Project 1: Automatic and Transparent Inspection Model

Goal: Explore the feasibility of using simple, well-understood operators for defect detection without deep learning models.

Readings & Resources:

- Dacl10k dataset for practical application with many classes and pixel-accurate annotations.
- Visprog paper (https://arxiv.org/abs/2211.11559) for understanding similar design structures and methodologies.

Roadmap:

1. Define a list of simple operators such as edge detectors, background-foreground separation, and color detection.
2. Utilize meta-learning or program synthesis to intelligently stack these operators to solve specific tasks.
3. Evaluate the effectiveness of this design in practical scenarios and iterate based on feedback and results.

Project 2: Multi-encoder Networks with Meta-Learning and Brain Like Representations

Goal: Build on previous work to design a decomposed model with parallel streams that mimics brain-like structures.

Readings & Resources:

1. Deep Prior and architecture search concepts.(https://arxiv.org/abs/2104.06788)
2. Examples of possible operators to extend neural networks. (https://arxiv.org/abs/2401.08603)
3. Net2brain package for comparing brain representations and neural network activations.(https://github.com/cvai-roig-lab/Net2Brain)

Roadmap:

1. Integrate insights from Mundt et al. and Jaziri et al. into the initial design.
2. Develop and test multiple configurations of multi-encoder networks.
3. Use the Net2Brain package to compare and analyze the effectiveness of the developed models against brain-like representations.

Project 3: Out of Distribution Detection with Diffusion Models

Goal: Investigate the application of diffusion models for detecting out-of-distribution data.

Readings & Resources:

- Exploration of out-of-distribution detection with diffusion models: DDPM OOD GitHub
- Another example using inpainting: https://openreview.net/pdf?id=HiX1ybkFMl
- Same methods that can be used with Diffusion models https://openreview.net/pdf?id=6y2KBh-0Fd9

Roadmap:

1. Study the current methods used in diffusion models for OOD detection.
2. Implement and test these methods on various datasets and define series of experiments to investigate the detection capabilities for different types of OOD data.
3. Analyse the results to refine and improve the detection strategies.

Project 4: Self-supervision for Graph Neural Networks

Goal: Improve the performance of graph neural networks in material sciences through self-supervised learning.

Readings & Resources:

- Literature on graph neural networks and their applications in material sciences. https://arxiv.org/pdf/2208.09481
- Contrastive Graph Neural Networks https://proceedings.nips.cc/paper/2020/file/3fe230348e9a12c13120749e3f9fa4cd-Paper.pdf
- Check this review also https://arxiv.org/abs/2102.10757

Roadmap:

1. Select a specific task in material sciences to apply GNNs for instance property prediction on molecules.
2. Investigate and apply self-supervised learning methods on graphs.
3. Evaluate the improvements and understand the required inductive biases and invariances.

Project 5: Anomaly Detection with Diffusion Models for TS and Tabular Data

Goal: Leverage diffusion models for anomaly detection in time series and tabular data.

Readings & Resources:

- Refer to Project 3 resources for foundational knowledge.
- Benchmark that we want to use here: https://github.com/Minqi824/ADBench/tree/main
- Implementation of diffusion Model for Tabular Data https://github.com/yandex-research/tab-ddpm
- Additional papers on anomaly detection using diffusion models
- https://arxiv.org/abs/2308.15069
- Similar methods can be applied time stepwise: Mahalanobis-based scores for textual OOD detection: Textual OOD Detection

Roadmap:

1. Adapt diffusion model architectures to suit time series and tabular data.
2. Define and test appropriate reconstruction measures.

3. Focus on uncovering hidden dynamics for enhanced detection capabilities.

Project 6: Self-supervised Learning for Time Series

Goal: Explore and enhance forecasting in time series using self-supervised learning methods.

Readings & Resources:

- Current literature on self-supervised learning applications in time series data. https://arxiv.org/pdf/2303.18205 and https://openreview.net/forum?id=pAsQSWlDUf
- Methods for Timeseries Forecasting https://arxiv.org/pdf/2210.02186 and NLinear/DLinear : https://arxiv.org/abs/2205.13504

Roadmap:

1. Combine soft contrastive learning with TimesNet and DLinear models.
2. Test and analyse performance across various downstream tasks (forecasting and anomaly detection mainly).
3. Adjust and refine methodologies based for optimal performance.

Project 7: RL for Options Trading

Goal: Enhance options trading strategies using advanced reinforcement learning techniques.

Readings & Resources:

- TradeMaster: https://github.com/TradeMaster-NTU/TradeMaster
- This survey offers different ways to use Diffusion Models for RL: https://arxiv.org/pdf/2311.01223
- A new Generative Model might be an interesting candidate. NeuralSDE for financial data NeuralSDE

Roadmap:

1. Implement and test RL algorithms on TradeMaster.
2. Explore the integration of generative models and their impact on trading performance.
3. Compare with baseline models and refine strategies based on outcomes.

Project 8: Disentanglement and Path Dynamics of Normalizing Flows and Diffusion Models

Goal: Study the variation in trajectory paths of generative models and improve performance through disentanglement.

Readings & Resources:

- DisDiff paper on unsupervised disentanglement of diffusion probabilistic models: DisDiff
- Consider Intrinsic Decomposition Approaches https://arxiv.org/pdf/2112.03842

Roadmap:

1. Study and implement disentanglement and intrinsic approaches and contrast their benefits.
2. Develop methods that combines decomposition and feature disentanglement to improve model robustness.
3. Test and refine these methods to achieve clearer and more predictable outputs.

Project 9: Explanation Shift

Goal: Develop a robust system for detecting and explaining shifts in data distributions.

Readings & Resources:

- Study on characterizing model performance with explanation shifts: Explanation Shifts

Roadmap:

1. Use the provided simulator to generate data with understandable and detectable shifts.

2. Develop detection and explanation mechanisms for these shifts.
3. Test and refine the models based on their ability to accurately detect and explain shifts.

Project 10: Data Science Project

Goal: Create a toolbox for exploring various data analysis techniques in logistics and other sectors.

Readings & Resources:

- See https://github.com/jakobrunge/tigramite
- See also this paper explaining Causal Assessment for Time Series Data. The goal is to use this method or similar to discover causal relations between different variables. https://www.nature.com/articles/s41598-023-37929-w

Roadmap:

1. Design and develop the toolbox integrating classical ML and advanced analysis methods.
2. Come up with a list of domain specific questions to investigate Dataset features.
3. Apply the toolbox to logistics datasets to explore correlations and causality.