Machine learning and deep learning approaches to model *in vitro* inflammatory responses of nanofibers scaffolds in tissue engineering

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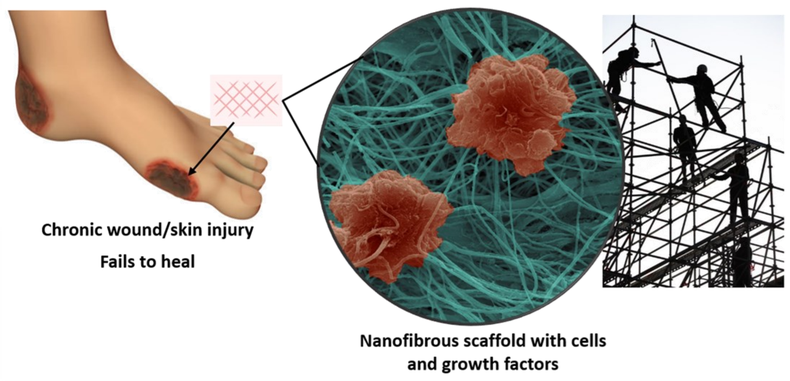
1. Context



50's Birth of AI

80's – 90's Interest of **AI techniques** in different clinical settings in **healthcare**

2010's Rise of AI in **healthcare applications**

70's 1st generation of scaffolds – **Bioinert**

80's 2nd generation – **Degradable**

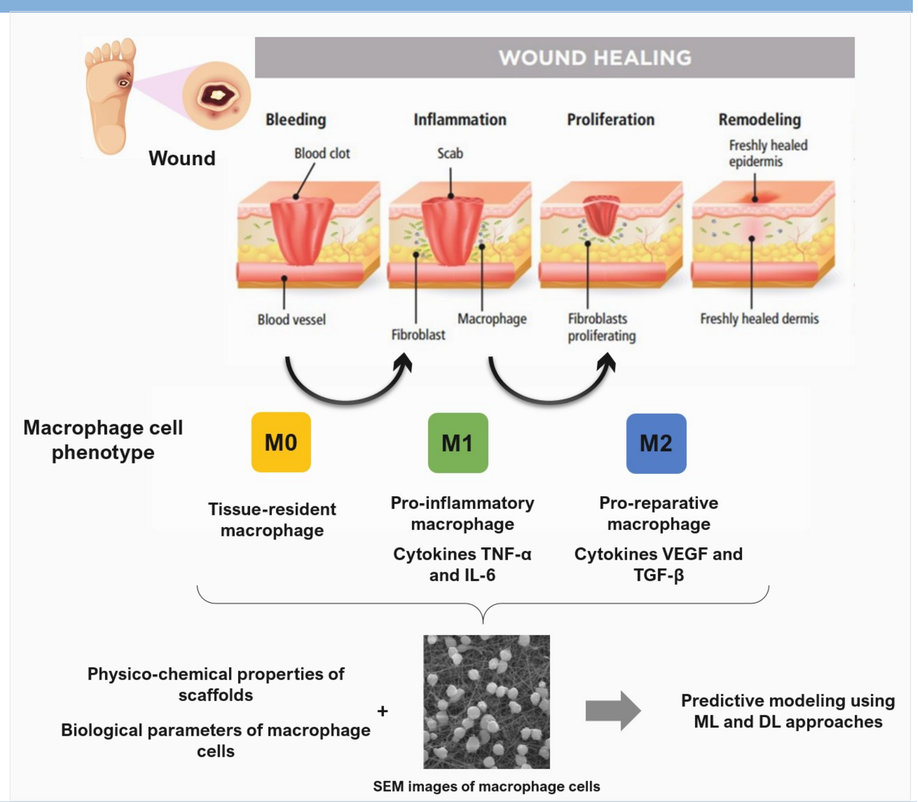
90's 3rd generation – **Bioactive**

00's 4th generation – **Encapsulate genes, cells and molecules**

2010's 5th generation – **Stimuli responsive**

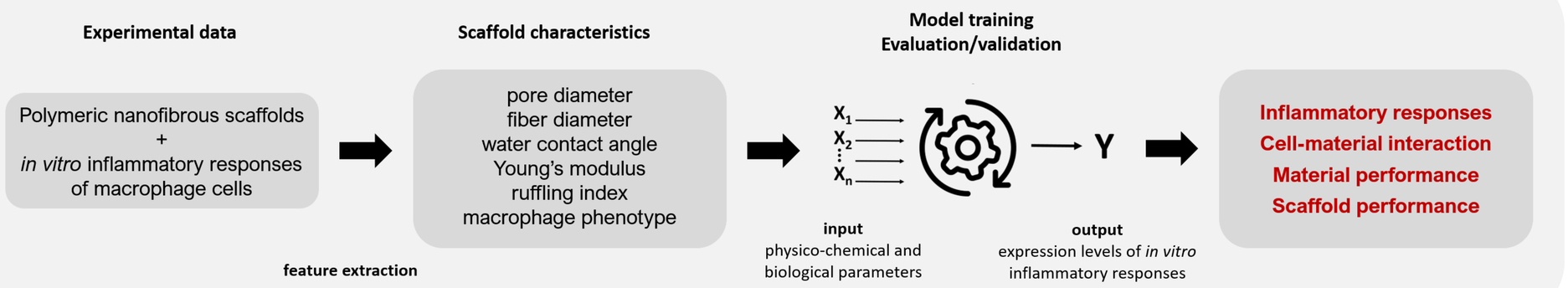
Today's challenge:

- In-depth understanding of **polymer-polymer interactions** and **cell-material interactions** on scaffolds for tissue regeneration
- Guide scaffold **design and performance**
- **Sustainable research process**

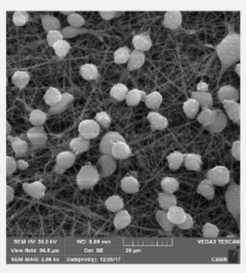


2. Machine learning workflow

- 159 observations from 12 families of scaffolds
- Supervised learning regression algorithms
- Python scikit-learn
- Simplified predictive model
- 80% training data and 20% testing



3. Macrophage Scanning Electron Microscope (SEM) image processing

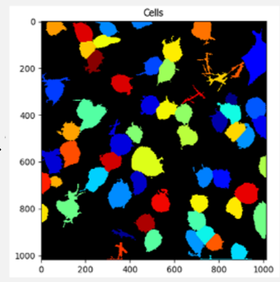


Original SEM image

Image processing modules

Correction modules for illumination and filtering

Object identification modules



Identified object (cells)

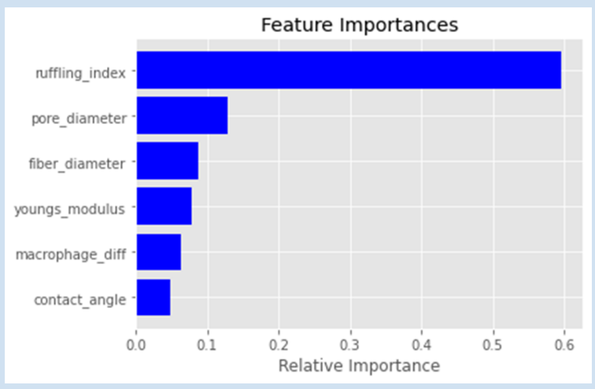
Single-cell measurement modules

- cell area/size
- cell count per image
- cell shape
- perimeter
- intensity
- texture

- Dataset of 41 SEM macrophage images
- CellProfiler image analysis software
- Modified pipeline of human HT29 cell images analysis
- Identify and quantify cell phenotypes
- Cell measurement data exportation for further analysis

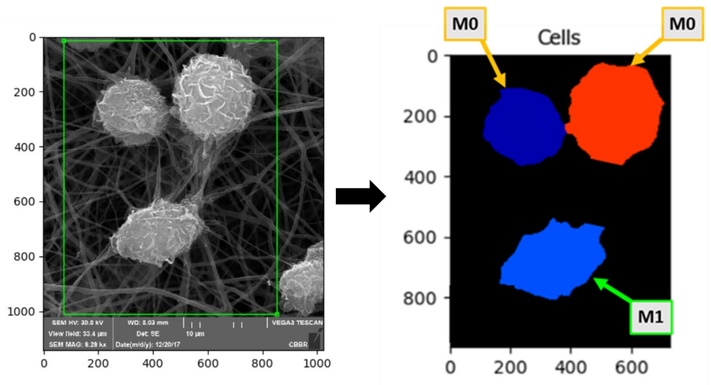
4. Preliminary results

Methods	Accuracy on training set (%)	Accuracy on testing set (%)	MAPE (%)
Linear regression	66.4	59.7	36.9
Support vector regression	72.1	64.1	31.9
Lasso regression	63.9	58.2	38.9
Ridge regression	67.7	62.5	34.9
Random forest regression	**92.8**	**89.3**	**8.9**
Decision tree regression	90.2	87.1	11.3
K-nearest neighbor	85.6	78.9	17.7



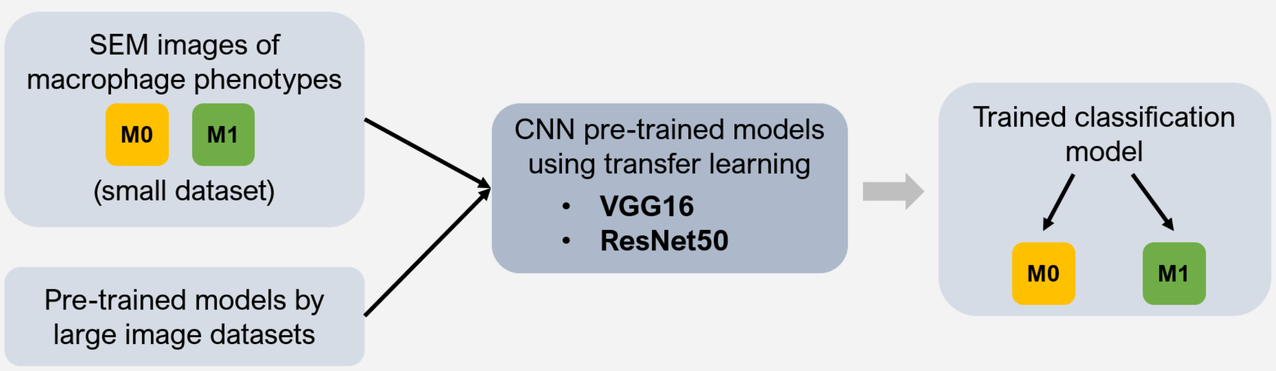
After hyperparameter tuning, **random forest regression** yielded the highest accuracy of **92.8%**. **Ruffling index, fiber diameter and pore diameter** were identified as the most relevant parameters influencing inflammatory responses. These results supported our previous findings (1,2). Preliminary results gave a better understanding of cell-material interactions and bring more evidence-based data to improve materials performance.

CellProfiler was found as an **effective tool** to process SEM macrophage cell images, detect and extract different type of features and measurements related to cell phenotypes. These measurements can be exported and used as phenotype indicators in future analysis to classify macrophage cells according to their phenotypes.



5. Preliminary Convolutional Neural Network (CNN) modeling

- Aim: assess the potential of applying CNN approaches to SEM image data to classify macrophage cells according to their phenotype
- Processing large amount of cell image data in a time efficient manner



References

1. Sujeeun, L. Y., Goonoo, N., Ramphul, H., Chummun, I., Gimié, F., Baichoo, S., Bhaw-Luximon, A. 2020. Correlating *in vitro* performance with physico-chemical characteristics of nanofibrous scaffolds for skin tissue engineering using supervised machine learning algorithms. *Royal Society Open Science*, *7*(12), 201293.

2. Sujeeun, L.Y., Goonoo, N., Moutou, M. M., Baichoo, S., Bhaw-Luximon, A., 2023. Predictive modeling as a tool to assess polymer-polymer and polymer-drug interactions for tissue engineering applications. Macromolecular Research, 31, 379–392,.

3. Sujeeun, L.Y., Goonoo, Chummun Phul, I., Baichoo, S., Bhaw-Luximon, A., 2023. Predictive inflammation phase of tissue regeneration nanofiber scaffolds using machine learning and deep learning approaches. (Submitted).