

**Model-Based Systems Engineering
(MBSE):**

Topic Modeling of Academic Journals

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01

Introduction

Adoption of MBSE

Goal 1

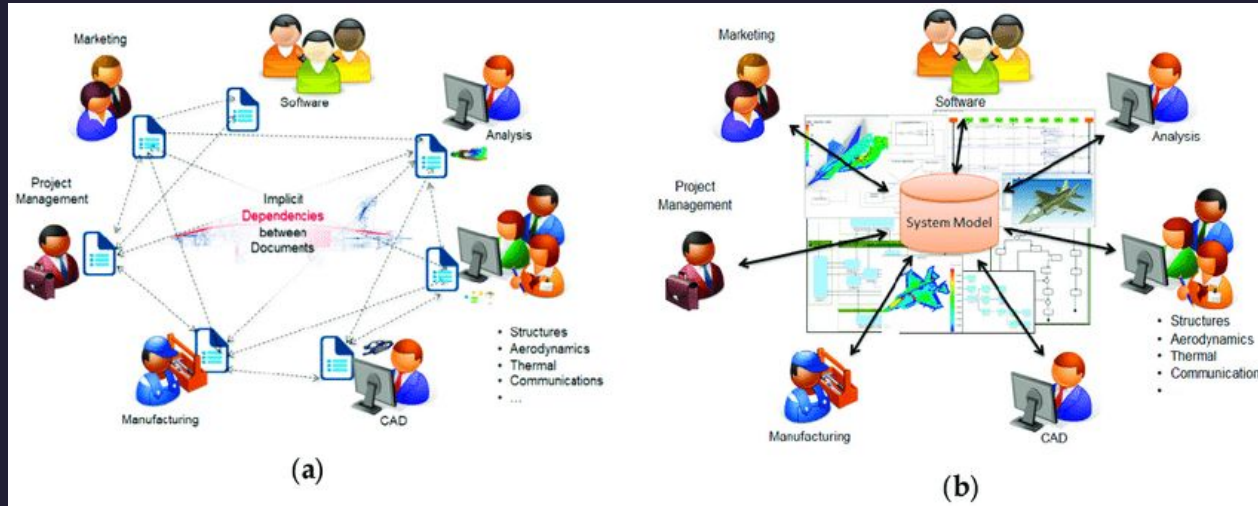
Manage Complexity

Goal 2

Improve Traceability

Goal 3

Enhance Communication



(a) Traditional Systems Engineering

(b) Model-Based Systems Engineering

Issues with Adoption of MBSE

Problem Statement

Systems engineering is a large established field. Due to the high start-up costs of adopting MBSE, large scope as well as inertia within the organization, it is difficult to:

- Identify organizational enterprise goals
- Focus R&D research efforts
- Identify latest trends

01

Org Enterprise Goals

- Where to scale up?
- Which stakeholder to engage?
- How to achieve economies of scale?

02

R&D Efforts

- Which aspect of the MBSE to implement first?

03

Latest Trends

- What is gaining traction in recent years?

Project Goals

- Explore the use of unsupervised models for topic modeling on academic journals
- Gain insight on topics/themes and their trends over the years
- Apply insight to guide organisational goals

02

Dataset

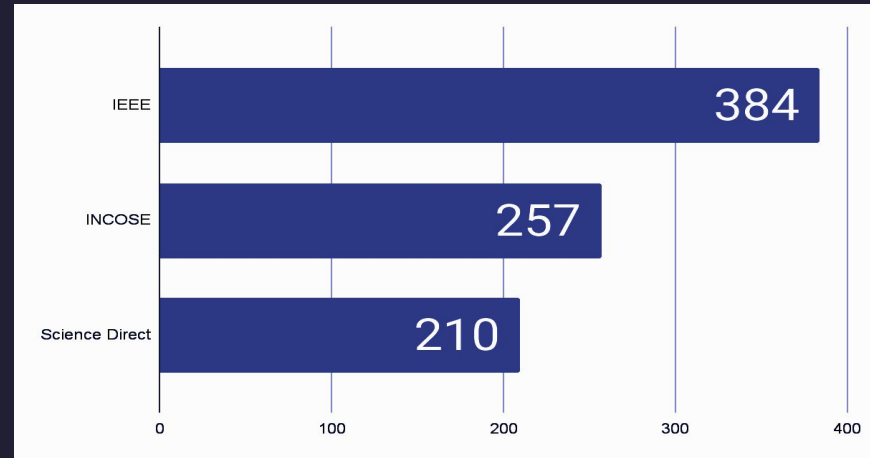
Dataset

851 Articles Collected

- Institute of Electrical & Electronics Engineers (IEEE)
- International Council on Systems Engineering (INCOSE)
- Science Direct

Article Format

- CSV Files
- Bibtex



Data Cleaning & Preprocessing

Remove apostrophes, URLs,
numbers, etc

Clean the Text

Convert different words with the
same meaning/intent into the
same word

Lemmatize



Tokenize

Convert sentences into
individual texts

Remove Stop Words

Filter words that provide no
context or words common in
every article

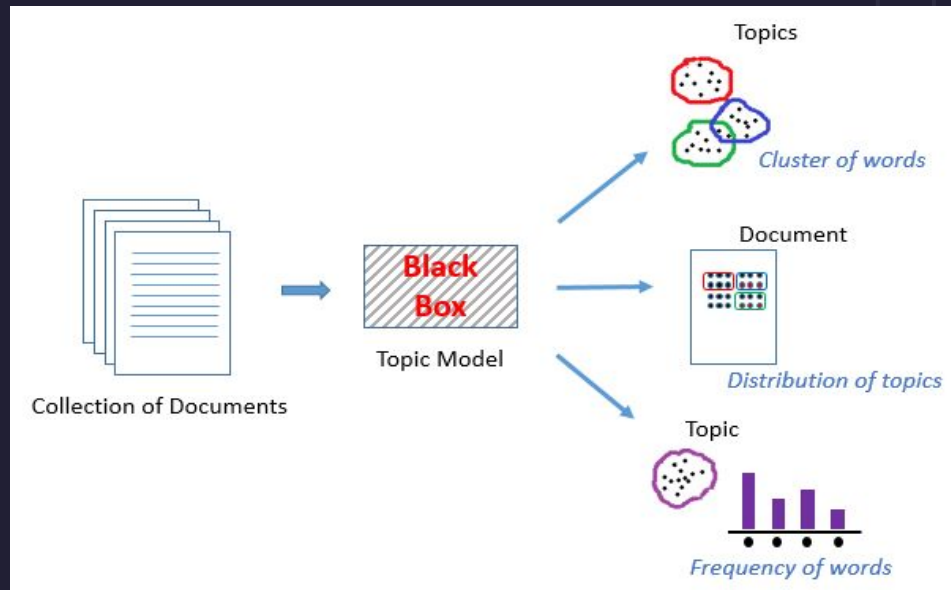


03

Modeling

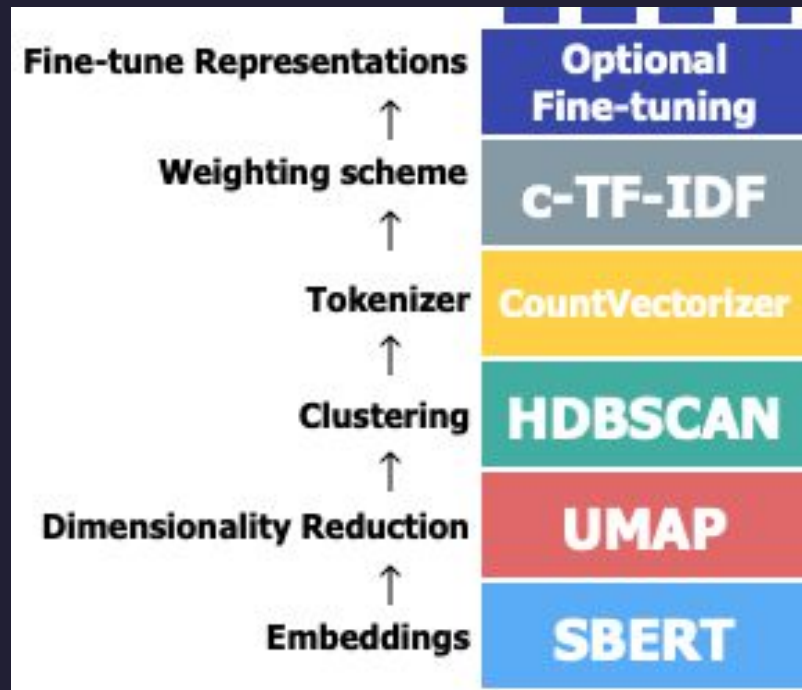
Topic Modeling

- Unsupervised machine learning
- Used to discover and extract topics or themes from a collection of documents
- Assign topics based on probability distribution of words
- E.g. Latent Dirichlet Allocation (LDA), Hierarchical Dirichlet Process (HDP), BERTopic



BERTopic

- Leverages on the BERT pre-trained language model
- Able to understand the contextual relationships between words
- Clusters documents together based on semantic similarity
- No need to define the number of clusters



BERTopic Modeling Process

17 topics identified (1/3 of dataset were outliers)

Initial Model

8 generalised topics were identified

Merge Similar Topics



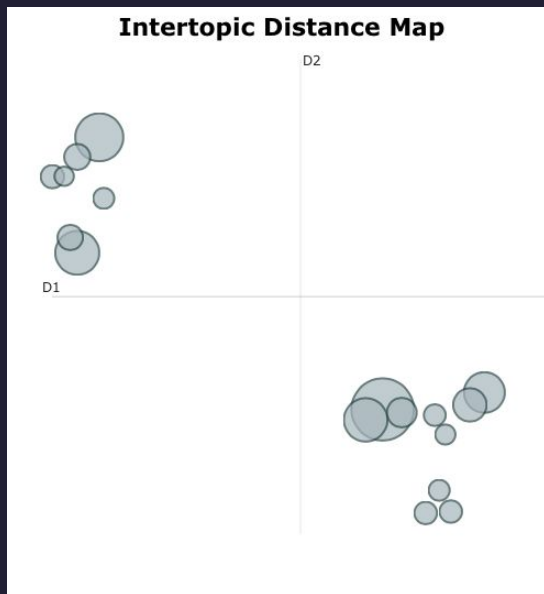
Summarise Topics

Summarise each topic and identify the similar ones using domain knowledge

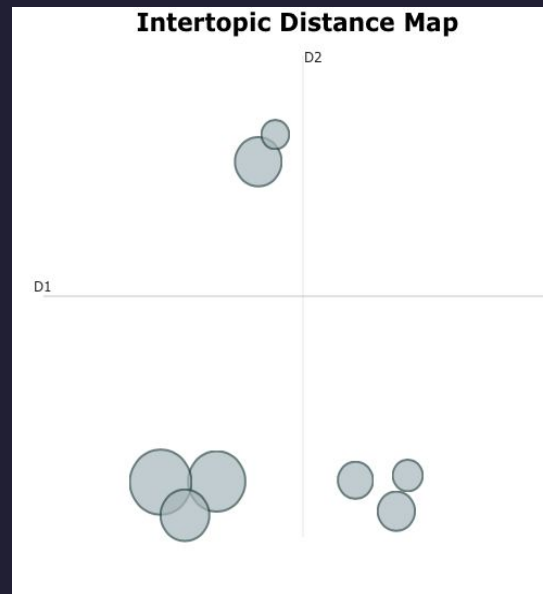
Reduce Outliers

Assign the outlier documents using the best matching c-TF-IDF representations

Intertopic Distance



Initial 17 Topics



Final 8 Topics

Identified Topics

Topic	Top 10 Key Words for Topic	Topic Label Using Domain Knowledge
0	cubesat, vehicle, spacecraft, satellite, requirement, nasa, modeling, submarine, payload, electric vehicle	Application of MBSE in Projects
1	sysml, modeling, simulation, modeling language, uml, language sysml, diagram, modeling language sysml, software, specification	Modeling language for MBSE
2	ontology, research, reuse, paper, industry, knowledge, semantic, tool, modeling, database	Adoption of MBSE and its Evaluation Metrics
3	development, product development, production, process, manufacturing, industrial, iot, product line, toolchain, development process	Product Development Process Using MBSE
4	reliability, safety analysis, fmea, fault tree, design safety, safety artifact, medical device, reliability analysis, failure mode, safety critical	Safety Assurance Using MBSE
5	mechatronic, inspection, inspection equipment, production scheduling, modeling, constraint, business rule, validation, property verification, mechatronic product	Validation & Verification Using MBSE
6	requirement, design, engineer, specification, hcd, wfrequirements, text-based requirement, cm process, property-based requirement, methodology	MBSE for Requirements Specification
7	digital twin, cyber, resilience, mbsecps, simplicity test-bed, security threat, vulnerability, twin technology, risk assessment, cpg	MBSE for Digital Twin and Cybersecurity



04

Insights & Recommendations

Reminder on Problem Statement

Problem Statement

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Topic Insights

Topic 0

Application of MBSE in Projects

- Real-life examples of MBSE application
- Aerospace, NASA, **Electric Vehicles**, Naval

Topic 1

Modeling Language for MBSE

- One of three pillars of MBSE
- Systems Modeling Language (**SysML**)

Topic 2

Adoption of MBSE and Evaluation Metrics

- Guide **adoption** process
- Evaluation metrics for **ROI**

Topic Insights

Topic 3

Product Development
Process using MBSE

- **Product Development**
- Manufacturing

Topic 4

Safety Assurance

- **Safety Analysis**
- **Reliability**
- **Failure Mode**

Topic 5

Validation & Verification
using MBSE

- **V&V** of product
- Inspection of equipment

Topic Insights

Topic 6

MBSE for Requirements
Specification

- ***Design Requirements***
Specification
- Change Management

Topic 7

MBSE for Digital Twin and
Cybersecurity

- Digital Twin
- ***Cyber Resilience***
- Vulnerability Assessment
- Security

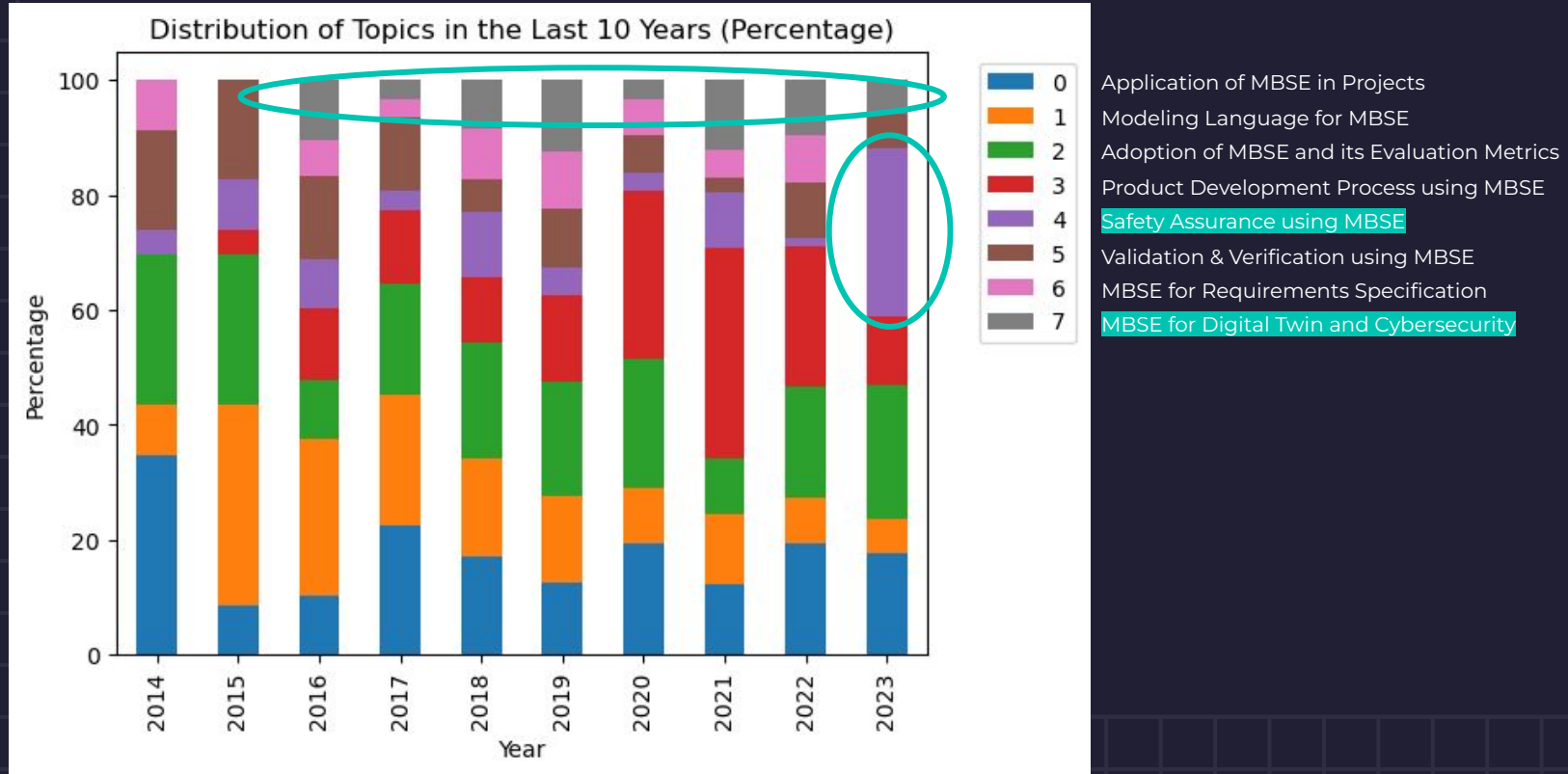
Identified Stakeholders

	Label	Stakeholder
Topic 0	Application of MBSE in Projects	EV-Electric Charging Pte Ltd subsidiary recently set up
Topic 1	Modeling Language for MBSE	All users , to learn language and modeling best practices
Topic 2	Adoption of MBSE and Evaluation Metrics	Core MBSE Team performing R&D to adopt MBSE in the Org
Topic 3	Product Development Process using MBSE	Fare Systems Team performing in-house product development

Identified Stakeholders

	Label	Stakeholder
Topic 4	Safety Assurance using MBSE	System Assurance Team performing and reviewing safety and reliability analysis for new projects
Topic 5	Validation & Verification using MBSE	Project Teams in charge of ensuring project delivery
Topic 6	MBSE for Requirements Specification	Engineering Teams in charge of specifying requirements for new projects
Topic 7	MBSE for Digital Twin and Cybersecurity	Cybersecurity & Project Teams delivering critical information infrastructure

Trends



Recommendations

Short Term

Engage Systems Assurance Team based on:

- Current trends
- Our teams have the same director (easier to overcome inertia to implement MBSE)
- Nature of systems assurance has significant impact given the importance of our MRT lines

Long Term

Present to management for decision making:

- Identified capabilities of MBSE and relevant stakeholders
- Planning at organisational level for adoption of MBSE



05

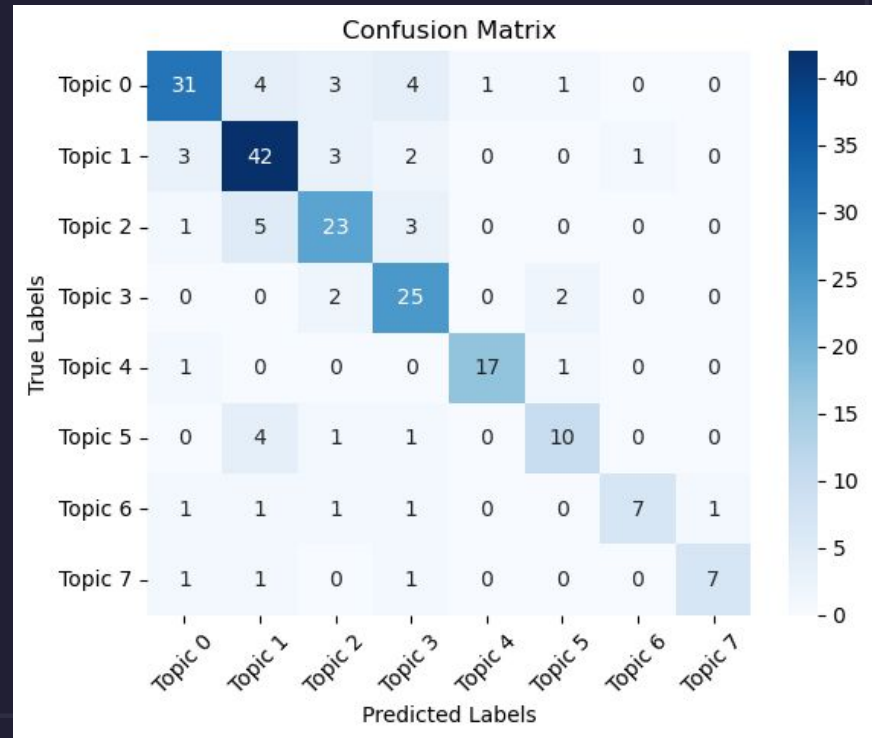
Support Tool

Classification Modeling

- New academic articles will continue to be published
- Naive Bayes classification model used to label new articles

76%

Macro Avg F1 Score / Accuracy





06

Future Works

Future Works

Break Down Topic 0

- Currently covers the application of MBSE for various fields
- Can be further broken down into aerospace, naval, electric vehicles etc
- Beneficial to stakeholders in specific fields

Create Front-End

- Need to process and label newly published articles
- Use front-end implementation to enable quick pre-processing and classification



Thanks!