Machine Learning Approaches in Agile Manufacturing with Recycled Materials for Sustainability

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Aparna S. Varde[1] and Jianyu Liang[2]

1. Department of Computer Science; Clean Energy & Sustainability Analytics Center (CESAC); Montclair State University, NJ, USA
2. Mechanical and Materials Engineering, Worcester Polytechnic Institute, MA, USA

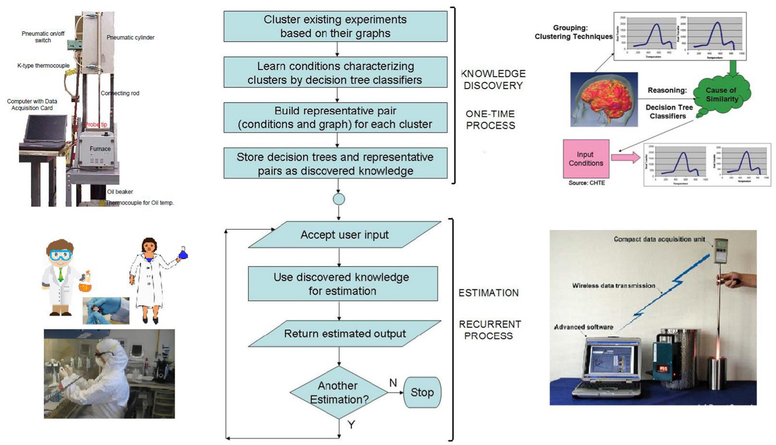
vardea@montclair.edu | jianyul@wpi.edu

Introduction

- Need to develop agile manufacturing techniques using **recycled & reclaimed metals**
- Safe & responsible way to turn a specific waste stream to value-added products, In line with **environmental sustainability**
- Investigate the role of AI: Developing **tools based on machine learning** to advance sustainable manufacturing

Earlier Work: AutoDomainMine

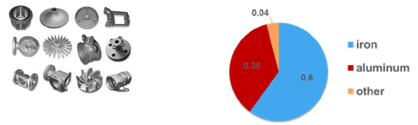
- Problem - Develop a computational estimation approach such that: (1) Given some or all of the input conditions of an experiment, display the most likely resulting graph. (2) Given desired graph in an experiment or ranges describing its features, determine the most appropriate input conditions to achieve it.
- Solution - AutoDomainMine: Automates a typical learning strategy of scientists via an integrated framework of data mining techniques (Varde et al. AAAI-2006).
- It obtains the desired levels of accuracy acceptable for targeted applications.
- Estimation needs far less time than lab experiments saving significant time & resources.
- Domain knowledge incorporated within AutoDomainMine & its sub-processes in order to make them more meaningful for computational estimation.
- Resulting tool AutoDomainMine found extremely useful (Varde et al. ACM SIGMOD 2007)
- Journal article authored based on its test-of-the-time success story due to numerous citations in CS & Materials Science, plus practical usefulness (Varde, ACM TKDD 2022).



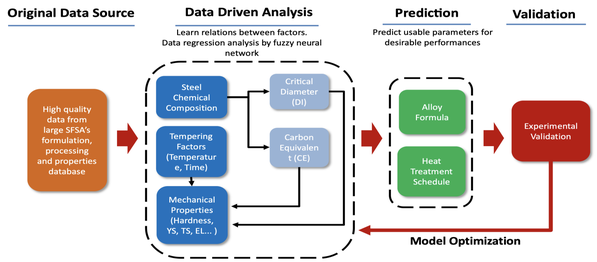
AutoDomainMine: Simulating learning strategies of scientists (Varde, ACM TKDD 2022)

Proposed Approaches

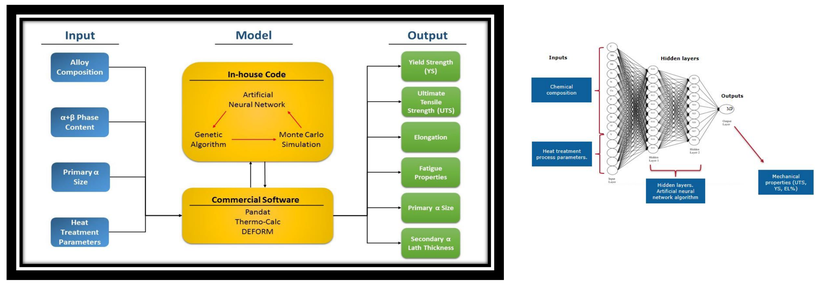
- Recommended breakdown of metal waste recipe at forward operating bases



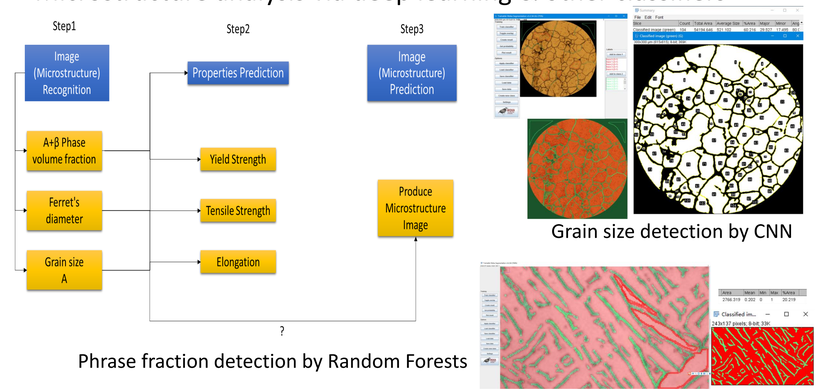
- Data-driven analysis method



- Modeling to optimize heat treatment parameters



- Microstructure analysis via deep learning & other classifiers

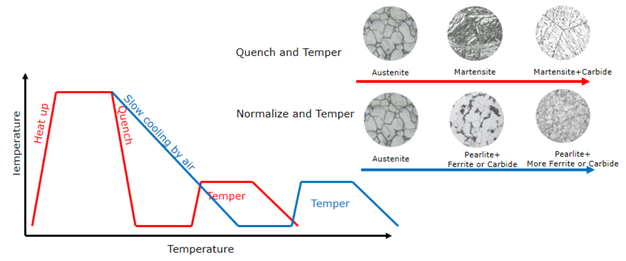


Phrase fraction detection by Random Forests

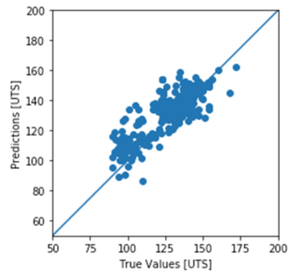
Grain size detection by CNN

Experimental Results

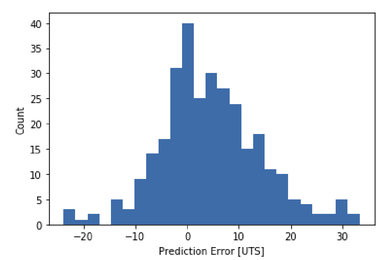
- Lab studies on microstructure development in Quench & Temper as well as Normalize & Temper are used for ANN experiments



- ANN prediction results e.g. ultimate tensile strength (quench temper)



True values vs. prediction (by chemical composition only)



Prediction Error vs. count: std. error of estimate: 9.81 ksi (kilo pounds per sq. inch)

Conclusions & Open Issues

- **Prior work** AutoDomainMine (AAAI, SIGMOD, TKDD), QuenchMiner (Varde et al. 2003 ASM HTS) etc. motivates this research
- **ANN results** give accuracy ~90%, high efficiency, low costs (lab experiment cost only), CNN & other classifiers are also very good.
- **Future challenges**: Explore computer vision models (VGG, ResNet etc.) for more accuracy, efficiency, robustness; Create tools using ML for decision support in agile manufacturing (like QuenchMiner in quenching); Assess impacts on sustainability with metrics based on use of recycled materials & effectiveness of developed products