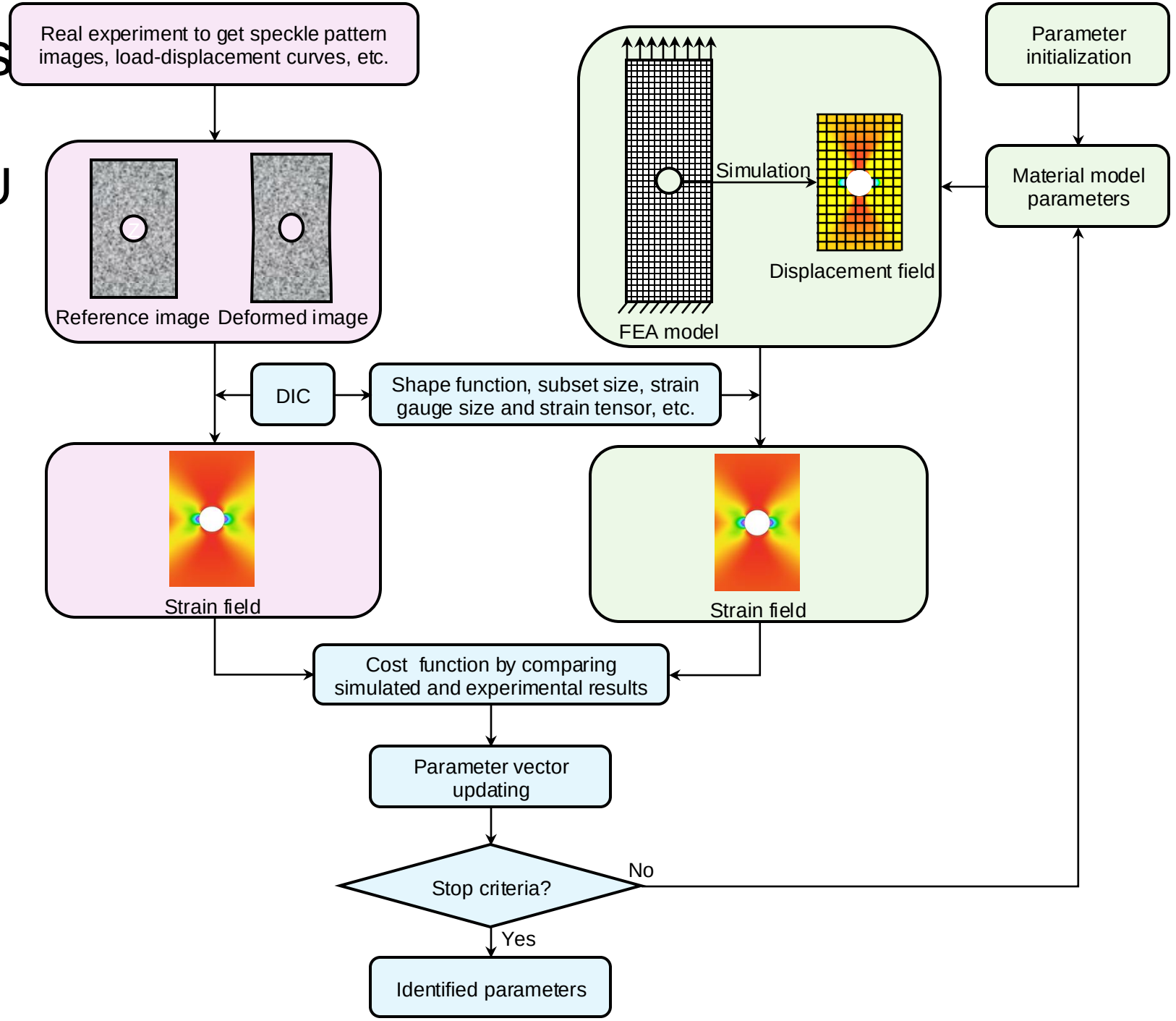
FEMU frameworks

DIC-leveling FEMU



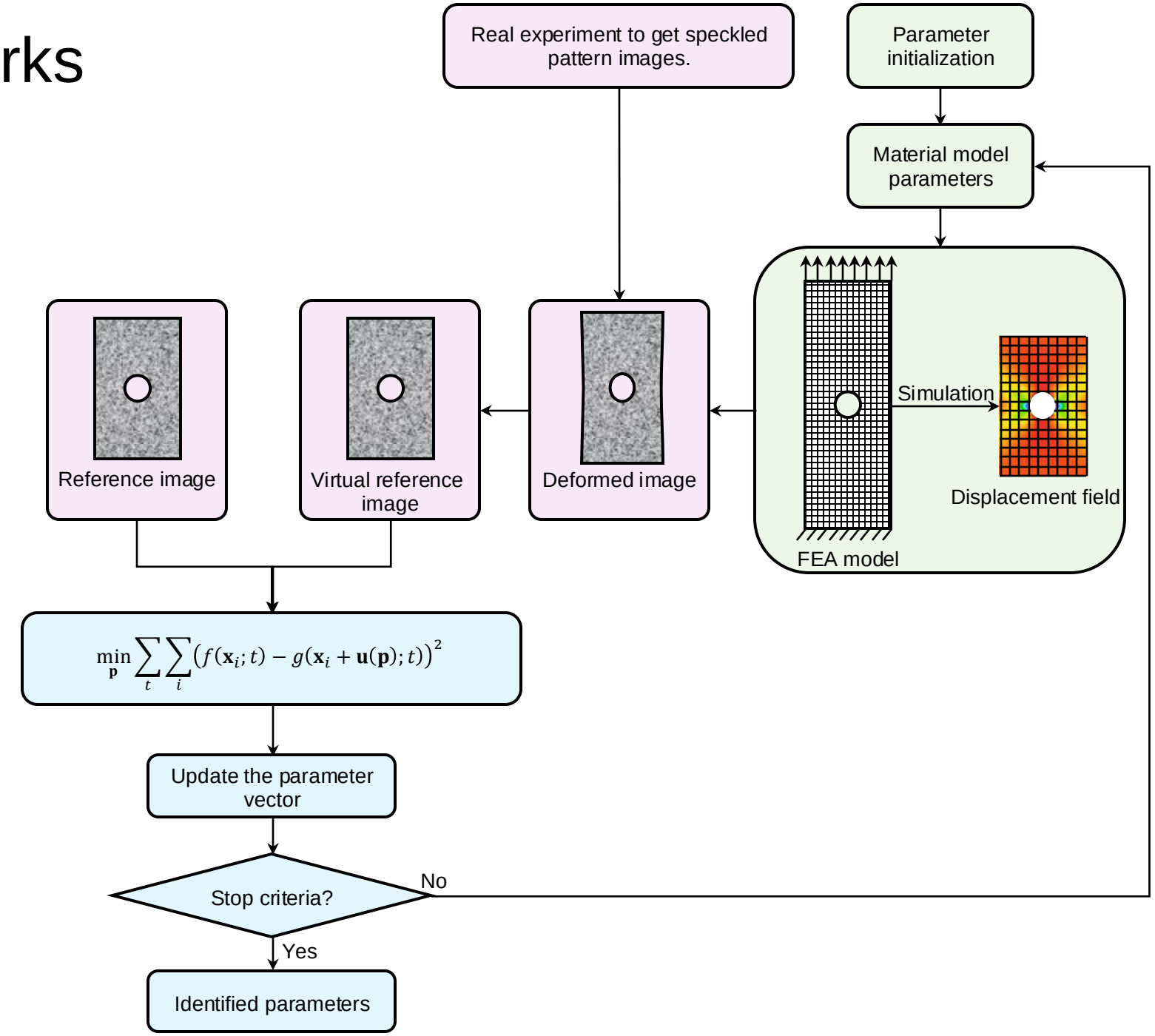
FEMU frameworks

Direct-leveling FEMU



FEMU frameworks

Integrated DIC



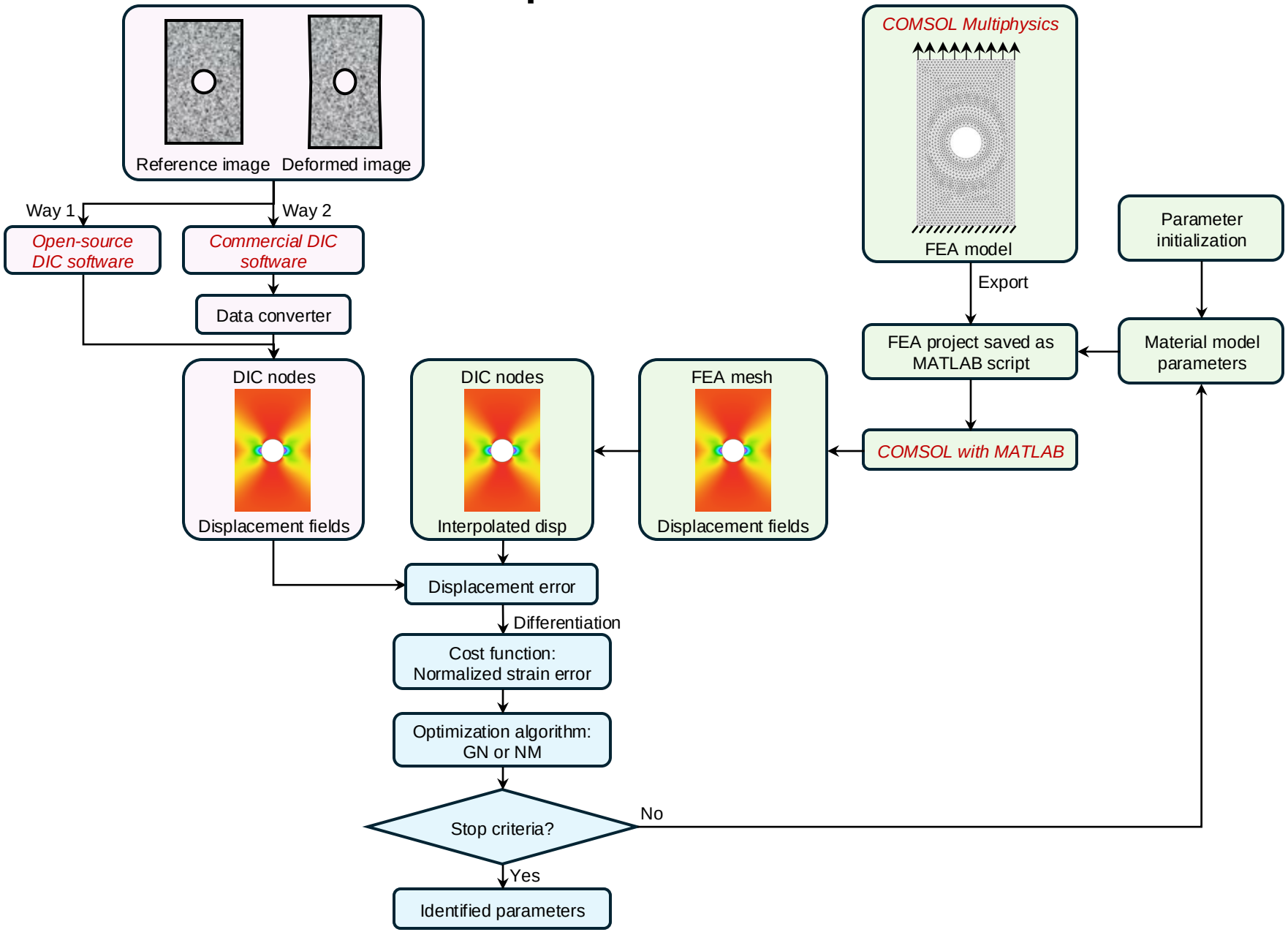
Challenges and future works

- Heterogeneous material calibration
- Multi-physics model calibration
- Generic test design
- Machine learning aided parameter identification
- High-efficiency FEMU
- Standardization
- All-in-one user-friendly platform development

FEMU-DIC: An Open-Source Software

- Stand-alone DIC software
- FEMU software

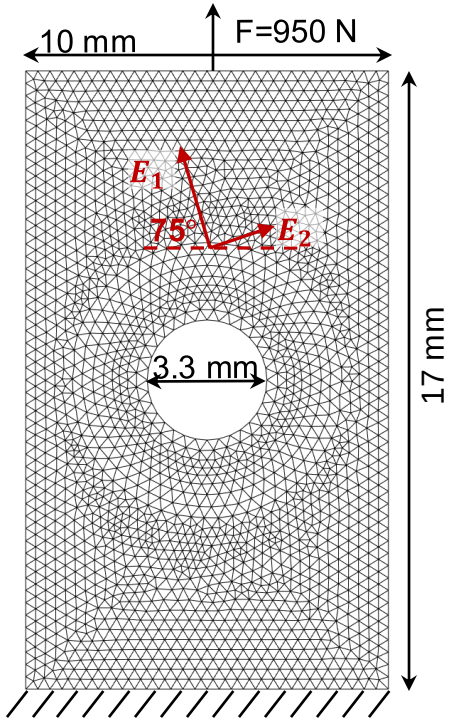
FEMU-DIC: Software description

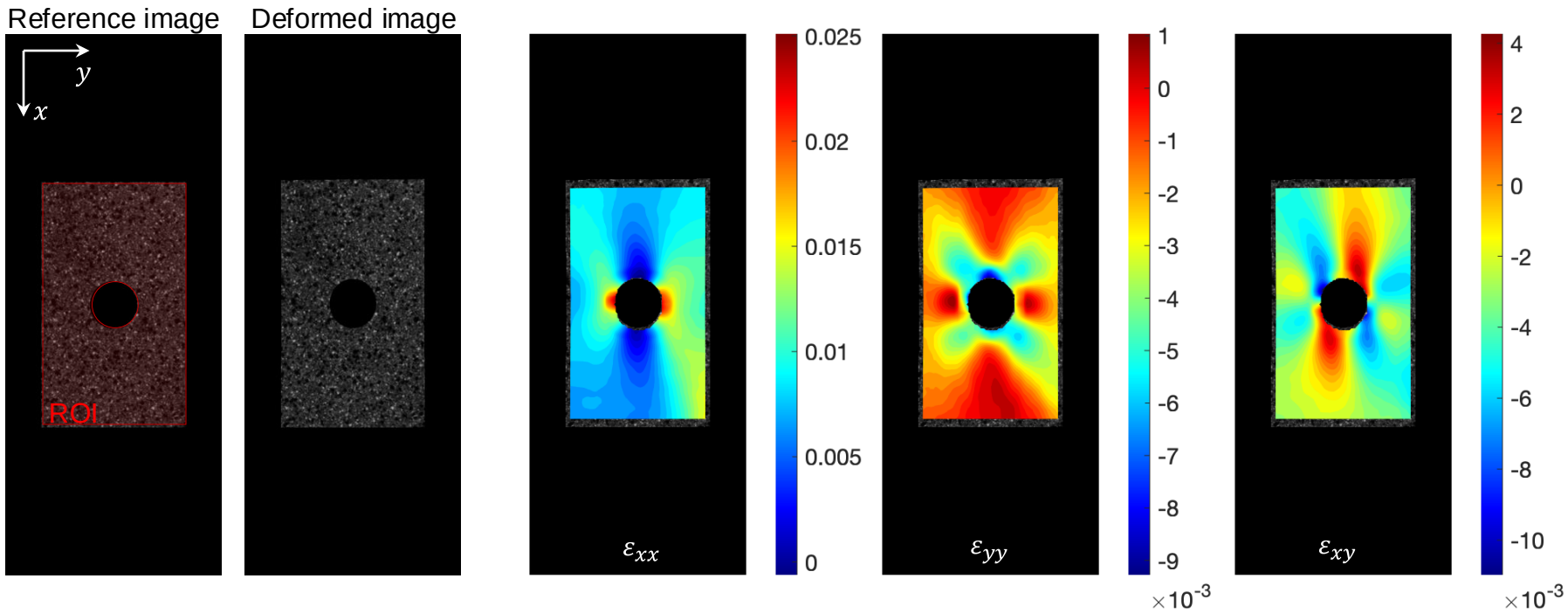


FEMU-DIC: Software description

FEMU-OPEN components	Settings
▪ **DIC**	
DIC platform	Open-source 2D-DIC software or commercial software (VIC-2D or MatchID-2D)
Method	Local DIC
Optimization algorithm	IC-GN
Shape function	First-order shape function
ROI selection	Rectangle and/or polygon
Strain calculation	Strain window method
▪ **FEMU**	
FEMU framework	Direct-leveling method
Sample	Uniaxial tensile test of perforated strip sample
Boundary condition	Force boundary condition
Cost function	FEMU-εN
Optimization algorithm	Gauss-Newton or Nelder-Mead algorithm
Data fusion	Interpolate from FEA mesh to DIC nodes
Initial guess	Manually given
FEA solver	COMSOL Multiphysics
Converge criteria	A limited iteration number & the maximum relative parameter increment is larger than a threshold

FEMU-DIC: Validation





Parameters	E_1 (GPa)	E_2 (GPa)	ν	G_{12} (GPa)	Running time (s)
Reference value	13.9	5	0.1	2	\
GN + Open-source DIC	13.903	5.2991	0.1021	1.9999	76
GN + MatchID-2D	13.966	5.0489	0.0997	2.0024	76
GN + VIC-2D	13.917	5.0159	0.0987	1.9996	71
NM + Open-source DIC	13.863	5.3709	0.0980	1.9995	246
NM + MatchID-2D	13.913	5.2816	0.0873	2.0057	229
NM + VIC-2D	13.824	5.1887	0.0873	2.0069	202

FEMU-DIC: GitHub

FEMU-DIC Public

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2D-DIC	Bug fixing	2 months ago
Demo	Bug fixing	2 months ago
FEMU	Bug fixing	2 months ago
Figure	Bug fixing	2 months ago
LICENSE	Initial commit	8 months ago
README.md	README.md	5 days ago

README | GPL-3.0 license

FEMU-DIC

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Project summary

FEMU-DIC is an open-source finite element model updating (FEMU) software. It includes two key parts:

About

FEMU-DIC includes both a standalone DIC software and the corresponding FEMU part.

- Readme
- GPL-3.0 license
- Activity
- 6 stars
- 1 watching
- 0 forks

Releases

No releases published
Create a new release

Packages

No packages published
Publish your first package

Languages

MATLAB 96.2% C++ 3.8%

Suggested workflows

Based on your tech stack

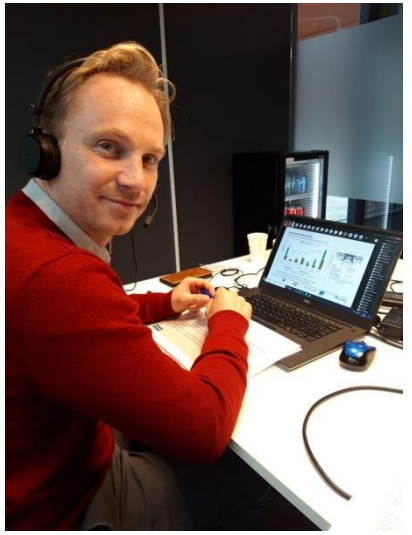
https://github.com/BinChenOPEN/FEMU-DIC

Coauthors

Prof. Bojan Starman

Prof. Miroslav Halilovič

Prof. Lars Berglund



Prof. Sam Coppieters

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