Artificial Intelligence Data-driven Model for Adolescent Idiopathic Scoliosis: Analysis, Prediction and Treatment

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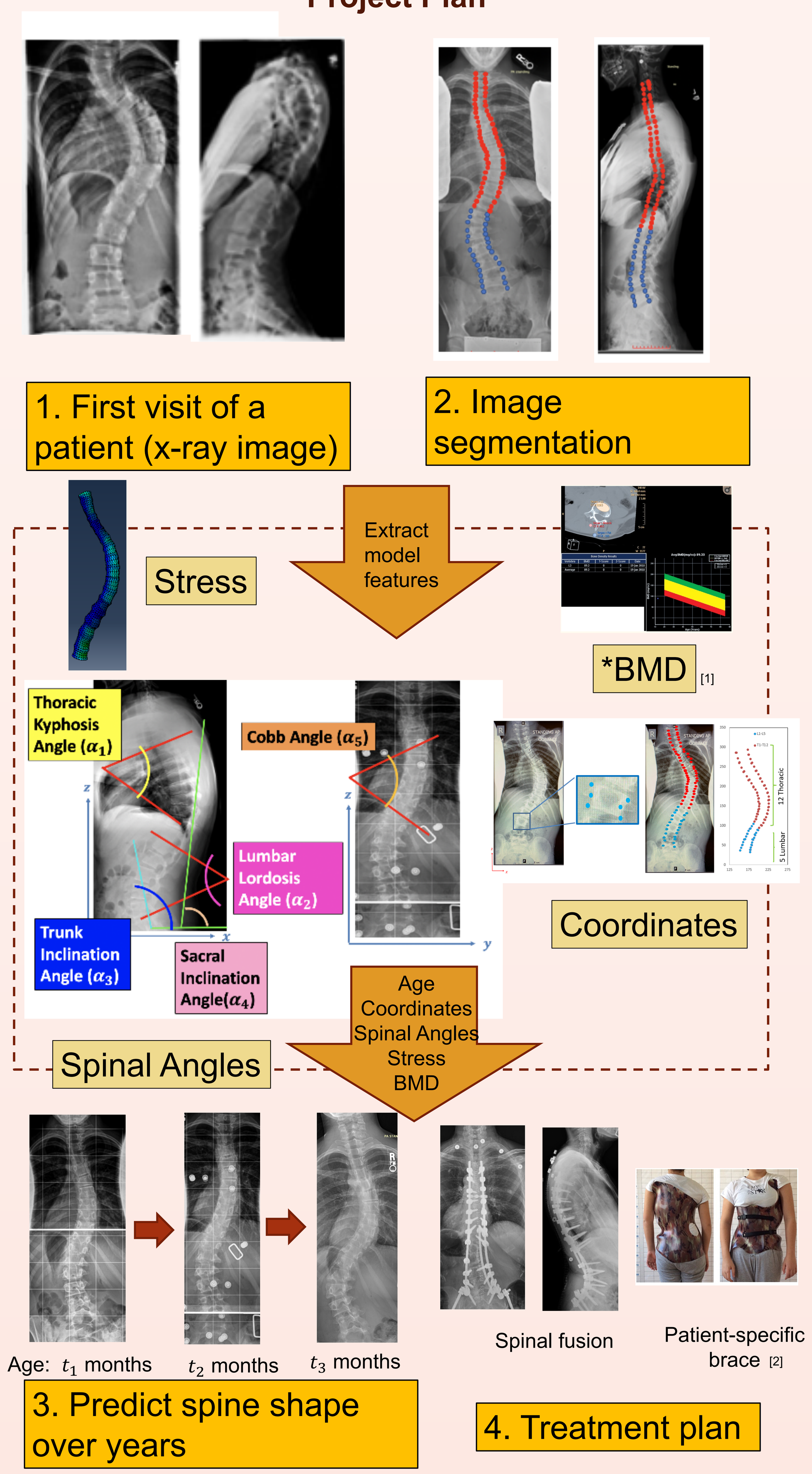
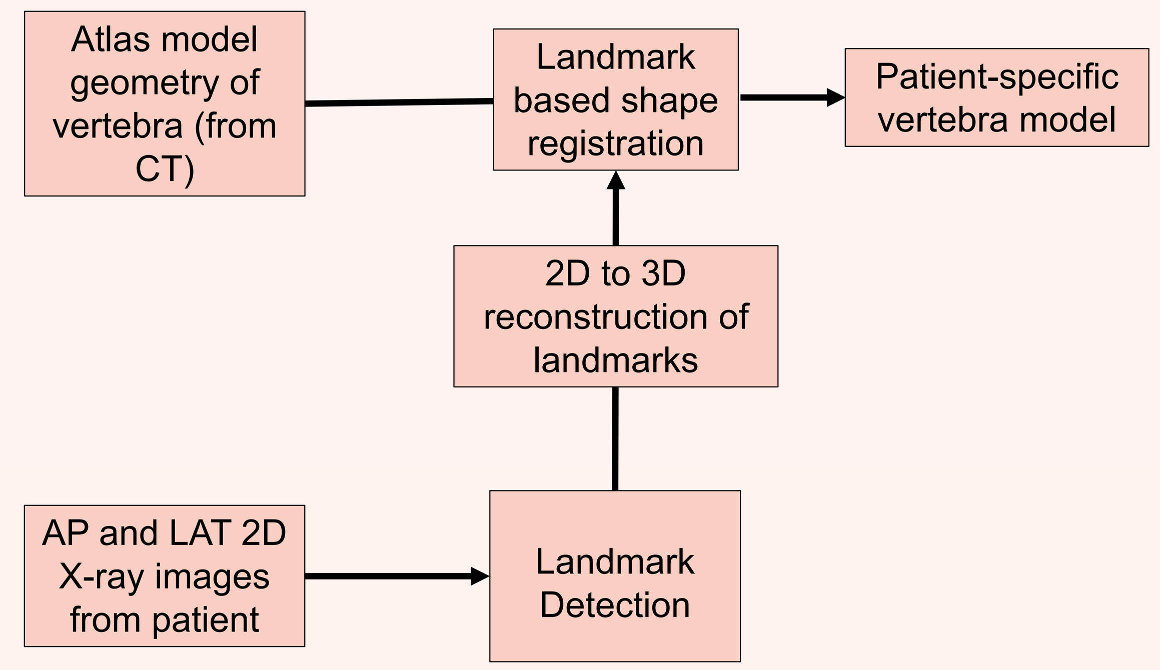
What is Scoliosis?

Scoliosis, 3D deformation of the human spinal column, is characterized by a lateral deviation of the spine, accompanied by axial rotation of the vertebrae. In this research, the primary focus is on **Adolescent Idiopathic Scoliosis** (**AIS**) which is the most common type of scoliosis affecting children mostly between ages 8 to 18 which bone growth is at its maximum rate. The treatment of scoliosis is highly dependent on the scoliosis curve. Currently, the selection of the most appropriate treatment option is based on the surgeon's experience. Therefore, developing a clinically validated, patient-specific, real-time predictive model of the spine will aid the surgeons in monitoring curve progression and proposing efficient methods of treatment for individual patients.

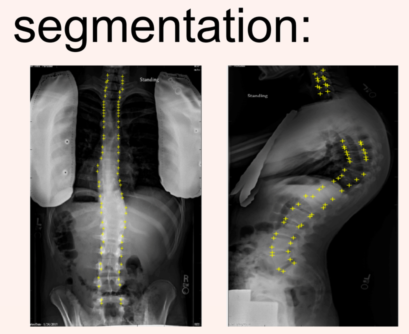
Project Plan



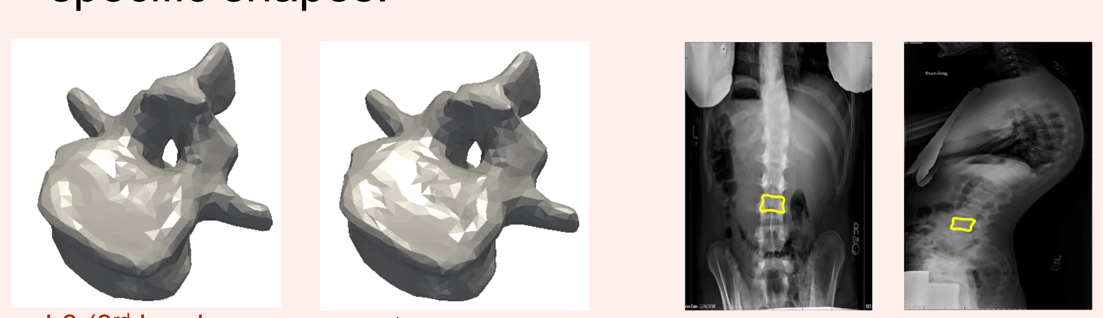
Task1: Automatic framework for the reconstruction of patient-specific spine geometry from medical images including X-ray and MRI



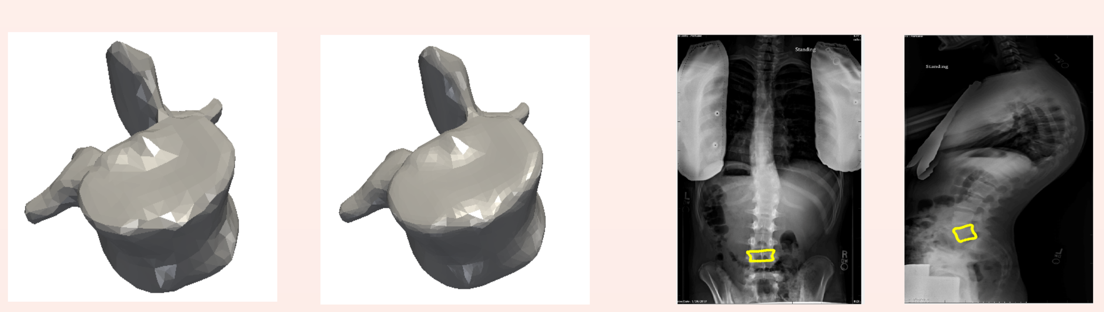
- Landmark detection from 2D anteroposterior (AP) and lateral (LAT) X-rays using novel B-spline based image segmentation:



- The landmarks are reconstructed in 3D space and integrated into the landmark-based deformable registration framework. Higher order B-splines are used to evaluate the deformation field and will be robust towards large variations in the patient-specific shapes.



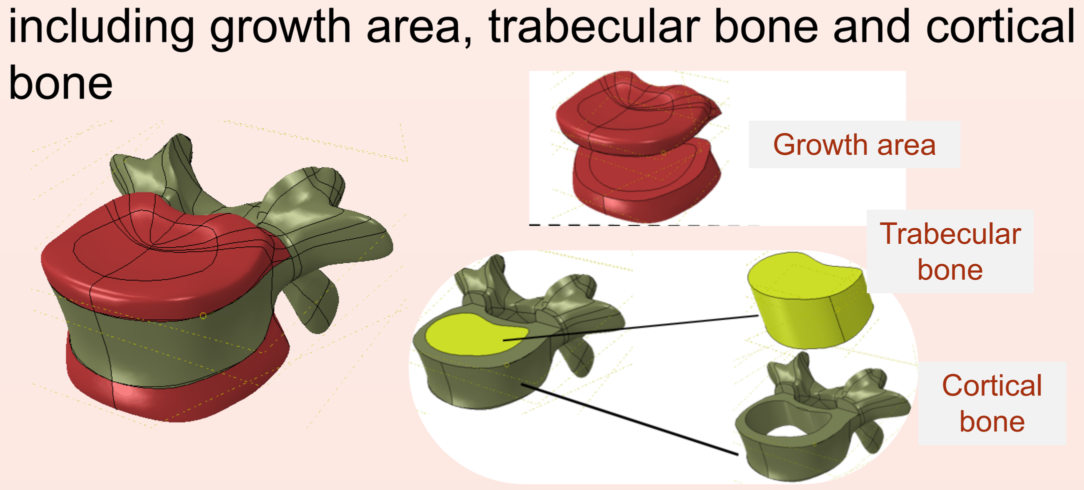
L3 (3rd Lumbar Vertebra) source mesh | L3 (3rd Lumbar Vertebra) mesh after registration | The contours of the registered L3 mesh overlaid on the patient X-rays



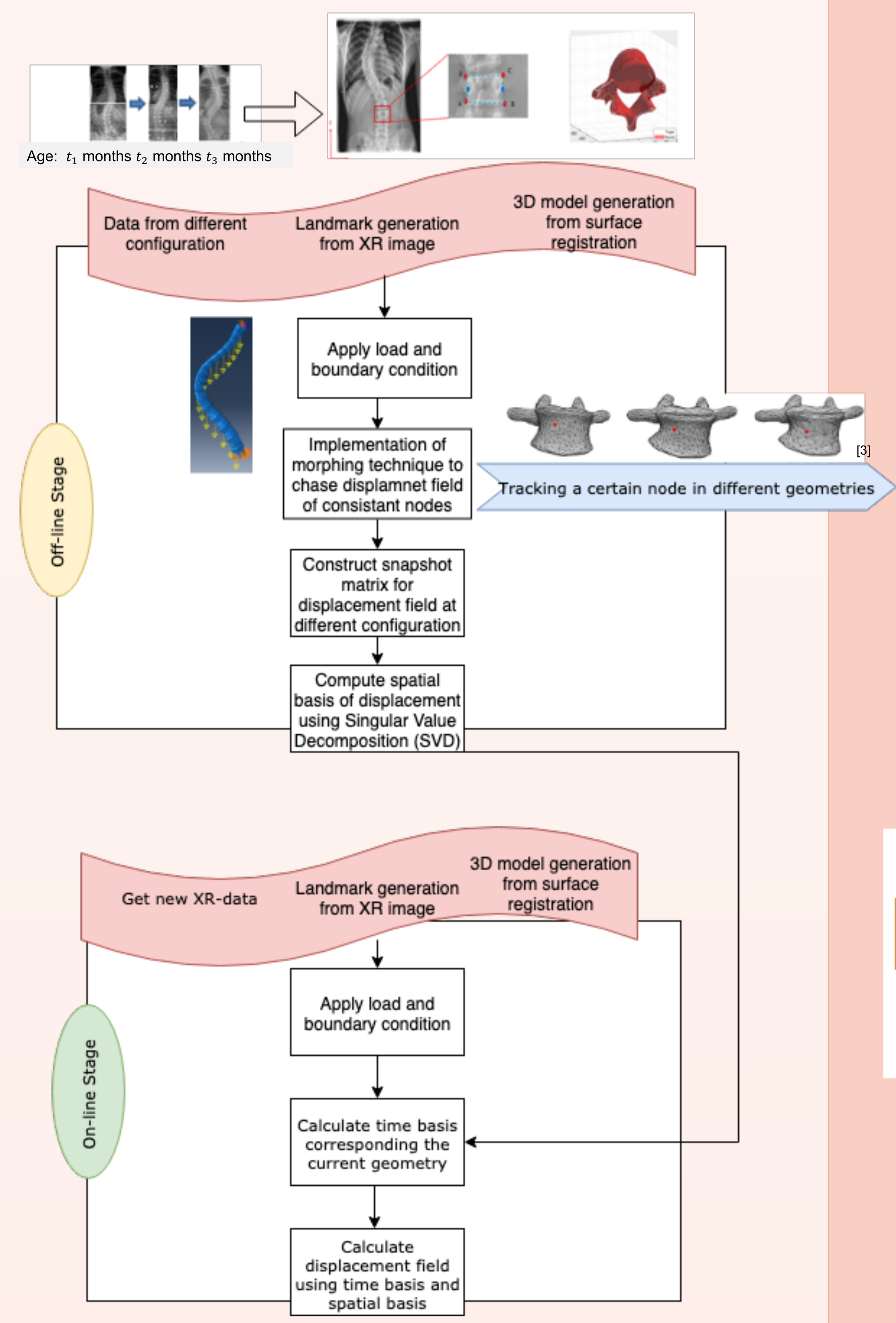
L4 (4th Lumbar Vertebra) source mesh | L4 (4th Lumbar Vertebra) mesh after registration | The contours of the registered L4 mesh overlaid on the patient X-rays

TASK 2: Developing a clinically validated patient-specific Reduced-Order Finite Element Model (ROFEM) of the spine

Generating the detailed geometry of the vertebrae, including growth area, trabecular bone and cortical bone



Developing the ROFEM using XR** data



TASK 3: Predicting the spine curvature using data mining methods

The third task is a physical guided finite-element neural network for predicting the spine curvature. Physical guided neural network (PGNN) is a neural network trying to solve problem with physical equations.

Model features

Features	Data points					
	1	2	3	.	.	Ns
X						
σ	.	.	.	.	.	.
α	.	.	.	.	.	.
t	.	.	.	.	.	.
Δt						
X*						
BMD						

Dimension of the data

X = Vector of input coordinates of a landmark [x1 x2 x3].

σ = Stress vector

[σ11 σ22 σ33 σ12 σ23 σ31].

α = Global angel vector

[α1 α2 α3 α4 α5].

t = Age of the patient.

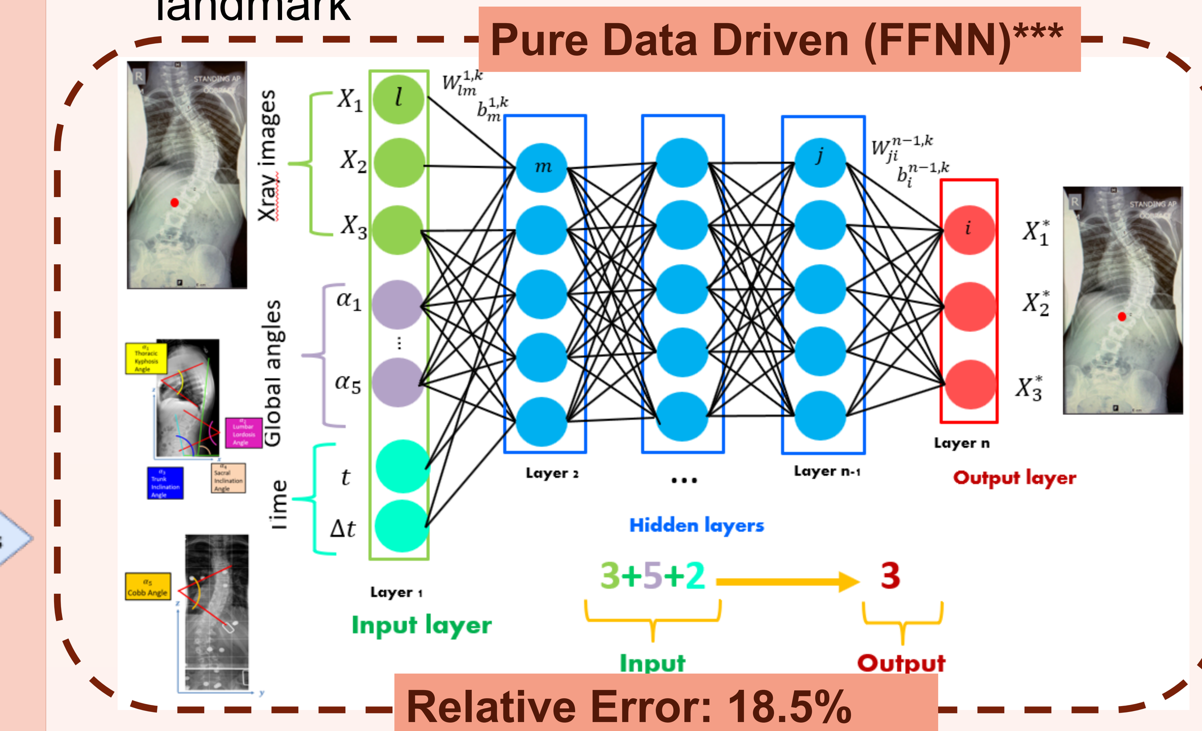
Δt = age variance between target age and current age (month).

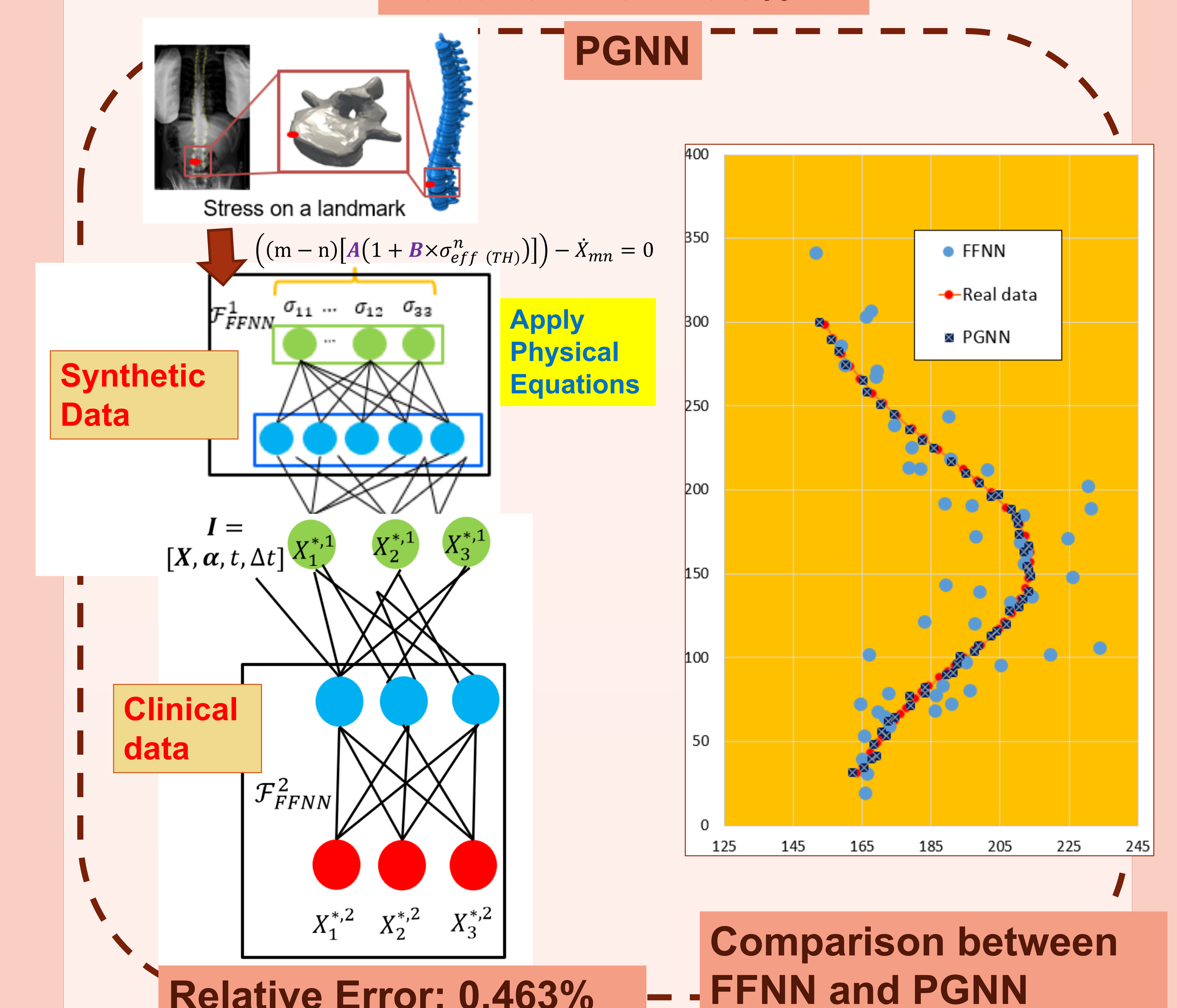
X* = Vector of output co-ordinates of a landmark $[x_1^* \ x_2^* \ x_3^*]$.

Ns= Total number of landmarks

Prediction

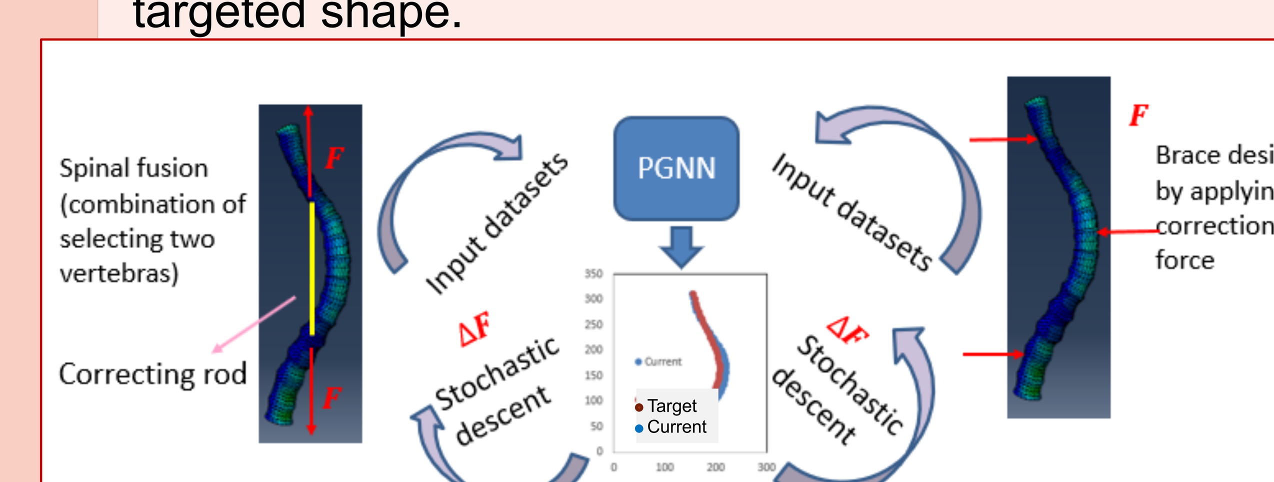
- Goal: predict the spinal curvature over years
- Training the NN to predict the position of each landmark





TASK 4: Proposing patient specific method of treatment

A patient-specific treatment therapy could be designed to target affected area and modify spine deformities. The model features will be transferred ROFEM solver. An initial treatment force will be applied as an initial guess. After several iterations, the spine curvature will be moved closer to the targeted shape.



References

[1] Sarioglu, Orkun, et al. "Evaluation of vertebral bone mineral density in scoliosis by using quantitative computed tomography." *Polish journal of radiology* 84 (2019): e131.
[2] Karavidas, Nikos. "Bracing In The Treatment Of Adolescent Idiopathic Scoliosis: Evidence To Date." *Adolescent Health, Medicine and Therapeutics* 10 (2019): 153.
[2] Galbusera, Fabio, et al. "Planning the surgical correction of spinal deformities: toward the identification of the biomechanical principles by means of numerical simulation." Frontiers in bioengineering and biotechnology 3 (2015): 178.

*Bone Mineral Density **X-ray *** Feed Forward Neural Network