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Replacing a cloud based computation tool on DrBoxOnline.com with faster running neural network

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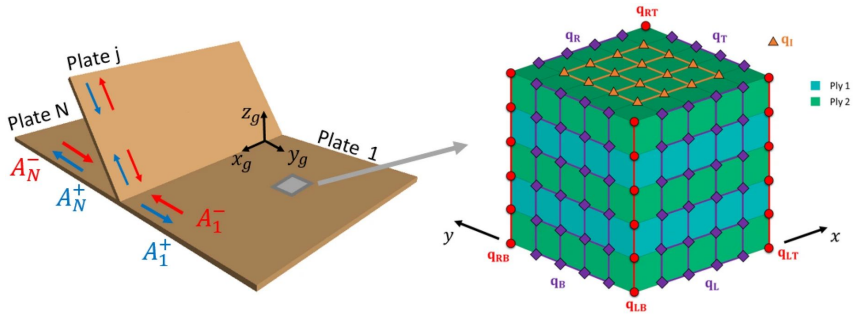
Problem Review: Predicting the Performance of Paper Boxes

Introduction

- **Corrugated Paper Boxes**: Widely used for packaging and logistics due to their lightweight, recyclable, and customizable properties.
- **Problem**: Prone to buckling during storage and shipment, causing:
  - Product damage
  - Lost revenue
  - Wasted resources
  - Customer complaints



Current Solution:

- **Dr. Box Calculator Pro**
  - a website providing users with an interface to predict the box's performance given certain information
  - Uses Finite Element Analysis (FEA) to predict buckling strength.
  - input dimensions, types and output force, deformation and failure of nodes in the meshes

Finite Element Analysis (FEA)

- **Definition**: A numerical method for predicting how a product reacts to real-world forces, vibrations, heat, and other physical effects.
- **Process**: Divides a complex problem into smaller, simpler parts (finite elements) and solves them.
- **Limitation**: Time-consuming and requires extensive computational resources.

Problem Review: Deep Neural Networks (DNN)

Proposed Solution

- **Deep Neural Networks (DNN)**: Replace FEA with DNN in Dr. Box Calculator Pro for faster and more efficient predictions.

Deep Neural Networks (DNN)

- **Definition**: A Deep Neural Network (DNN) is an artificial neural network with multiple layers between the input and output layers, allowing it to model complex non-linear relationships.
- **Advantages**:
  - **Feature Learning**: DNN automatically learn features from raw data, eliminating the need for manual feature extraction.
  - **Scalability**: DNNs can handle large-scale data and complex models, making them suitable for big data applications.
  - **End-to-End Learning**: DNN can learn directly from input to output, simplifying the pipeline by reducing the need for intermediate steps or separate models.

Benefits

- **Speed**: Instant predictions of buckling strength.
- **Efficiency**: Lower computational costs and faster analysis.
- **Scalability**: Capable of handling diverse box types and conditions.

Literature Review 1: Numerical and Experimental Analysis of Corrugated Cardboard Boxes [1]

Overview

- **Objective**: To predict the compression force of cardboard boxes considering various cutout configurations on the sidewalls.
- **Materials Used**: Single-wall B-flute corrugated cardboard with specific components for outer liner, fluting medium, and inner liner.

Methods

- **Experimental Setup**:
  - Conducted Box Compression Tests (BCT) under controlled humidity and temperature.
- **Numerical Model**:
  - Utilized Abaqus FEA software.
  - Modeled only 1/8 of the box to simplify the analysis.
  - Applied homogenized linear elastic orthotropic material models with Hill plasticity.
  - Conducted buckling analysis to determine the mode of global imperfections.
  - Use the above result in compression tests.

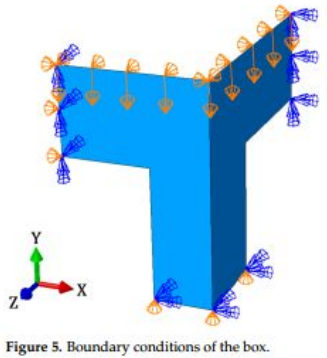


Figure 1. Boundary Conditions

Key Findings

- Achieved high accuracy in predicting compression force from BCT with variations for different cutout rates.
- Proved that numerical model can effectively replicate experimental results, though accuracy decreases slightly at higher cutout rates.

[1] Fehér, Lajos, et al. "Compressive Strength of Corrugated Paperboard Packages with Low and High Cutout Rates: Numerical Modelling and Experimental Validation." Materials, vol. 16, no. 6, 2023, p. 2360, https://doi.org/10.3390/ma16062360.

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Literature Review 1: Numerical and Experimental Analysis of Corrugated Cardboard Boxes

Innovative Integration

- **Combines ANN with FEA**: Utilizes neural networks to enhance the prediction of buckling strength, improving on traditional FEA limitations.

Advantages Over Traditional Methods

- **Increased Accuracy**: Integrating ANNs with FEA improves prediction precision over traditional methods, especially in complex scenarios with varied cutout rates and designs.
- **Faster Simulations**: ANNs expedite the analysis process, providing rapid evaluations and significantly reducing simulation times compared to conventional FEA.
- **Greater Flexibility**: Our hybrid approach adjusts effortlessly to different box materials and designs, enhancing adaptability and scalability in packaging solutions.

Future Prospects

- **Broad Application**: Suitable for diverse packaging needs, ensuring robust, efficient, and accurate design and analysis.
- **Cost-Effective**: Reduces the need for extensive physical prototyping, lowering development costs and accelerating production cycles.

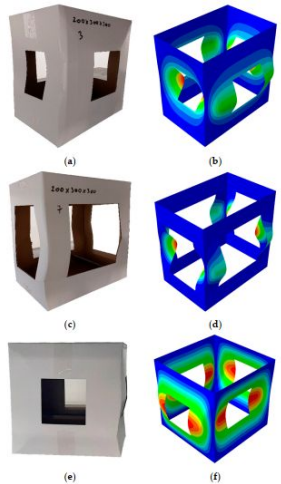

Figure 2. Numerical Analysis

[1] Fehér, Lajos, et al. "Compressive Strength of Corrugated Paperboard Packages with Low and High Cutout Rates: Numerical Modelling and Experimental Validation." Materials, vol. 16, no. 6, 2023, p. 2360, https://doi.org/10.3390/ma16062360.

Literature Review 2: Integration of artificial neural network with finite element analysis for residual stress prediction of direct metal deposition process [2]

Overview

- **Objective**: The primary objective is to develop a novel ANN-based modeling approach integrated with FE analysis to predict residual stresses in AISI 304 L parts created through the DMD process, enhancing prediction accuracy and computational efficiency.

Methods

- **FE Analysis**: focusing on the thermal and mechanical response of materials.
- **ANN Integration**: An ANN is trained using datasets generated from FE simulations to predict residual stresses. This model uses spatial coordinates and temperature history as inputs.
- **Model Testing**: validated by comparing against traditional FE analyses for different geometric structures.

Key Findings

- The integrated model significantly reduces computational time while maintaining high prediction accuracy for residual stress distributions in DMD fabricated parts.

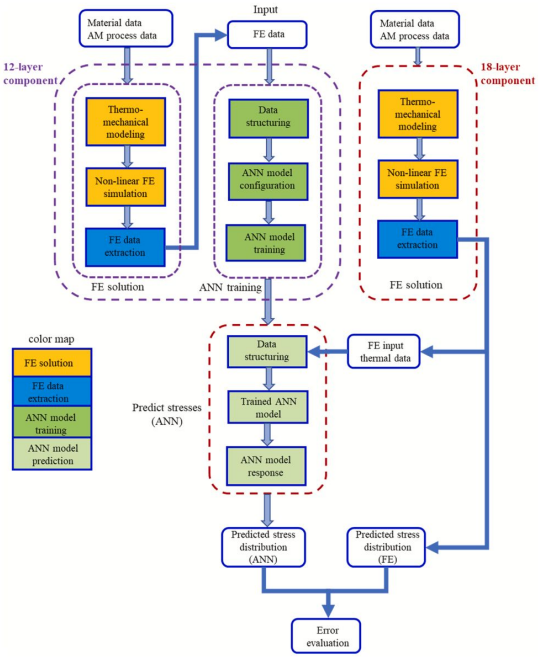

Fig. 7. Schematic algorithm of the novel approach of integrating ANN and FE analysis.

[2] Hajializadeh, F., and A. Ince. "Integration of Artificial Neural Network with Finite Element Analysis for Residual Stress Prediction of Direct Metal Deposition Process." *Materials Today Communications*, vol. 27, 2021, p. 102197, doi:10.1016/j.mtcomm.2021.102197.

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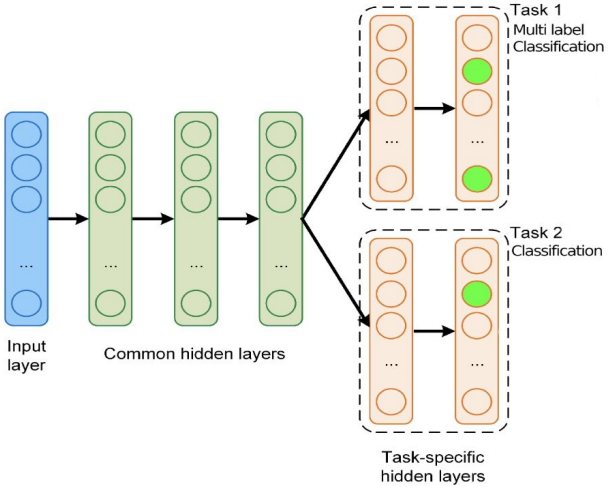
Literature Review 2: Integration of artificial neural network with finite element analysis for residual stress prediction of direct metal deposition process [2]

Innovative Integration

- **Multi-task labeling:** The output label includes categorical and numerical data
- **Increasing number of outputs:** Each xyz dimension has more 128 outputs to generate.

Future Prospects

- **Broad Application**: Suitable for future physical models with number of small inputs vs. large number of outputs for multi-task labeling prediction.
- **Cost-Effective**: Reduces the need for extensive physical prototyping, lowering development costs and accelerating production cycles.



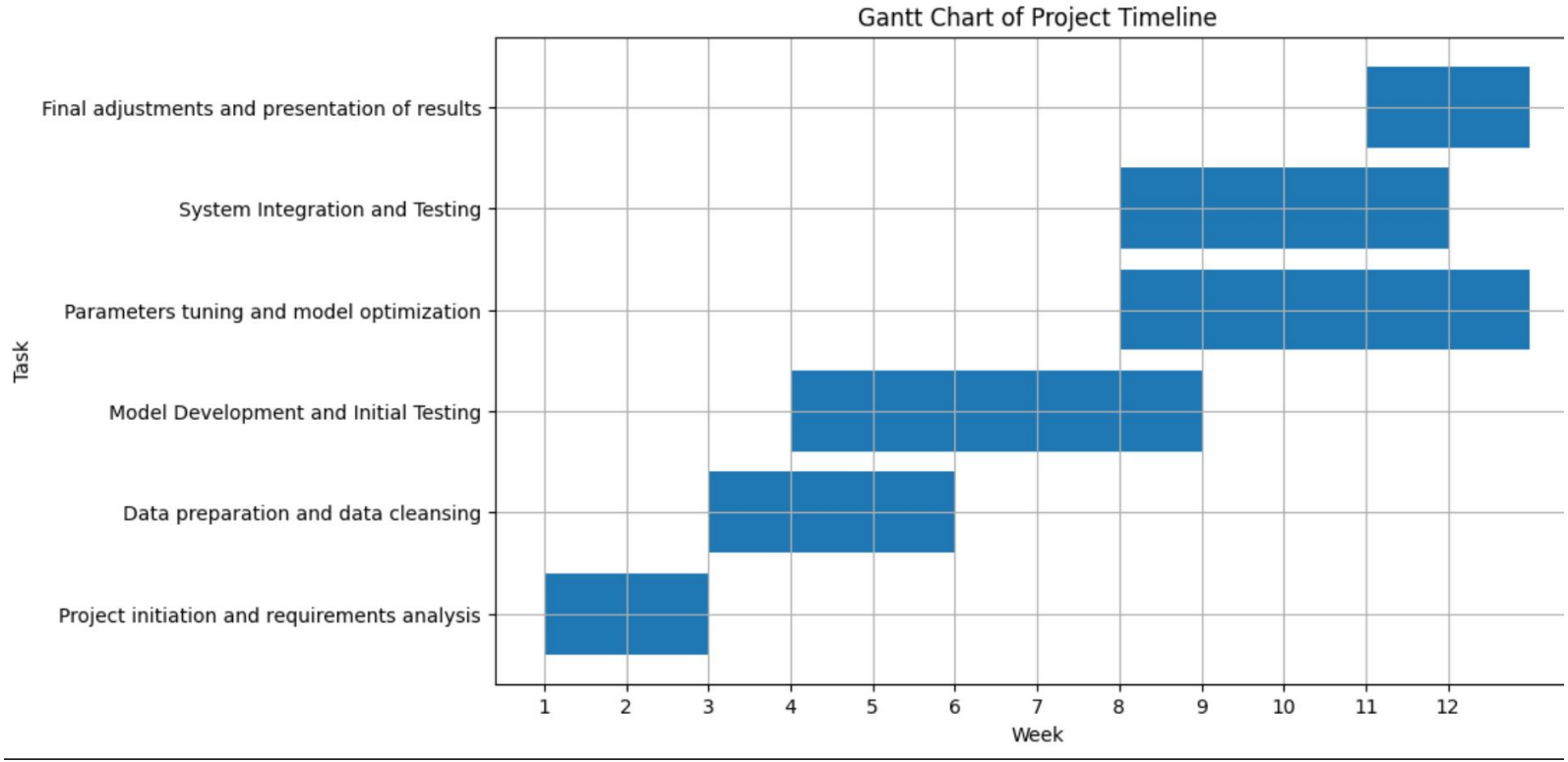
[2] Hajializadeh, F., and A. Ince. "Integration of Artificial Neural Network with Finite Element Analysis for Residual Stress Prediction of Direct Metal Deposition Process." *Materials Today Communications*, vol. 27, 2021, p. 102197, doi:10.1016/j.mtcomm.2021.102197.

Requirements and Specifications

Basic idea: Current finite element based websites are used as reference.

Requirements	Specifications	Target	Measurement
Accuracy	Predictive accuracy within 90%	≥ 90% accuracy	Statistical analysis of prediction vs actual
Speed	Analysis time per simulation	≤ 5 minutes	Time tracking software
Customization	Support diverse conditions	Handle 20+ variables	System configuration checks
Reliability	System operational uptime	99.9% uptime	Server Monitoring tools

Project Schedule



Q&A

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THANK YOU !