USNCCM15 Short Course:
Machine Learning Data-Driven Discretization Theories, Modeling and Applications

Summary and Future Work

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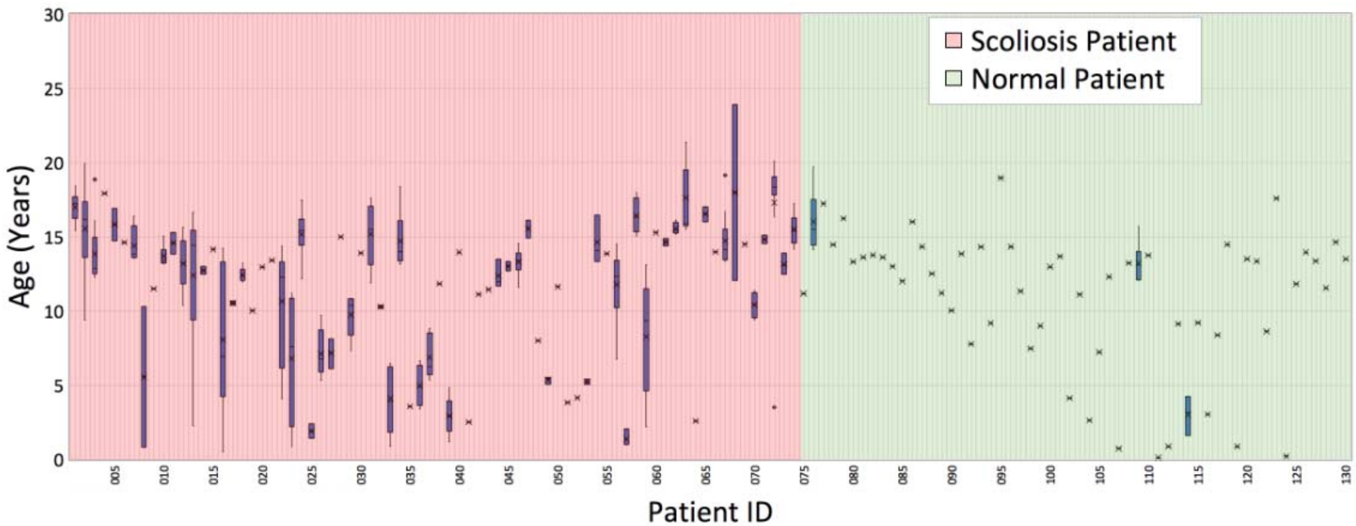
USNCCM15
Austin, Texas, USA

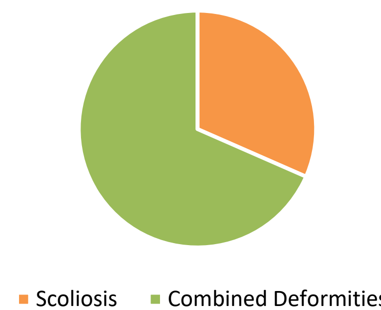
Northwestern University

Statistical description of data

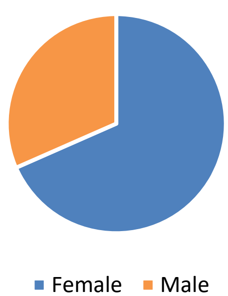
76 Scoliosis Cases (Patient ID = 1, 2, …, 76)	54 Normal Cases (Patient ID = 77, 78, …, 130)



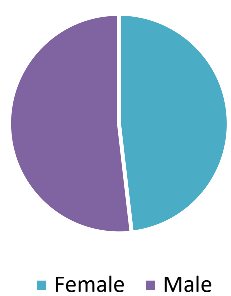
Scoliosis vs. Combined Deformities



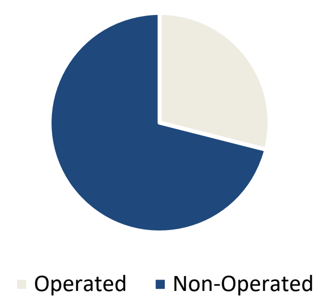
Male vs. Female (amongst Scoliosis Patients)



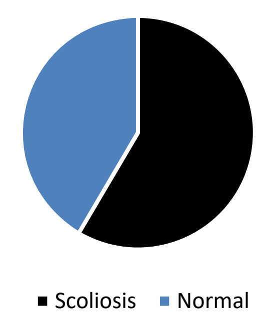
Male vs. Female (amongst Normal Patients)



Operated vs. Non-Operated (amongst Scoliosis Patients)



Normal vs. Scoliosis



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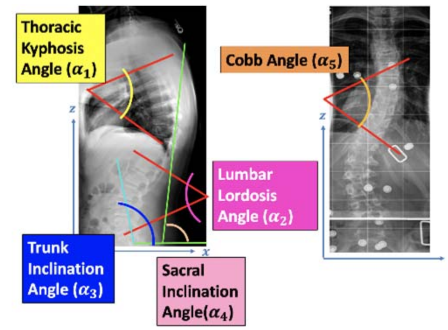
Possible approach

First visit of a patient (x-ray image)

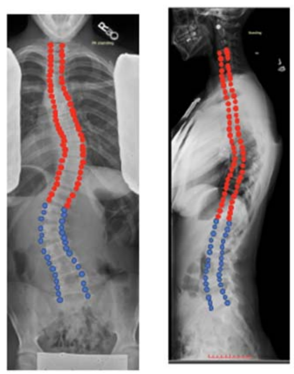
Extract model features

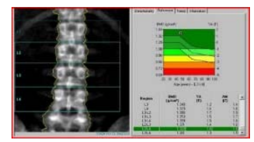
Age
Co-ordinates
Spinal Angle
Stress
BMD



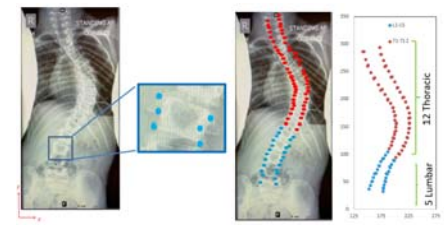
Spinal Angles

Image segmentation



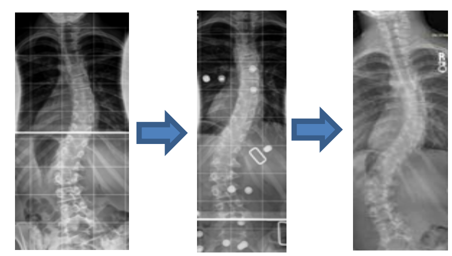


*BMD



Coordinates

Predict spine shape over years

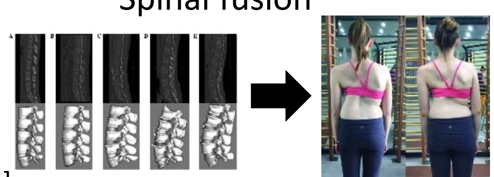


Age: t_1 months t_2 months t_3 months

Spinal fusion

Treatment plan

Surgery (Spinal Fusion)
Design Patient Specific Brace
Physical Therapy
Observation



[1]

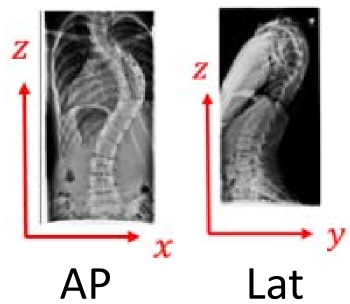
*Bone Mineral Density

[1] *Li, Xiao, Zhao. Experimental and Therapeutic Medicine. 2014.*

Prediction (A. pre-processing data)

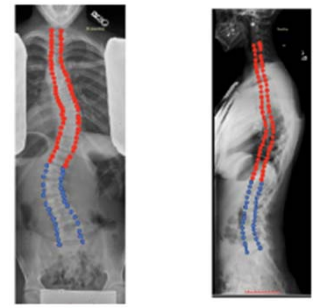
A.1. Document the data in Lurie

Document the patient’s spinal deformity type, gender, pre- and post-operated data



A.2. Xray data (2D images)

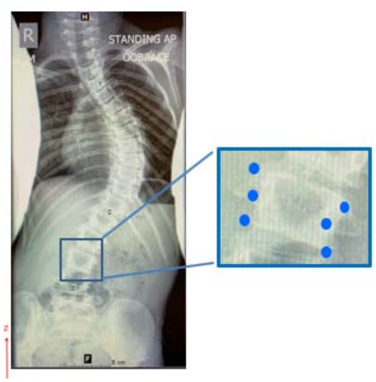
Get the anteroposterior (AP) and lateral (Lat) views of each individual patient



A.3. Image segmentation

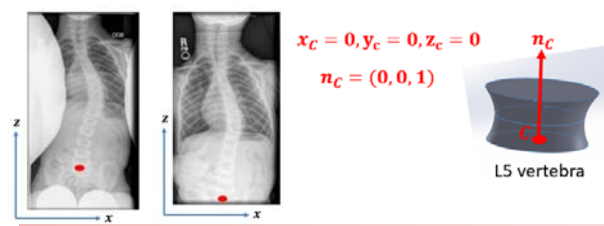
Segment the 2D images to distinguish the vertebrae

A.4. Assigning landmarks



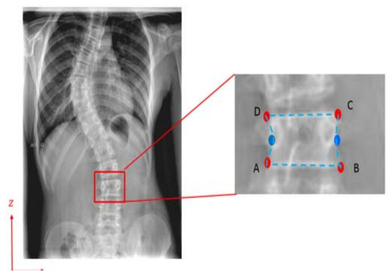
Assign six landmarks to each vertebra on each view to characterize the position of individual vertebrae

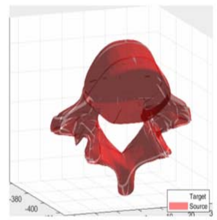
A.5. Unifying data



Perform rigid body transformation and rotations to make the bottom center point of L5 the reference

Prediction plan (B. detailed model and ROM)

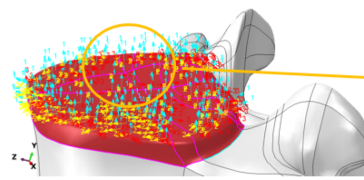




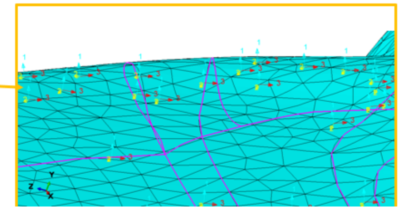
X-ray image → Landmarks of a vertebra → 3D vertebra generation

B.1. Register landmarks on the detailed vertebra STL file

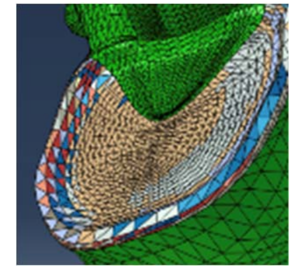
A detailed geometric model is generated based on the assigned landmarks



Surface elements



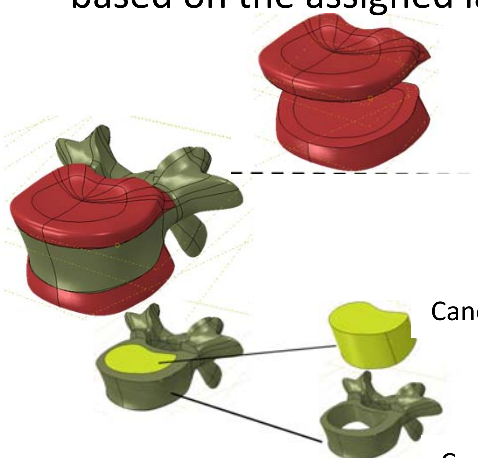
Discrete normal for each element



Clustered surface

Clusters based on the normal direction of the surface

B.2. Elements are clustered based on the normal direction to incorporate the growth

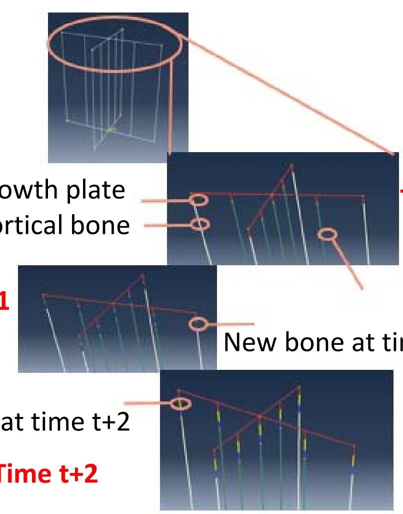


B.3. Generate ROM based on the detailed geometric model

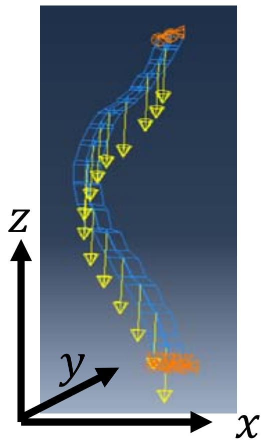
B.4. Dynamic ROM formulation to calculate

- ❑ Newly formed bone at each time step
- ❑ Growth bone
- ❑ Cortical and cancellous bone
- ❑ Clusters corresponding to the detailed model

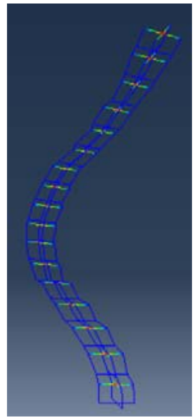
ROM



Prediction plan (C. calculating growth)



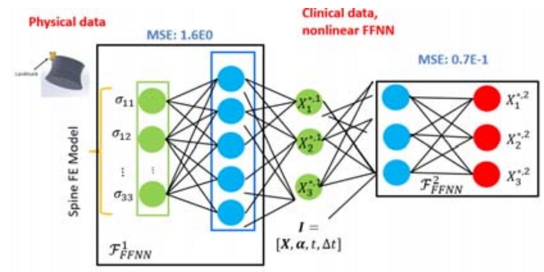
C.1. Apply BC and load



C.2. Capture stress on clusters in ROM

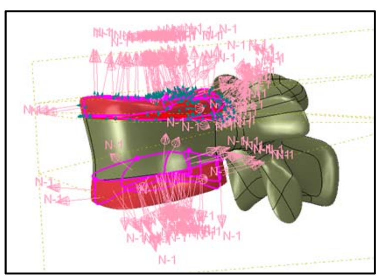
- Gravity Load at the center of each vertebra
- Bottom part is fixed at all translational degrees of freedom
- Top vertebrata is fixed in x and y

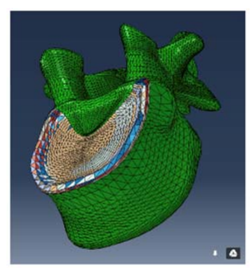
Stress from ROM is passed to the NN to predict the growth for each landmark



C.3. Input the stress to the NN

C.4. Calculate the growth with NN

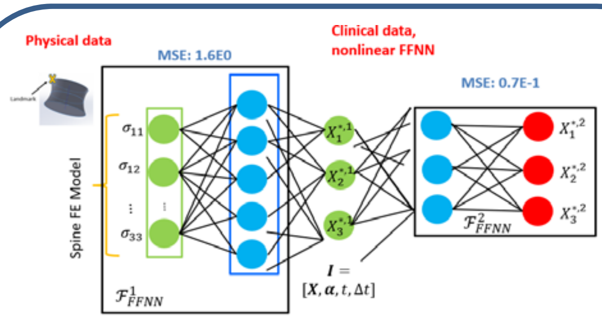




C.5. Update the cluster nodes based on the normal direction of the elements

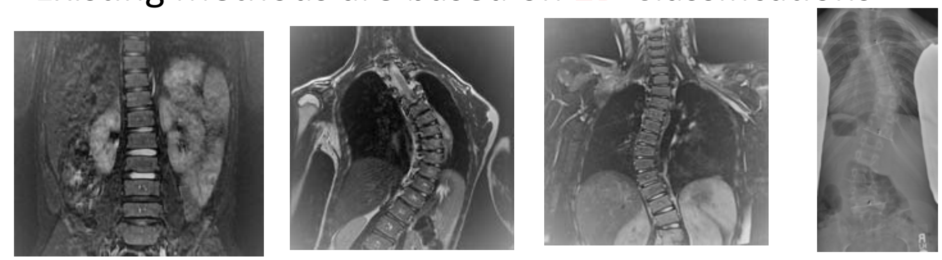
- Geometrically detailed model is updated based on the growth value proposed by the NN
- Cluster numbers are updated corresponding the new position of the elements

Treatment plan



Predict the curvature (from PGNN)

Existing Methods are based on **2D** Classifications



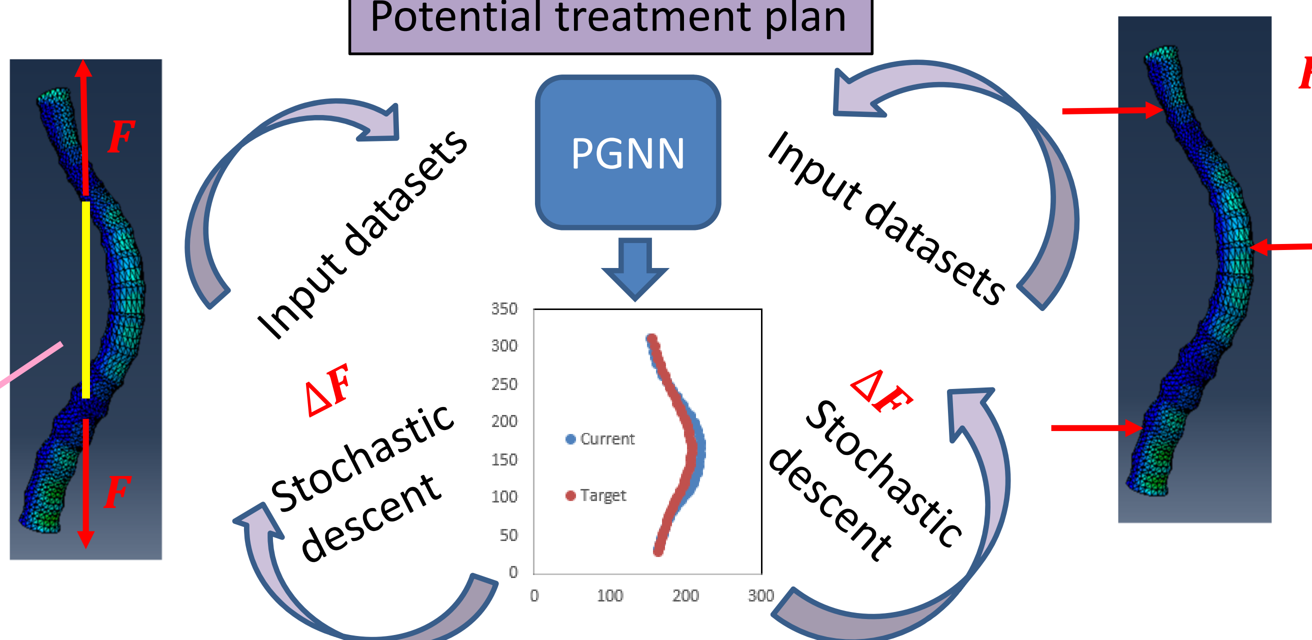
Lumbar | Thoracic | Double | thoracolumbar

Cluster the deformity type (**3D**)
Combination of lordosis, kyphosis and other deformities

Potential treatment plan

Spinal fusion (combination of selecting two vertebras)

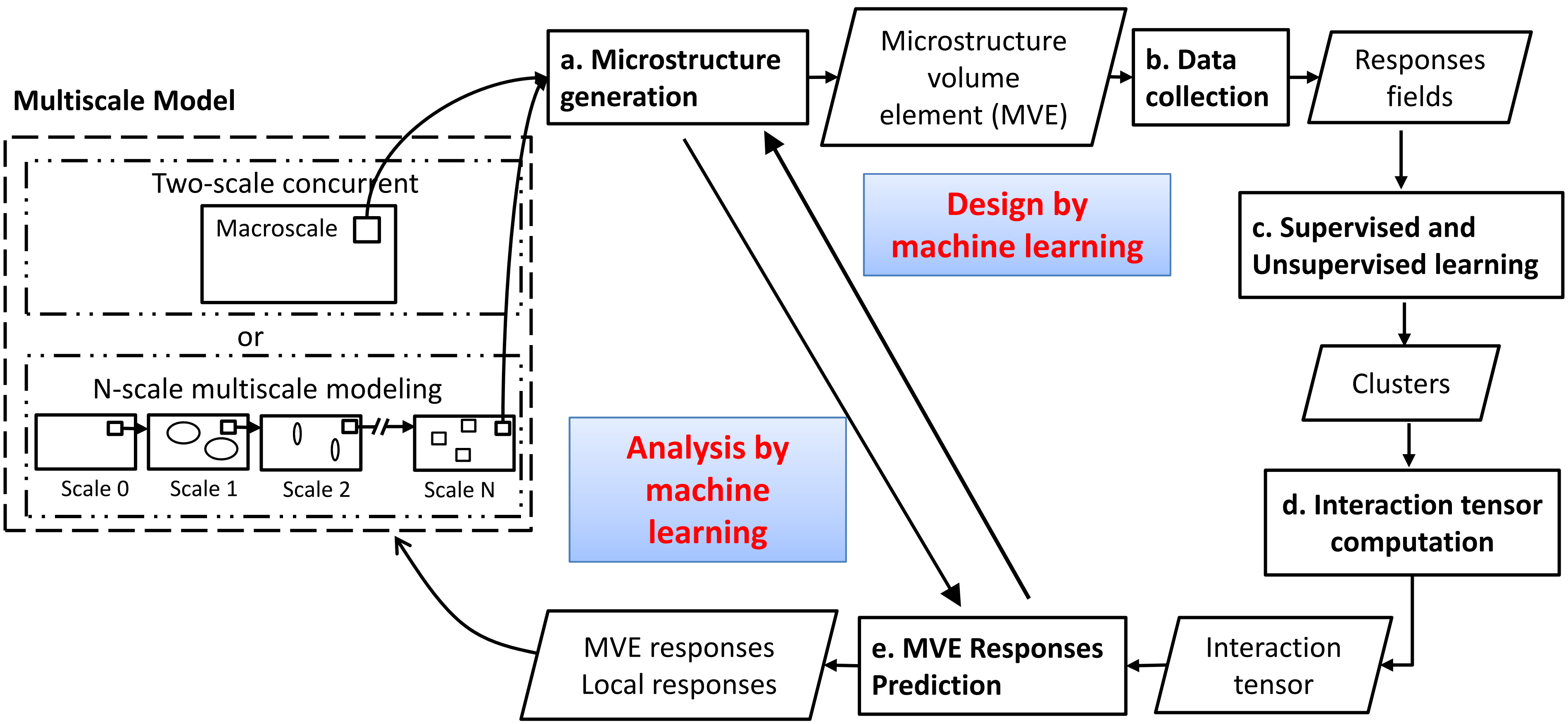
Correcting rod



Brace design by applying correction force

Mechanistic data-driven methods for engineering, mechanical science and mechanics of materials®

Objective: a specific method and system to aggregate dissimilar material geometry, properties, and interactions to predict combined properties and performance



Patent pending

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