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Material performance evolution discovery based on entity extraction and social circle theory

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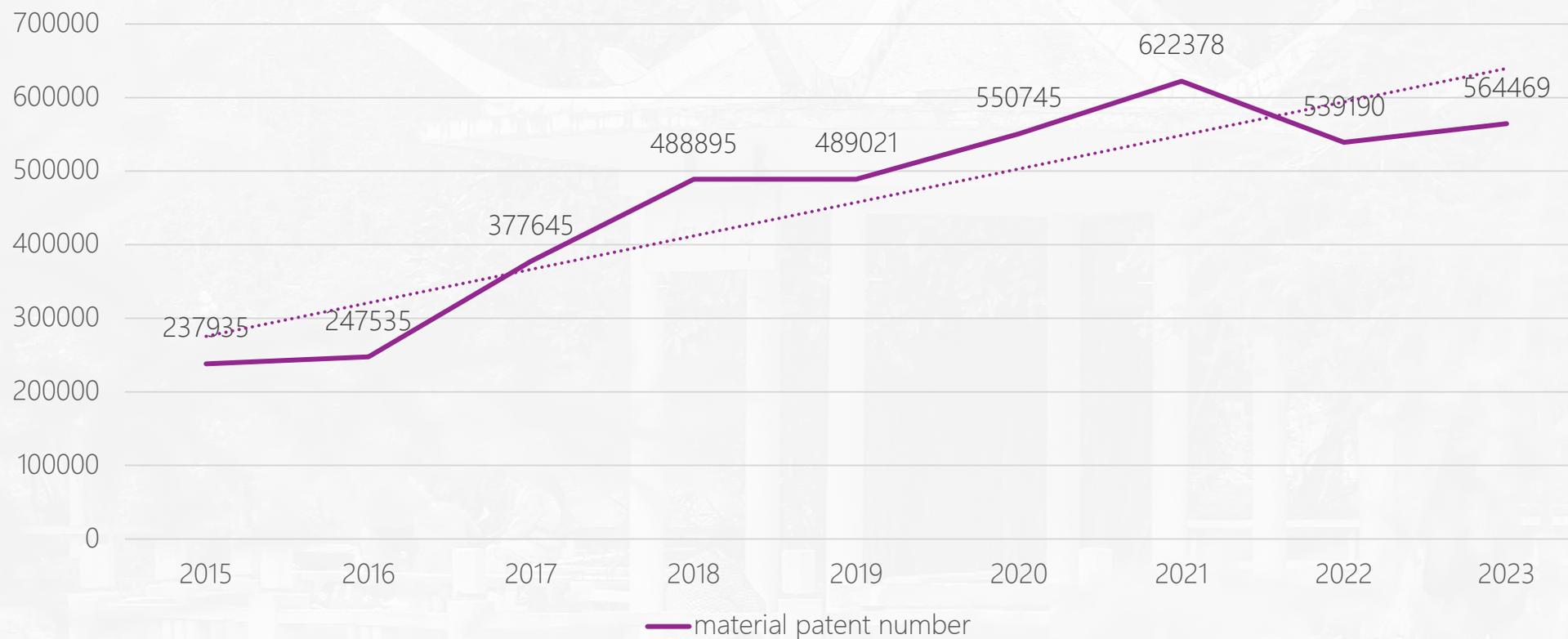Department of Information Management, School of Economics and Management, Nanjing University of Science and Technology, Nanjing China

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2015-2023 Material Patent Publication Number Statistics

material patent number

*Data Source: WIPO Patent Search

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Materials are **the main symbol of human progress as well as one of the important columns of modern civilization**, and their evolution process **reflects the progress and development of human civilization** to a certain extent, which is not only the product of industrial civilization, but also an important resource of the economy and society.

In the face of the massive manufacturing and innovation of all kinds of materials, **exploring the logical connections and evolutionary patterns between material performance changes**, as well as **the complex relationships between material manufacture processes**, is of great significance for the generation of new materials and the allocation of innovative resources.

CONTENTS

01

Background of the Study

Background of the Study

	Research situation	Limitation
Entity extraction	①The task of **entity extraction in the general field** has reached a high level ②Research **in the field of materials is relatively poor**.	① Neglecting **the domain and specificity** of the patent text ② Ignoring the **logic and relevance** of the internal context of a single patent
Topic Recognition	① **LDA**-based topic modeling ② **Clustering and Improved Variants** for Mining Topics	① Lack of **semantic association of words or phrases** under the same topic ② Poor **interpretability**
Evolutionary analysis	①Evolution of theme **intensity** ② Evolution of theme **content**	① based on similarity and ignoring **"first the change, then the new topic"** ② Neglecting the analysis of **the causes of dynamic changes and evolution**

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III
affect

material performance ← I determine ← material's microstructure ← II change ← manufacture process
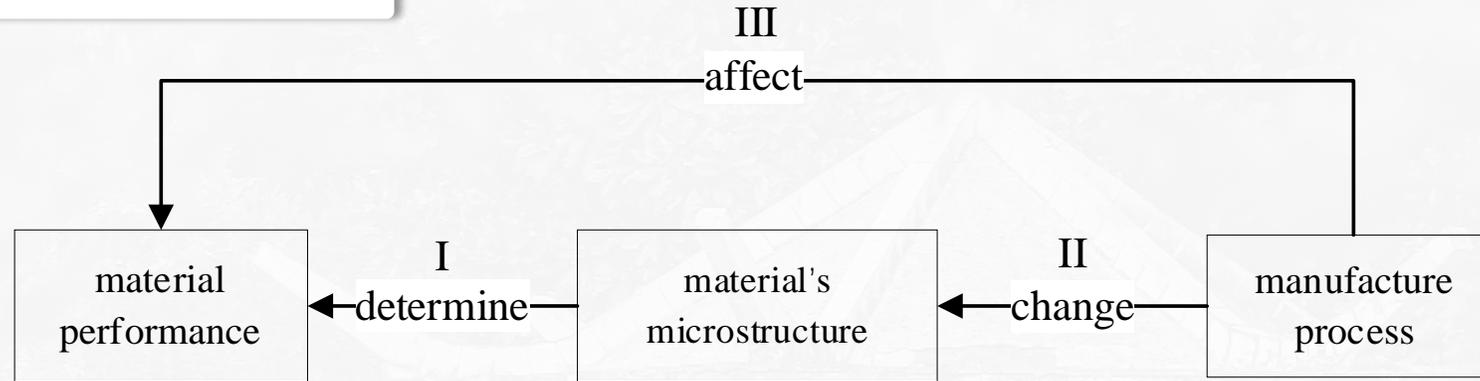
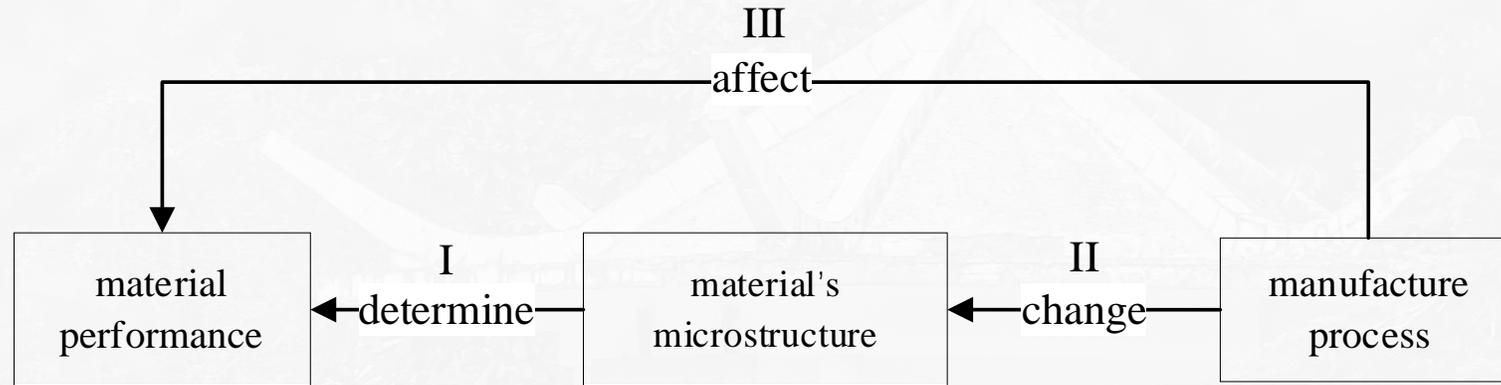| Research Approach	Limitations
I Mainly **focus on the influence of factors** such as the chemical composition, microscopic characteristics of materials **on the evolution of their performance**	1. **Demands high professional knowledge** of researchers and readers as well as experimental equipment.
II Mainly **through the analysis of the microstructure of the material**, to **explore the effect of different manufacture process on the performance of the material**	2. **The microstructure of materials usually exists in localized regions**, focusing on the local performance of materials, which **restricts the comprehensive understanding and description of the evolution of the overall performance of materials**.

III
affect

```
material          I                material's          II              manufacture
performance    ←─determine──      microstructure     ←─change──          process
```

	Research Approach	**Limitations**
III	Tending to pay more attention to **the influence of different manufacture process conditions on the material performance** (such as local links and control points in the material manufacture process)	1. The material **manufacture process** is often **complex and interrelated** 2. Neglecting to **consider the combined effects** of the overall manufacture process and the material properties and **the causes** of the evolution of the performance.

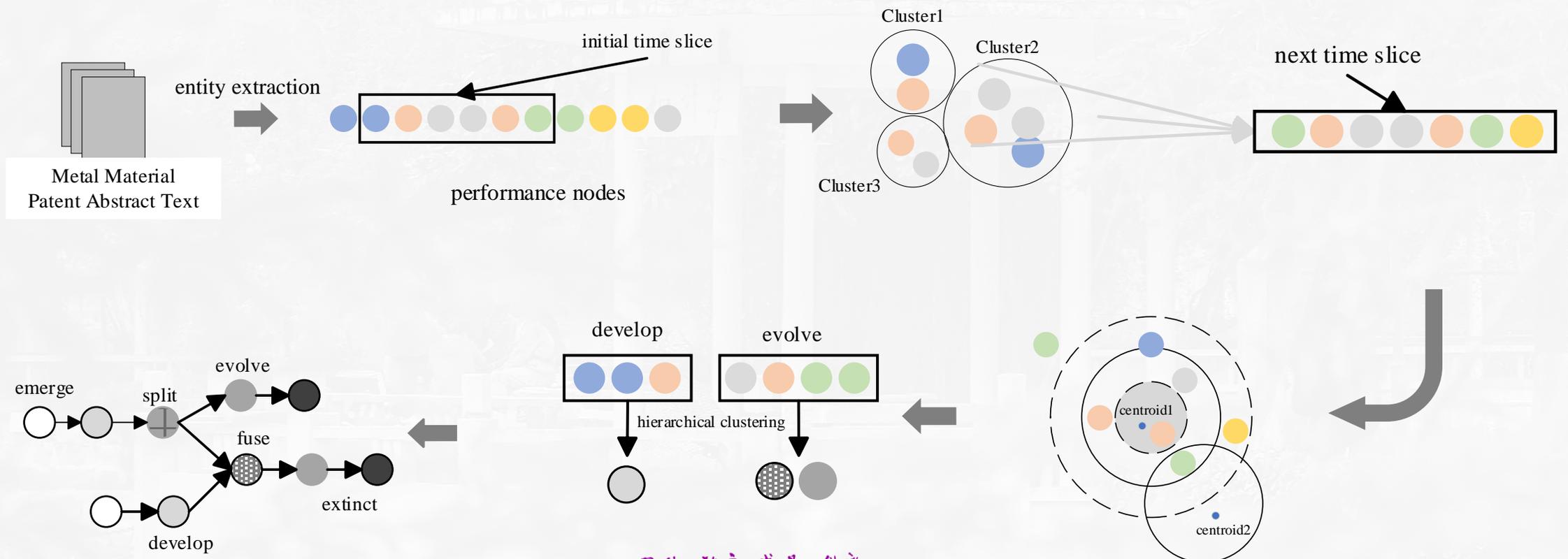# 02
Content of the Study

The purposes of this paper

➢ Realizing "**first the change, then the new topic**", constructing the dynamic evolution path of material performance.

➢ Exploring **the complex associations** of material performance

Content of the Study

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Question

➢ Q1:How to **select materials**

➢ Q2:How to realize **the extraction of material performance** from patent

➢ Q3:How to construct **the dynamic evolution path** of material performance

1.Data selection

➢ the concept of Germany's **"Industry 4.0"**——the integrity of the evolutionary results

➢ **metal material** ——one of the key foundational materials

2.material entity extraction

➢ defining the **two entity types** along with their **relationship**

➢ construct the **material entity extraction model**——the **relevant entity extraction**

3.The construction of dynamic evolution path

➢ introduce **the social circle theory**

➢ define **six types of evolution** and **evolution relationship recognition algorithm**

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1. Data selection

- **Data background**：Germany's "Industry 4.0"

- **Data source**：the Derwent Innovations Index database

- **Time interval**：2011-2023

- **Data area**：metal material

- **Why introduce the data background**：if we collect data at random intervals, it may lead to a lack of completeness and accuracy in the final analysis of the evolution results.

⇌

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2.1 Definition of entity and relationship

The **manufacture process** usually includes **the steps** and **the raw materials required**, so this article uses **verb phrases** instead of manufacture process.

manufacture process

↓ causal relationship

material performance

AB · · · NOVELTY · - · Photothermal · seawater · desalination · material · with · multi-level · structure comprises porous metal foam material deposited with nano-carbon (C) material by plasma enhanced chemical vapor deposition (PECVD) method, and synthesizing C/tungstate heterostructure as light-absorbing material by solvent thermal reaction of tungstate (I) with plasmon resonance effect.

· · · USE · - · Photothermal · seawater · desalination · material · with · multi-level · structure.

· · · ADVANTAGE · - · The · photothermal · seawater · desalination · material · is hydrophobic by using corrosion resistant and hydrophobic porous metal foam material as a support and hydrophobic carbon material coating, and has very strong light absorbing capability and photothermal conversion capability, which is good for timely converting absorbed light energy into heat energy for seawater desalination. The water does not reach the surface of the light absorber during water evaporation, so that damage due to salt accumulation is prevented and long life of the material is achieved.

· · · DETAILED · DESCRIPTION · - · Photothermal · seawater · desalination · material · with · multi-level · structure · comprises · porous · metal · foam · material · deposited · with · nano-C · material · by · plasma · enhanced · chemical · vapor · deposition · (PECVD) · method, · and · synthesizing C/tungstate (WO3-x) heterostructure as light-absorbing material by solvent thermal reaction of WO3-x (I) with plasmon resonance effect.

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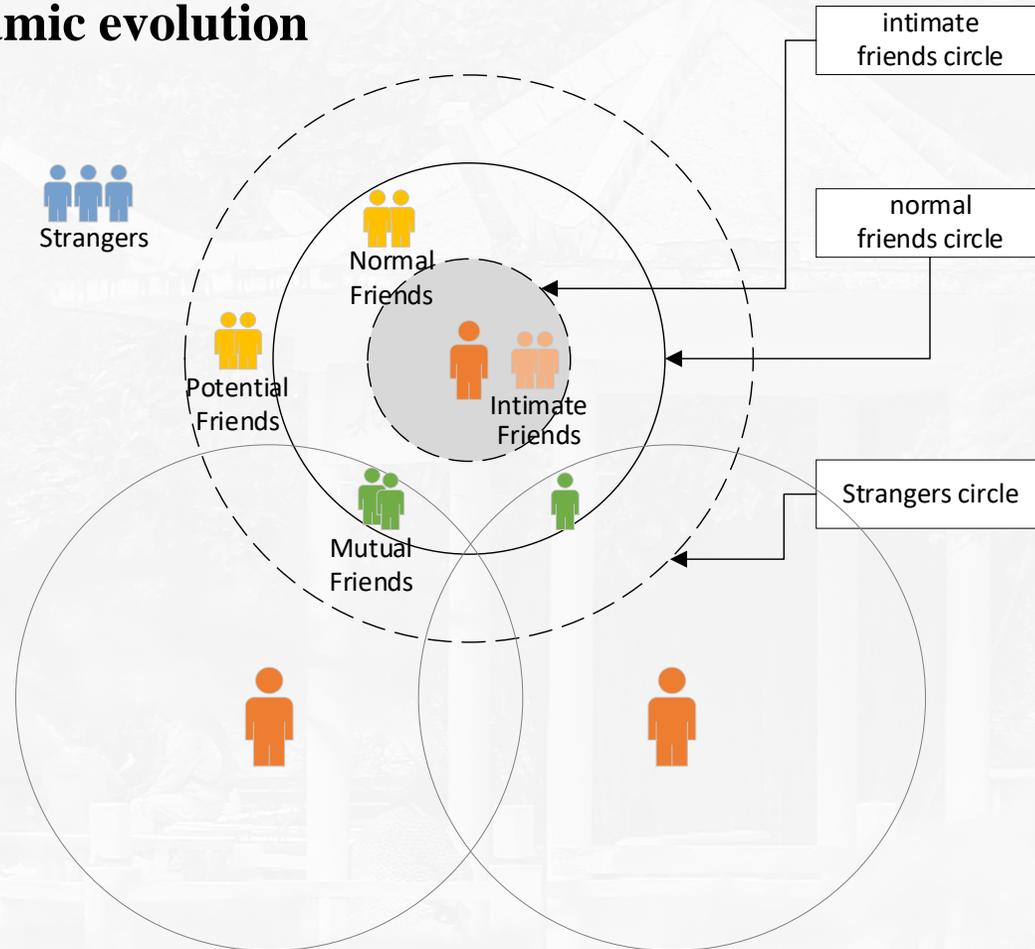NANJING UNIVERSITY OF SCIENCE & TECHNOLOGY

2.2 Extracting the material entities

- **Data annotation** : **labeling key entities** in the NOVELTY and ADVANTAGE sections of the material patent respectively

- **Construction of material entity extraction model** ：construct an entity extraction model (**BERT-BiLSTM-CRF**) by combining syntactic dependency analysis and attention mechanism

- **Realize the extraction of material entity** ： get **the performance node of each material**

3. The construction of dynamic evolution

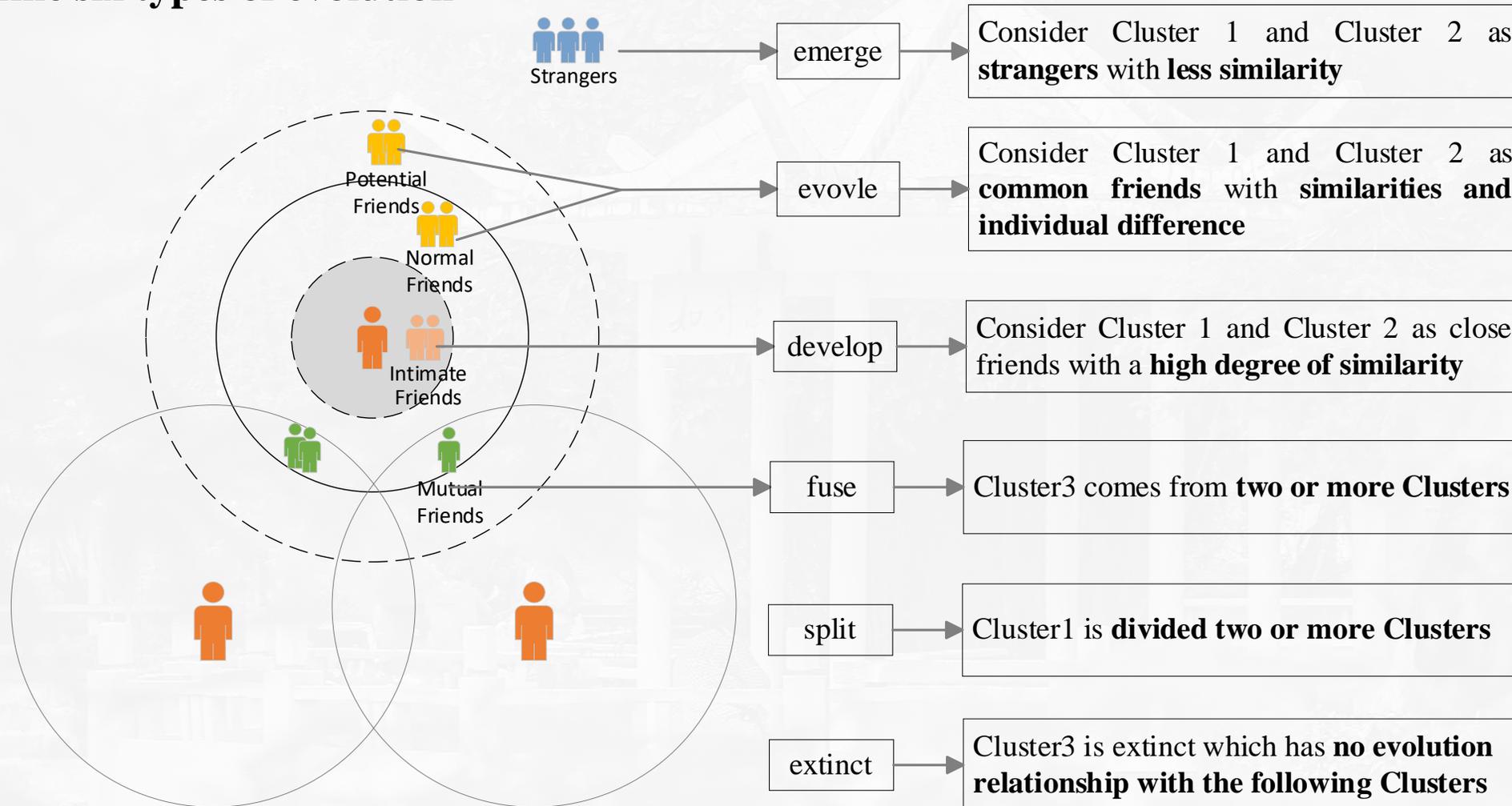

intimate friends circle

normal friends circle

Strangers circle

Strangers

Normal Friends

Potential Friends

Intimate Friends

Mutual Friends

intimate friends
∨
normal friends
∨
potential friends
∨
strangers

Social Circle Theory

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3.1define six types of evolution

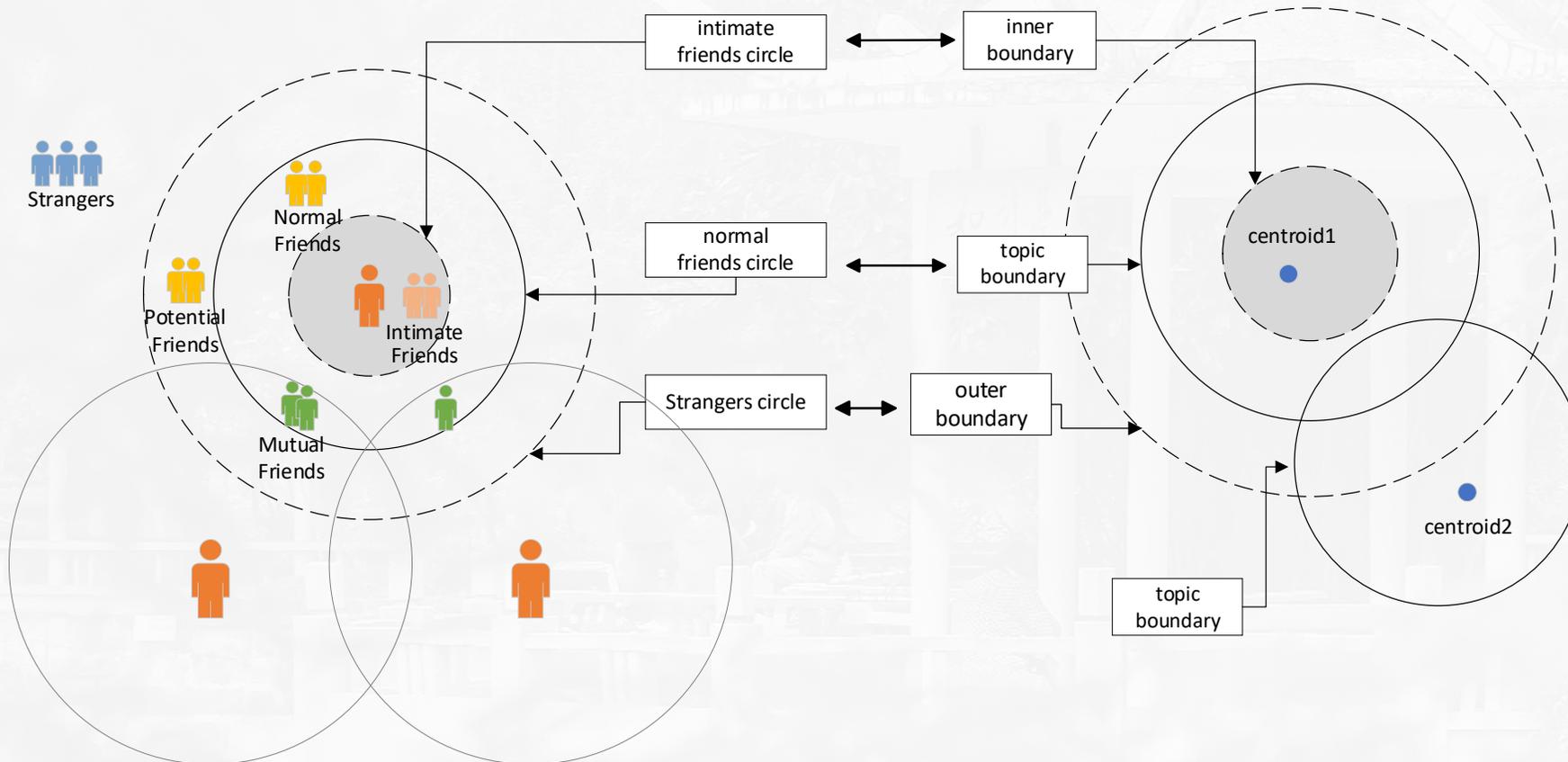|	
Strangers → emerge	Consider Cluster 1 and Cluster 2 as **strangers** with **less similarity**
Potential Friends / Normal Friends → evovle	Consider Cluster 1 and Cluster 2 as **common friends** with **similarities and individual difference**
Intimate Friends → develop	Consider Cluster 1 and Cluster 2 as close friends with a **high degree of similarity**
Mutual Friends → fuse	Cluster3 comes from **two or more Clusters**
→ split	Cluster1 is **divided two or more Clusters**
→ extinct	Cluster3 is extinct which has **no evolution relationship with the following Clusters**

3.2 Algorithm for Identifying the Evolution Relationship of Performance Nodes

- ➤ **centroid1 & centroid2:** initial topics

- ➤ **topic boundary:** the maximum Euclidean distance between each topic's patent and its centroid

- ➤ **Inner and outer boundary:** extending the topic boundary outward and shrunk by a ratio

3.2 Algorithm for Identifying the Evolution Relationship of Performance Nodes

inner boundary

topic boundary

outer boundary

topic boundary

evolve

emerge

develop

fuse

centroid1

A

C

B

D

centroid2
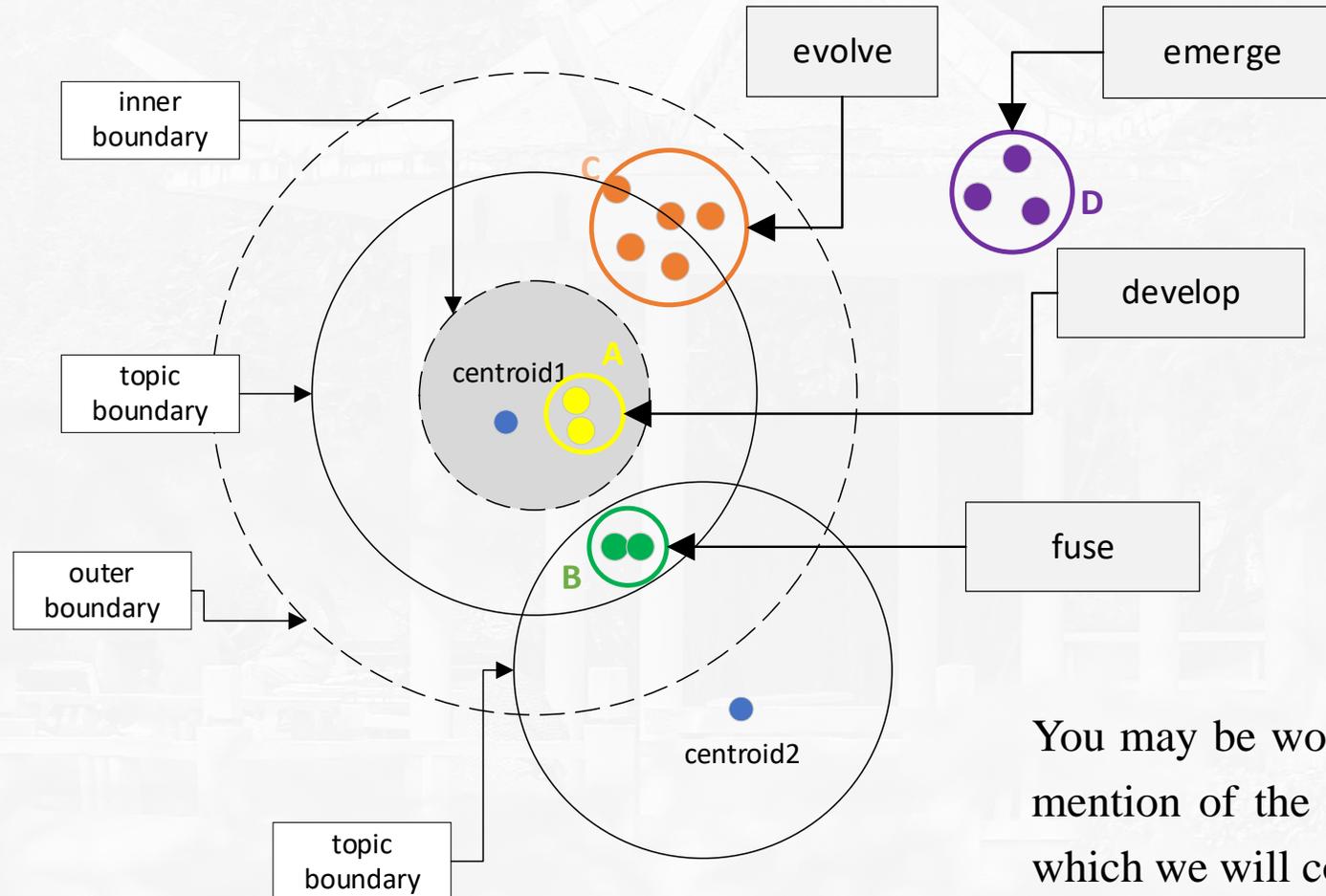
You may be wondering why there is no mention of the **split** and **extinct** types, which we will cover on the next page!

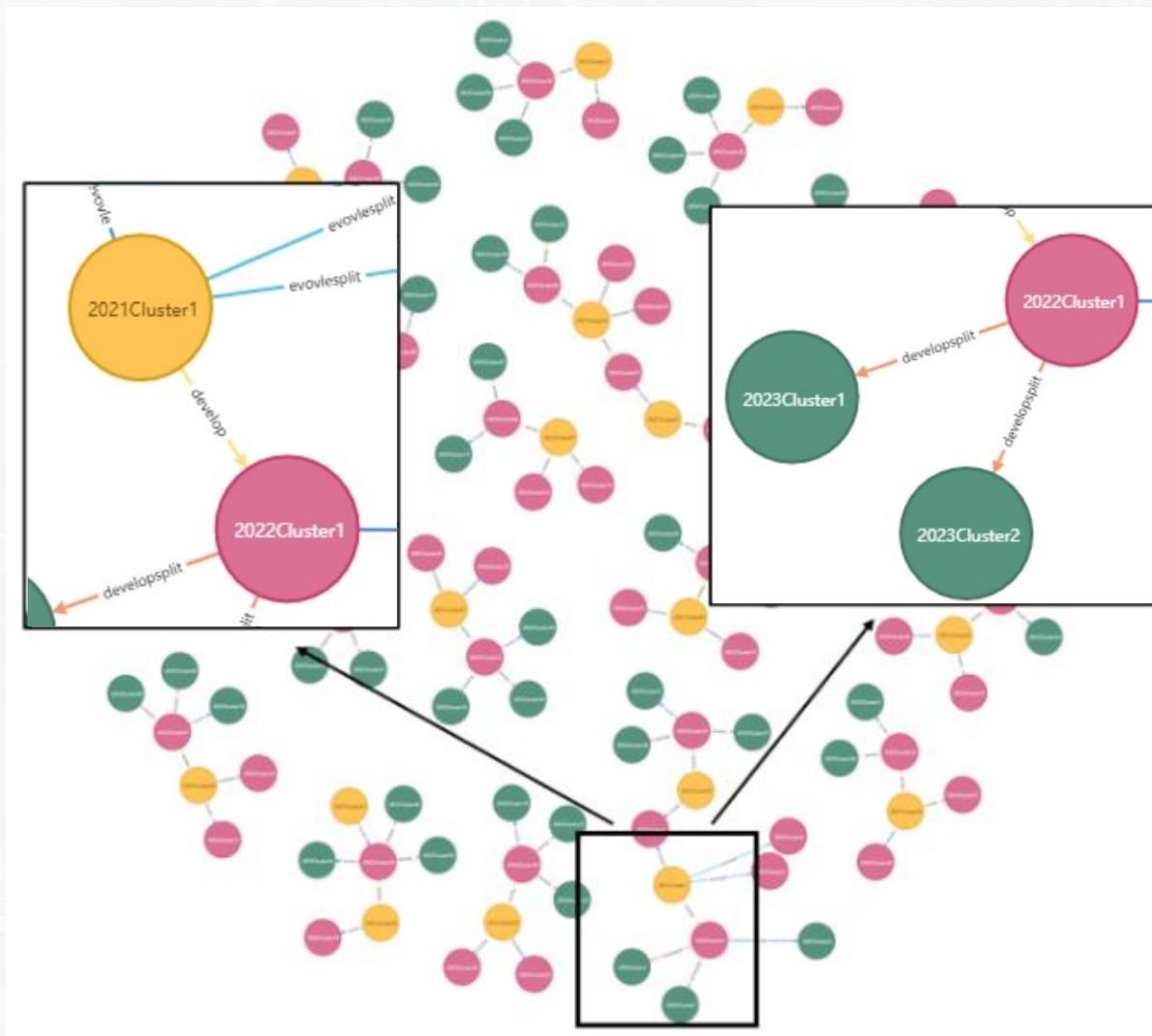# 3. The process of constructing the dynamic evolution path
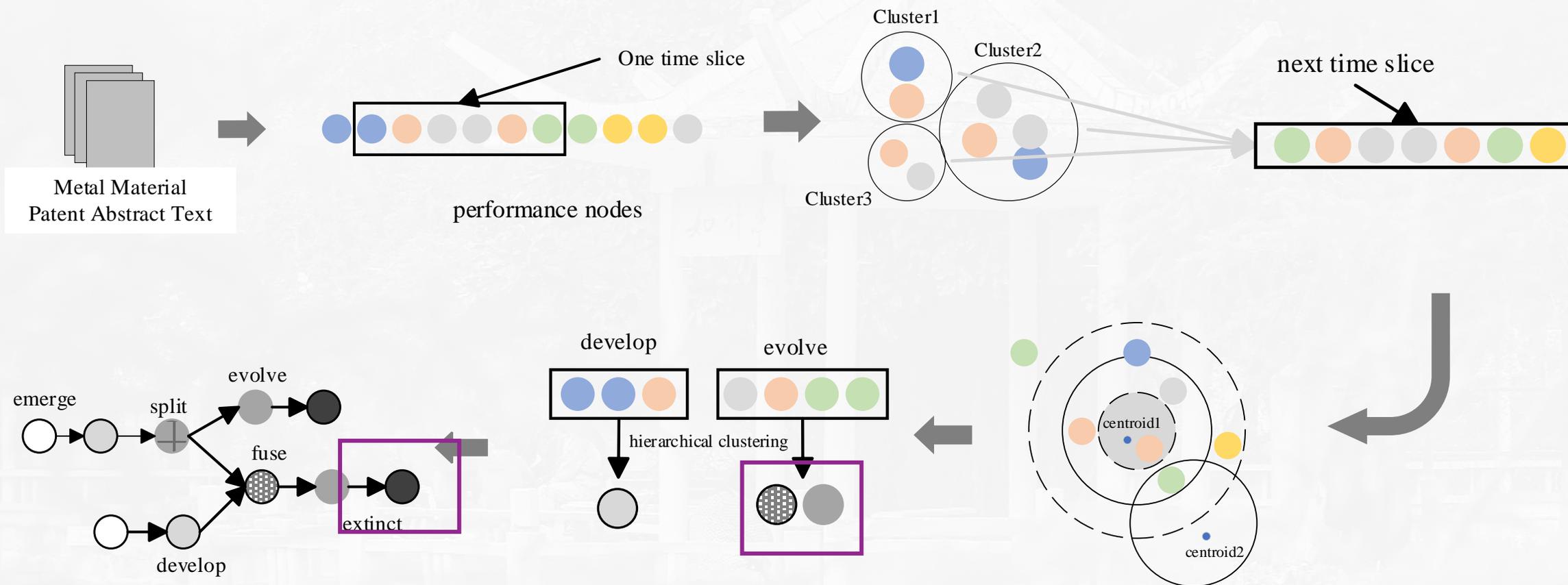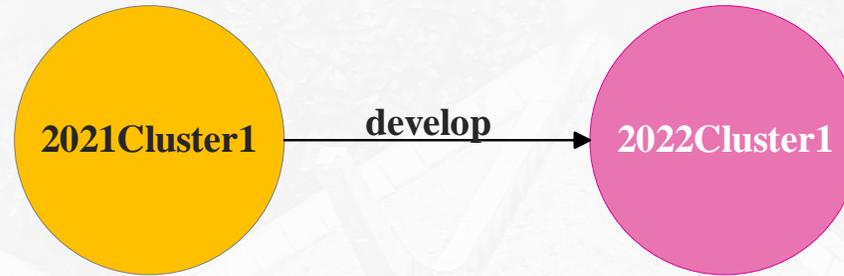
03

Findings of the Study

2021Cluster1 → **develop** → 2022Cluster1

Findings of the Study	
2021Cluster1	'high alloy excellent low corrosion' 'resistance good powder strength temperature'
2022Cluster1	'high excellent alloy low mechanical', 'strength corrosion resistance process good'
findings	**improve the corrosion resistance and mechanical performance** of metal materials
evidence	**aligns with the practical application requirements** of metal materials [1]

[1]Y.B. Lei, Z.B. Wang, B. Zhang, Z.P. Luo, J. Lu, & K. Lu. Enhanced mechanical properties and corrosion resistance of 316L stainless steel by pre-forming a gradient nanostructured surface layer and annealing. Acta Materialia. 2021, 208, 116773. doi: 10.1016/j.actamat.2021.116773.

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Conclusion and Prospect

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➤ **Conclusion**

- propose an algorithm for **identifying the evolution relationship** of performance nodes **based on ring boundaries**

- **"first the change, then the new material performance topic"**, realize the **dynamic accumulation** and construction of metal material performance **evolution path**

- enrich and improve the **topic evolutionary analysis method**

➤ **Prospect**

- **combine the manufacture process entities** of each material to further **analyze the causes** of the evolution of material performance in depth

- better understand **the evolution trends** and the **changing patterns** of material performance

THANK YOU!

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Joint Workshop of the 5th Extraction and Evaluation of Knowledge Entities from Scientific Documents and the 4th AI + Informetrics (EEKE-AII2024), April 23~24, 2024, Changchun, China and Online