Mathematical modeling for the aging of technical system

(Mathematical modeling for the aging of the technical systems: the necessity of machine learning)

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Introduction

- The process of aging is diverse and has an impact on every part of the system. It is very difficult to increase the effectiveness of operating technical systems without continuous monitoring of their condition and predicting the emergence of problems while in use.

- The change of properties in a system over a period of time affected by one or more influencing variables is known as aging.

- Aging phenomena is directly related to wear of material or failure of system which highly requires a method to predict the failure. For this requirement mathematical modelling is used to predict the age of any technical system.

- After modeling the aging system, its reliability is main factor which is to be define to execute the model to predict the aging. Hence reliability of these probability models plays an important role to predict the aging.

Introduction

- Aging Process of materials with their behavior
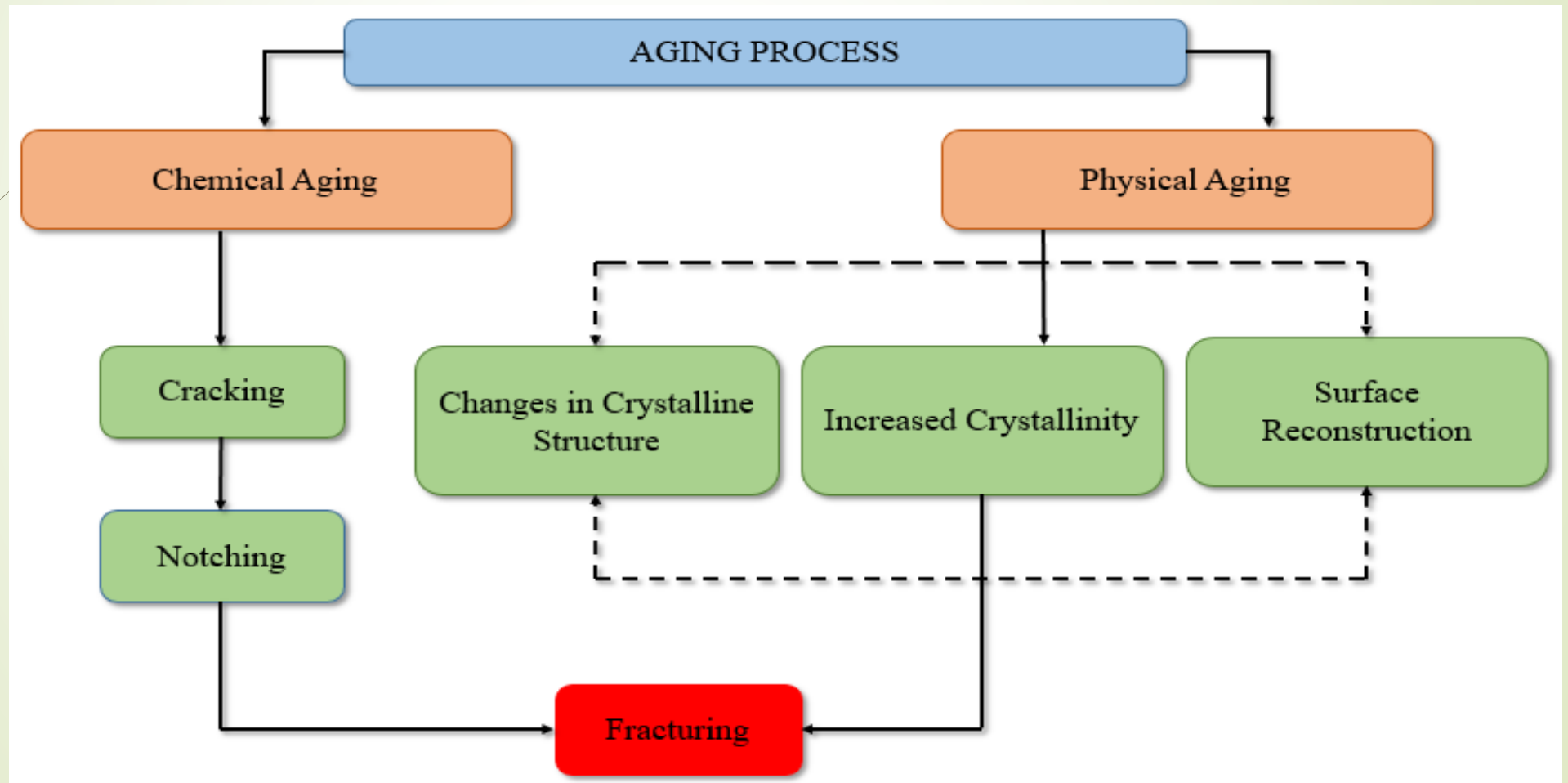
Introduction

- There are different factors involved in aging process, which are as followed:

  ❖ Thermal Aging

  ❖ Mechanical Aging

  ❖ Electrical Aging

- The following are the primary aspects of the basic prediction approach:

  ❖ Detecting the failure point of a technical system.

  ❖ Analyzing change in parameter and evaluating the technical system's performance.

  ❖ Determining a duration to breakdown estimation of a technical system.

  ❖ Establishing a prediction range.

Summary of Previous Work

- In the 2nd semester

  I published an article which is **"**AGING OF TECHNICAL SYSTEMS – LITERATURE REVIEW**"** in production engineering Journal.

- In this article, literature of aging of technical systems is studied briefly. I found 2 major topics. They are maintenance management and mathematical modelling.

- Based on this, their connections with other important key factors was briefly studied in the field of aging.

- In this review I comparatively discuses all the methods and their theories.

Summary of Previous Work

- In 3rd semester,

  I gave a direction to our previous work which is to make a mathematical model to define the aging by means of Markov process. Two main suggestions are given to calculate the reliability for the independent probability models, one is the recursive equation approach, and the other is the Markov chain approach.

- In this particular study I briefly presented all the Markov process and their application to find the aging of a technical system. Types and application of Markov process in according with today's research is presented in this paper. I made a base of Markov based model with the help of MATLAB. This Markov model is coded to illustrate the probability of aging states over time.

Summary of Previous Work

- In parallel, under the supervision of Prof. Tünde Kovács 2 subjects were studied. 1st is Impairment of structural materials and 2nd is Fracture mechanics.

- I studied about the fracture mechanism of different materials and their results based on their structure.

- I format this study to publish an article to show the aging of selected materials which is Aluminum alloy. I conducted aging test on Al-Mg-Si which is also known as 6082 Alloy.

- The aim of this study is to evaluate the aging of this particular aluminum alloy.

- "EXPERIMENTAL STUDY OF THE ALUMINIUM ALLOY AGING" – JOURNAL OF SCIENDO. 17 MARCH 2022. This paper is presented in 27th Young Engineers' International Scientific conference of young engineers.

Summary of Previous Work

- In the 4th semester,

    I studied 2 subjects. 1st is "Finite element modelling of materials technologies" with Prof. Dr. Viktor Gonda. In this subject Finite element analysis is briefly studied and with the help of Marc Mentat software simulation analysis is experimented.

- Second subject was "The impact of the Industry 4.0 to the manufacturing technology" with Prof. Dr. Balázs Mikó. In this subject maintenance strategies are studied and its implementation in Industry 4.0 is evaluated.

Summary of Previous Work

- In parallel, another conference paper is published at "Conference of Aeronautical Science 2022 Szolnok" in the editions of Aviation Scientific Publications 2022/1 and 2.

- "SIMULATION OF AGING OF AIRCRAFT" - JOURNAL OF AERONAUTICAL SCIENCE BULLETINS. 7 APRIL 2022.

- This paper is presented as "Simulation of aging of Aircraft". The aim of this study is to present a mathematical model which is used to predict the aging of aircraft system. I used Markov process theory to illustrate this aging process. As per the model, results and future work are determined and discussed briefly.

- After successfully completing the 2 years of doctorate and victoriously passing the complex exam, I completed all the subject credit requirement and now focusing on further requirements to defend the thesis.

Present Work

- Moreover, Differences in patterns of aging are crucial to understand the link among material aging, chemical aging, economical aging, and human health aging.

- If there are significant changes in the real-world system, the quality of the model suffers. This is a significant problem for modelers of technical systems.

- Rapid technological, economical, social, and political change has been a characteristic of modern times.

- Due to its multidisciplinary and its cross-field nature, we came across to a conclusion that by the use of mathematical modeling, it will be very inefficient to find the better prediction outcomes with high accuracy.
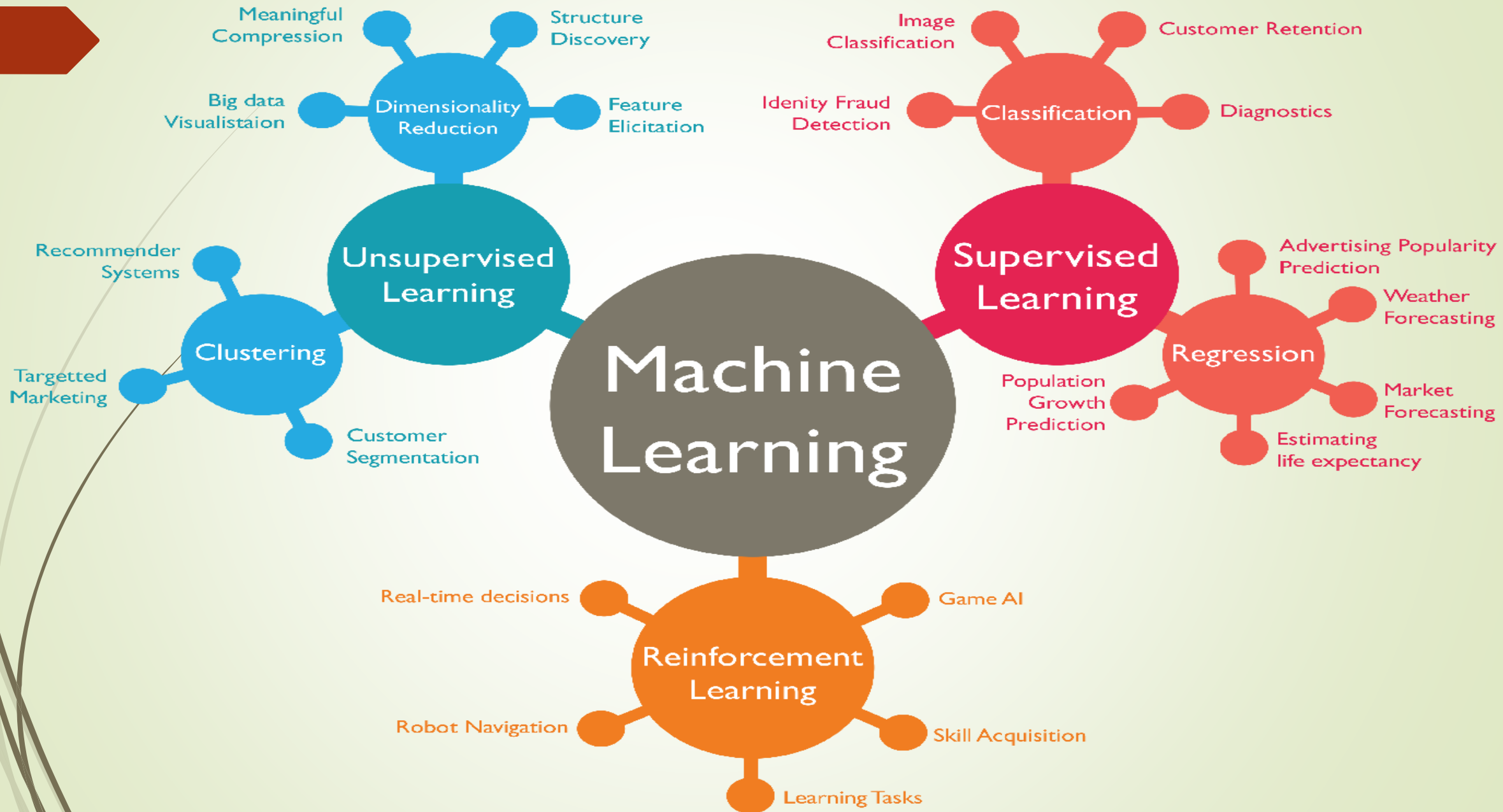
Present Work

- I found that, due to the complex nature of mathematical modeling is not sufficient to understand the true nature of problem, and mathematical modeling are not much efficient and reliable for modeling aging.

- We also know that, using modern techniques like, ML and artificial intelligence techniques is much more effective than using simple mathematical modeling.

- ML empowers insight and understanding into the large datasets to handle the complexity of aging, which helps to learn and understand variables better.

- This is why I chose to use machine learning methods to predict the aging under the guidance of my supervisor Dr. Amir Mosavi, which helps me to explore and understand the machine learning application.

Present Work

- In this recent (5th) semester,

  As per the suggestion of my supervisor, to improve the research area and increase the research possibilities with respective to present the better result, we added Machine learning and Artificial intelligence method in addition to Mathematical Modeling to predict the aging or to forecast the remaining service life of any technical system.

- We are working on 2 conference paper. These 2 conference papers will be presented in IEEE 17th International Symposium on Applied Computational Intelligence and Informatics (SACI-2023).

Present Work

- **Supervised learning algorithms** build a mathematical model of a set of data that contains both the inputs and the desired outputs.

- **Unsupervised learning algorithms** take a set of data that contains only inputs, and find structure in the data, like grouping or clustering of data points.

- **Semi-Supervised learning algorithms** lies between Supervised and Unsupervised machine learning. It represents the intermediate ground between Supervised (With Labelled training data) and Unsupervised learning (with no labelled training data).

- **Reinforcement learning algorithms** works on a feedback-based process, in which an AI agent (A software component) automatically explore its surrounding by hitting & trail, taking action, learning from experiences, and improving its performance.

Present Work

- In parallel,

   This modification in my research helps me to write these conference papers. In result, a conference paper is submitted which is "Machine Learning and Mathematical Models for Prediction of Structural Aging   Process" – SACI 2023.

- Apart from this, another conference paper is in process, which will describe "Machine learning" methods and use of AI to predict the remaining useful life of any technical system.

- The main purpose of this study is to present various control processes and methods to forecast operational conditions and system's breakdown, to be able to maximize the efficiency of technological systems.

Present Work

- Throughout the current research approach, the classification of the aging process and a description of its mathematical modeling are included as state-of-the-art of aging models, performance, and its evaluations.

- Whereas, in today's world, the adaptation and importance of different machine learning (ML) methods like deep learning (DL), decision trees (DT), conventional neural networks (CNN), support vector machines (SVM), regression analysis, and artificial neural networks (ANN) are described briefly which helps to increase the efficiency of modeling of aging process.

- The development of forecasting analysis by the use of ML techniques are offering excellent efficiency, economical solutions and significantly assisted to simplify the complicated mathematical equations describing physical phenomena of structural aging.

Future Frame Work

- Future directions for my research, that integrate; machine learning with efficient pre-processing methods to increase the forecast efficiency of technical system

- To get the required modeling results, we consider to work on a particular technical system i.e. Turbofan engine.

- To write a journal article, I received a dataset from a Swiss research group.

- For this we are working on degradation data set of turbofan engine. The work is still in process. Results and conclusion will be share after publication.

- The main aim will be able to find the engine degradation's starting point which is a crucial aspect in remaining useful life predictions.

Publication List: -

No.	Title	Journal	Status
1	Aging of Technical Systems : Literature Review - journal of production engineering (1821-4932): 24 1 pp. 69-74 (2021) doi.org/10.24867/JPE-2021-01-069	Production engineering Journal. Serbia	Published
2	M. Mudabbiruddin and L. Pokoradi, "Markovian Model of Ageing Processes - Core Model," pp. 000073–000076, 2022. doi:10.1109/SACI55618.2022.9919534.	IEEE 16th International Symposium on Applied Computational Intelligence and Informatics. SACI 2022	Published
3	M. Mudabbiruddin and T. A. Kovács, "Examination of Aging of alsi1mgmn Type Aluminium Alloy," vol. 17, pp. 50–54, 2022. doi: 10.33894/mtk-2022.17.11	27th Young Engineers' International Scientific conference of young engineers. Sciendo's Journal	Published
4	Simulation of aging of aircraft - Journal of aeronautical science bulletins. 7APRIL 2022.	Conference of Aeronautical Science 2022 Szolnok. Aviation Scientific Publications 2022/1	Published
5	Machine Learning and Mathematical Models for Prediction of Structural Aging Process	IEEE 17th International Symposium on Applied Computational Intelligence and Informatics. SACI 2023	Submitted
6	Machine Learning Methods and Application For The Aging Process and Remaining Service Life	IEEE 17th International Symposium on Applied Computational Intelligence and Informatics. SACI 2023	Under Preparation

Thank you.