## DEMAND
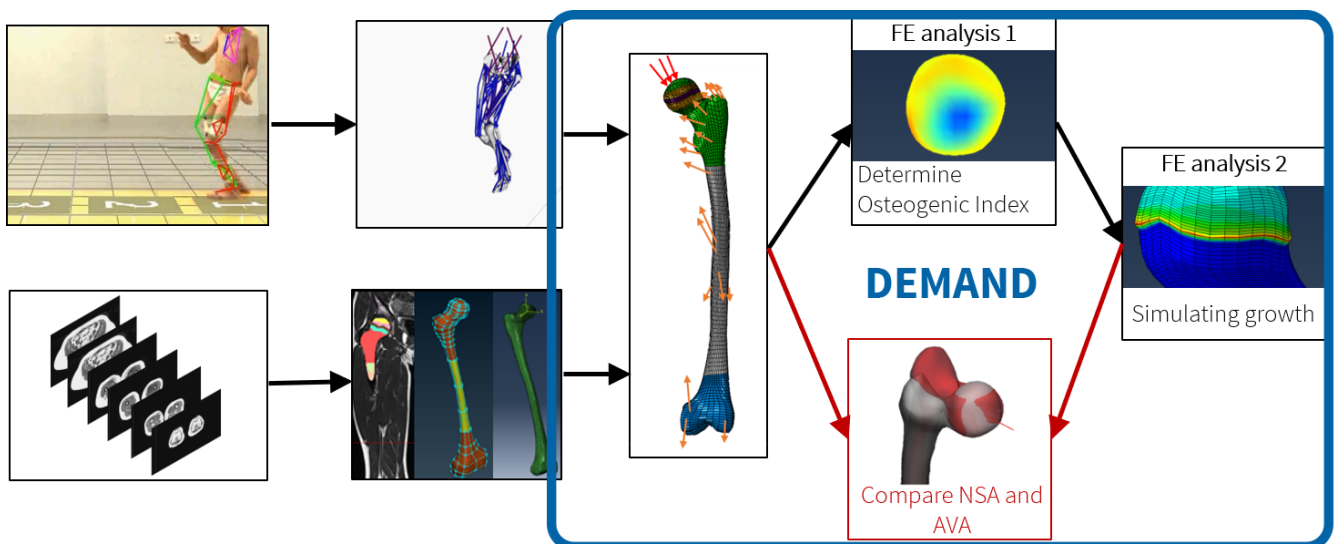
vali**D**at**E** a **M**odel to **A**void bo**N**y **D**eformities

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# What is DEMAND?

**DEMAND**, is an acronym for the main goal of this project which is to "vali**D**at**E** a **M**odel to **A**void bo**N**y **D**eformities".

It is a toolbox which allows to perform femoral growth simulations based on a mechanobiological model (Carriero et al., 2011; Kainz et al., 2020; Shefelbine and Carter, 2004; Yadav et al., 2017, 2016).

This mechanobiological model used to be challenging and very time-consuming because hexahedral elements are required within the growth plate.

DEMAND-Toolbox enables the setup of meshes from STL files easily and create finite element models with forces from musculoskeletal simulations automatically. Femoral growth predictions can be performed with many different parameters (loading only in single directions, changes of material properties, different growth direction, ...)

The goal of this toolbox is to allow many researchers to perform the multi-scale mechanobiological model with personalized femoral geometry in an easy and comprehensive way. It also helps to improve comparability between future studies.

DEMAND-Toolbox is solely based on freely available software (for research purposes).

- General handling of the femoral geometry is done with parts of the STAPLE-Toolbox - Modenese and Renault, 2021
- Base Meshing is done with Coreform Cubit
- Mesh refinement is done with MeshLab - Cignoni et al., 2008
- Finite Element Analysis are run with FEBio - Maas et al., 2012
- Application built with MATLAB App Designer

This repository also contains **example data for one participant including MRI data and 2 different loadings** (generic gait2392 model and personalized model with specific anteversion- and neck-shaft-angle of the participant).

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## Getting Started

Before you can run analysis follow the steps below carefully to avoid any problems.

1. **Install the DEMAND program by running the DEMAND_Installer.exe**
2. Run program and select a working directory, which will contain all data from now on.
3. Make sure that you have **writing permissions on the installation folder!**
4. **Install python** (recommended version = 3.10.4 - download here)
5. **Install pymeshlab**: open CMD and run this:

   ```
   py -m pip install pymeshlab
   ```

6. **Install Coreform Cubit**: It is free (up to 50k elements) for researchers! Create an account on the Coreform Website and download latest version here - Version 2022.4 was used for testing After installation run the program and be sure it is working
7. **Install FEBio**: It is free! Create an account on the FEBio Website and download latest version here - Version 3 (FEbio, not FEBio Studio) was used for testing
8. **Restart the DEMAND program to be sure paths are loaded correctly**
9. **Be sure to fill in everything in the General Settings Tab**
   - Select correct Cubit Installation Path, typically "C:\Program Files\Coreform Cubit 2022.4\bin"
   - Select correct FEBio path (to exe), typically "C:\Program Files\FEBioStudio\febio\febio.exe"
   - Click "Check all", **every lamp needs to be green!**

**Perfect, now you are ready to run some analyses!**

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## Usage

**Be sure that you set up everything correctly!** - see section above

### Femur Segmentation

This program uses STL files of a femur as input. We obtain them from magnetic resonance images which we segment using 3D Slicer. An example scene is given in the folder "example*data/MRI/Anonymous_L".

The STL files **have to** be in correct format, so please be sure that you have appropriate input data. The femur has to be split in several parts representing the different parts of the bone (**filenames have to contain the text in the brackets! L stands for left, if you have a right femur, it should be R...**)

- full femur (**L_femur.stl**)
- head (top part above the growth plate) (**L_head.stl**)
- growth plate (**L_growthplate.stl**)
- proximal trabecular (**L_prox.stl and L_prox_2.stl**)
- cortical bone (**L_cortical.stl and L_cortical_2.stl**)
- bone marrow (**L_marrow.stl**)
- distal trabecular (**L_dist.stl and L_dist_2.stl**)

Some parts have to be split in two parts (because of the 50k element limit in Coreform Cubit Education license)

The segmented femur should like something like this



## Loading from Muskuloskeletal Simulations

To do

## Run analysis

Please follow the steps in the program itself, but basically the steps are the following:

1. set up a proband (femur) some geometry features will be calculated in this step and everything is prepared to create meshes for this geometry.
2. create a hexahedral mesh
3. set up an analysis by defining material properties and loading condition
4. run analysis
5. check results (osteogenic index, growth, max. deflection during loading, ...) of the analysis in the program or load the data in MATLAB
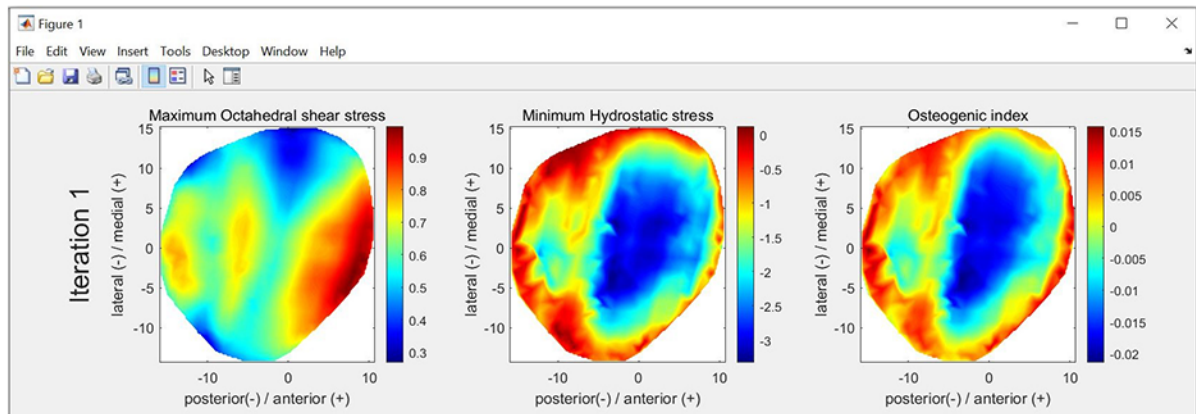
## Roadmap

The toolbox will be maintained regularly, new features will be added continously. Below list of features is not complete and also not in the order of planned implementation. If you request any other features get in contact with me.

- ☐ Re-check Abaqus Growth models
- ☐ Validate Growth Methods (FNDD, PSD, NORM) --> we are currently conducting a longitudinal study about femoral bone growth.
- ☐ Improve plots

## Contributing

Contributions are what make the open source community such an amazing place to learn, inspire, and create. Any contributions you make are **greatly appreciated**.

If you have a suggestion that would make this better, please fork the repo and create a pull request. You can also simply open an issue with the tag "enhancement". Don't forget to give the project a star! Thanks again!

1. Fork the Project
2. Create your Feature Branch (`git checkout -b feature/AmazingFeature`)
3. Commit your Changes (`git commit -m 'Add some AmazingFeature'`)
4. Push to the Branch (`git push origin feature/AmazingFeature`)
5. Open a Pull Request

## License

## Contact

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Project Link: https://github.com/willikoller/demand