Invited: Mapping Two Decades of Innovation: Lessons from 25 Years of ISPD Research

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History of ISPD

Why ISPD Research Evolved?

- **Challenges in Physical Design**: Growing complexity in VLSI demanded advanced EDA techniques.
- **Scaling & Technology Shifts**: From planar designs to FinFETs, 3D ICs, and AI-driven automation.
- **Industry Needs**: Power, performance, and area optimization drove new research directions.

Then vs. Now

✔ **1997-2005** → Focus on **placement & routing**, early combinatorial methods.

✔ **2005-2015** → Shift to **power-aware design**, FinFET adoption, and multi-core systems.

✔ **2015-Present** → Integration of **AI/ML, chiplets, 3D ICs, and advanced packaging**.

Why we did this project?

The Challenge

For 25 years, ISPD has driven **physical design advancements**, but **no structured analysis** has explored how research evolved over time. We lack a **big-picture view** of:

✔ **Key breakthroughs & recurring challenges**

✔ **Which research had the most impact & why**

✔ **What past trends reveal about the future**

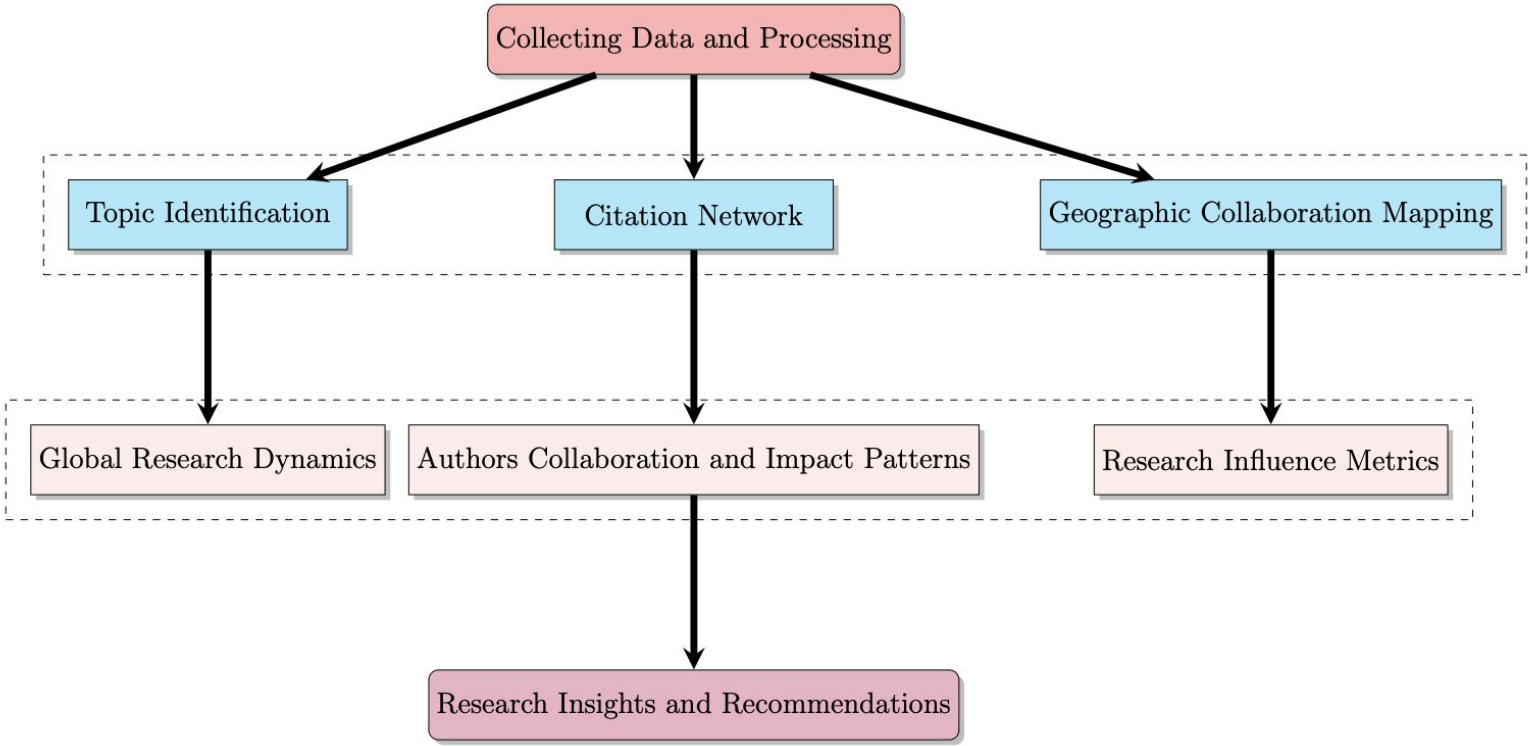
Why This Matters?

✔ **Researchers** → Find underexplored areas & build on past work

✔ **Industry** → Bridge the gap between academia & real-world adoption

✔ **ISPD Community** → Data-driven insights to shape future research

Overall Methodology



Approach

Data

✔ **Abstracts & Titles** → Identify key research themes.

✔ **Author Affiliations** → Map global contributions.

✔ **Publication Dates** → Track research evolution over time.

✔ **Citations** → Measure research impact & influence.

Analysis

We used **NLP, citation network analysis, and geospatial mapping** to:

✔ **Identify major research themes** (e.g., classic topics vs. emerging trends)

✔ **Analyze research impact & collaboration networks**

✔ **Predict future research directions** based on historical data

Data Collection and Preprocessing

"To analyze 25 years of ISPD research, we first needed a clean and structured dataset."

✔ **Collected** over **700+ ISPD papers** from **2000 to 2024**

✔ Extracted **titles, abstracts, authors, affiliations, citations**

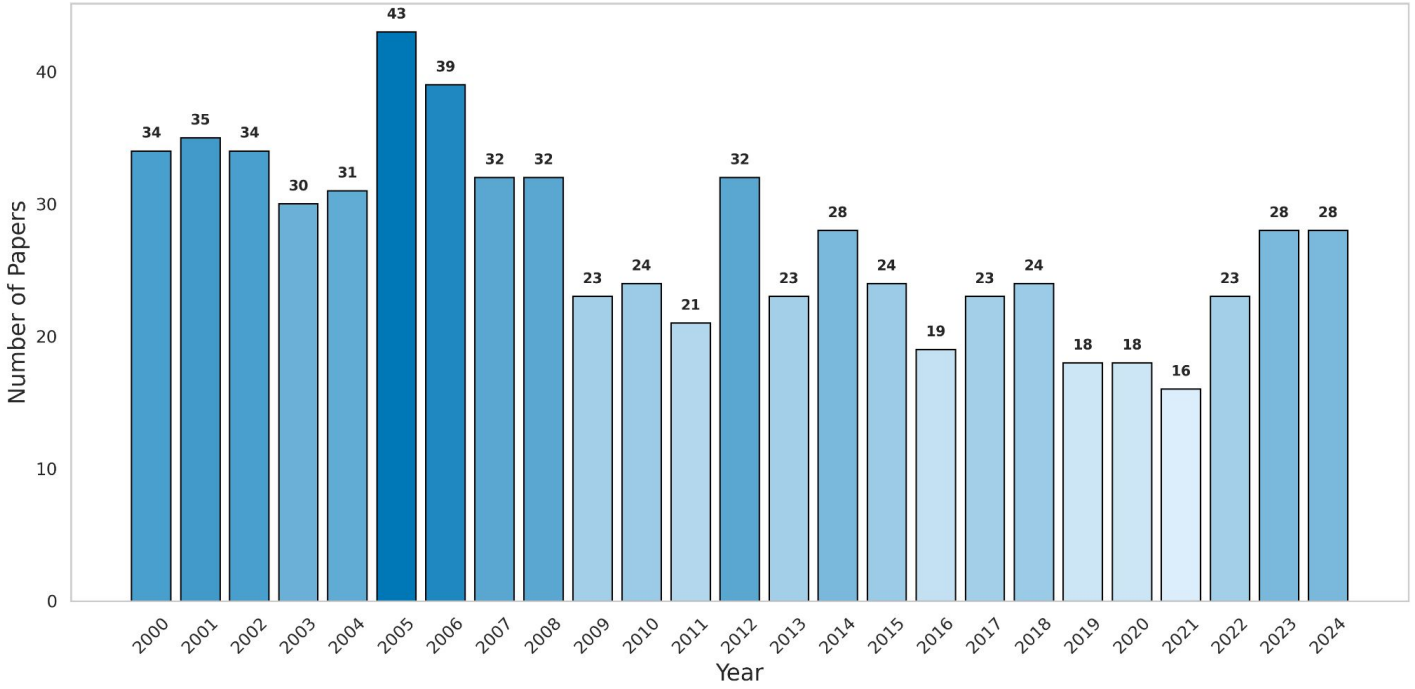
✔ **Preprocessed text** → Tokenization, stopword removal, stemming, lemmatization

✔ Built **directed citation graphs** to track research influence

✔ **Geocoded author affiliations** to analyze global collaboration patterns

"This preprocessing step was essential for accurate topic modeling, citation analysis, and community detection."

Number of Research Papers Published Each Year



Modeling Topics

1. Data Embedding with Transformers

✔ Used **BERT embeddings** to represent text in a high-dimensional space.
✔ Captured **semantic relationships** between research topics over time.

2. Topic Modeling Approaches

- **BERTopic** → Identifies dynamic topic trends using transformer embeddings.
- **LDA (Latent Dirichlet Allocation)** → Classical probabilistic topic modeling for comparison.

3. Topic Clustering

✔ **Topic Extraction** → Modeled main topics **within each research cluster/group**.

✔ **Trend Analysis** → Tracked topic evolution over time.

BERTopic for ISPD Research Trends

1️⃣ How We Used BERTopic

- ✔ **Extracted & processed text** from ISPD papers (titles, abstracts, keywords).
- ✔ **Applied BERT embeddings** to capture contextual meaning of research topics.
- ✔ **Clustered papers** into dynamically evolving topics over time.

2️⃣ What We Found

- ✔ **Consistent Topics:** Placement & routing remain core research areas.
- ✔ **Emerging Trends:** AI/ML in physical design is growing rapidly.
- ✔ **Declining Areas:** Older methodologies like early partitioning & floorplanning are fading.

3️⃣ Why This Matters

- ✔ Helps **identify shifts in research priorities** over decades.
- ✔ Reveals **potential future directions** for ISPD.
- ✔ Provides a **data-driven view** of how research evolves.

Impact of Modeling

BERTopic modeling

BT	word 1	word 2	word 3	word 4	Count
1	design	physic	circuit	technolog	107
2	placement	cell	wirelength	placer	99
3	design	layout	learn	pattern	97
4	rout	algorithm	tree	steiner	82
5	interconnect	thermal	delay	wire	69
6	clock	tree	skew	power	67
7	FPGA	design	ASIC	placement	57
8	floorplan	block	algorithm	represent	39
9	power	grid	current	design	38
10	analog	circuit	cluster	design	27

LDA modeling

LDA	word 1	word 2	word 3	word 4	#
1	physic	optim	time	design	195
2	global	rout	algorithm	placement	91
3	perform	chip	power	design	84
4	problem	pin	design	rout	81
5	wirelength	algorithm	cell	placement	60
6	placement	benchmark	power	floorplan	43
7	method	densiti	thermal	circuit	38
8	technolog	lithographi	design	layout	32
9	variat	skew	tree	clock	32
10	placement	FPGA	algorithm	cluster	26

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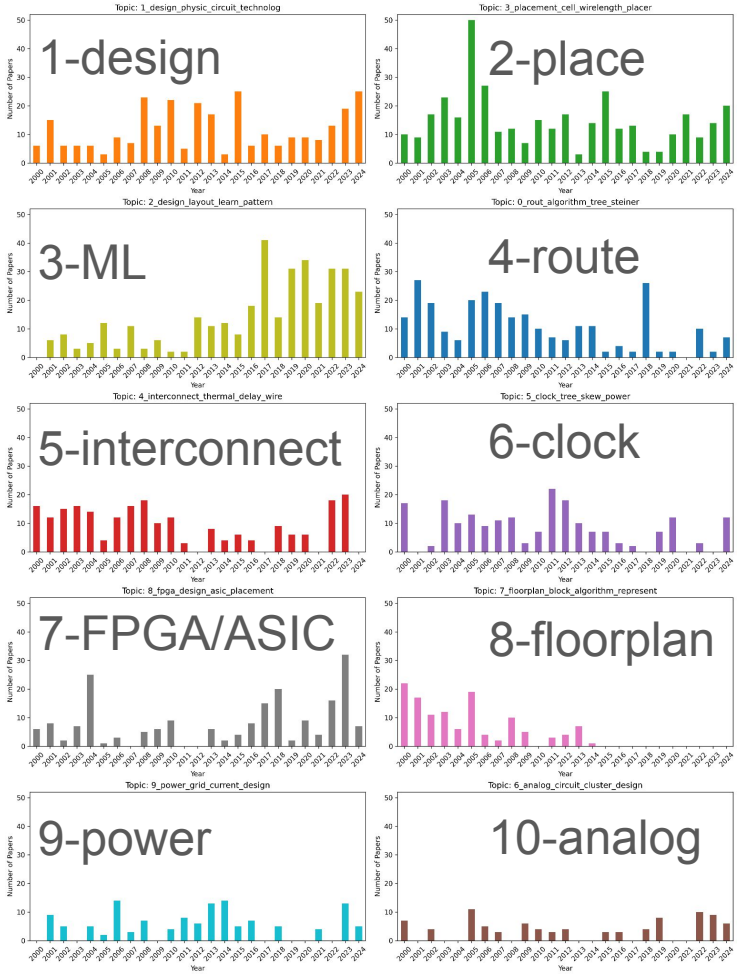
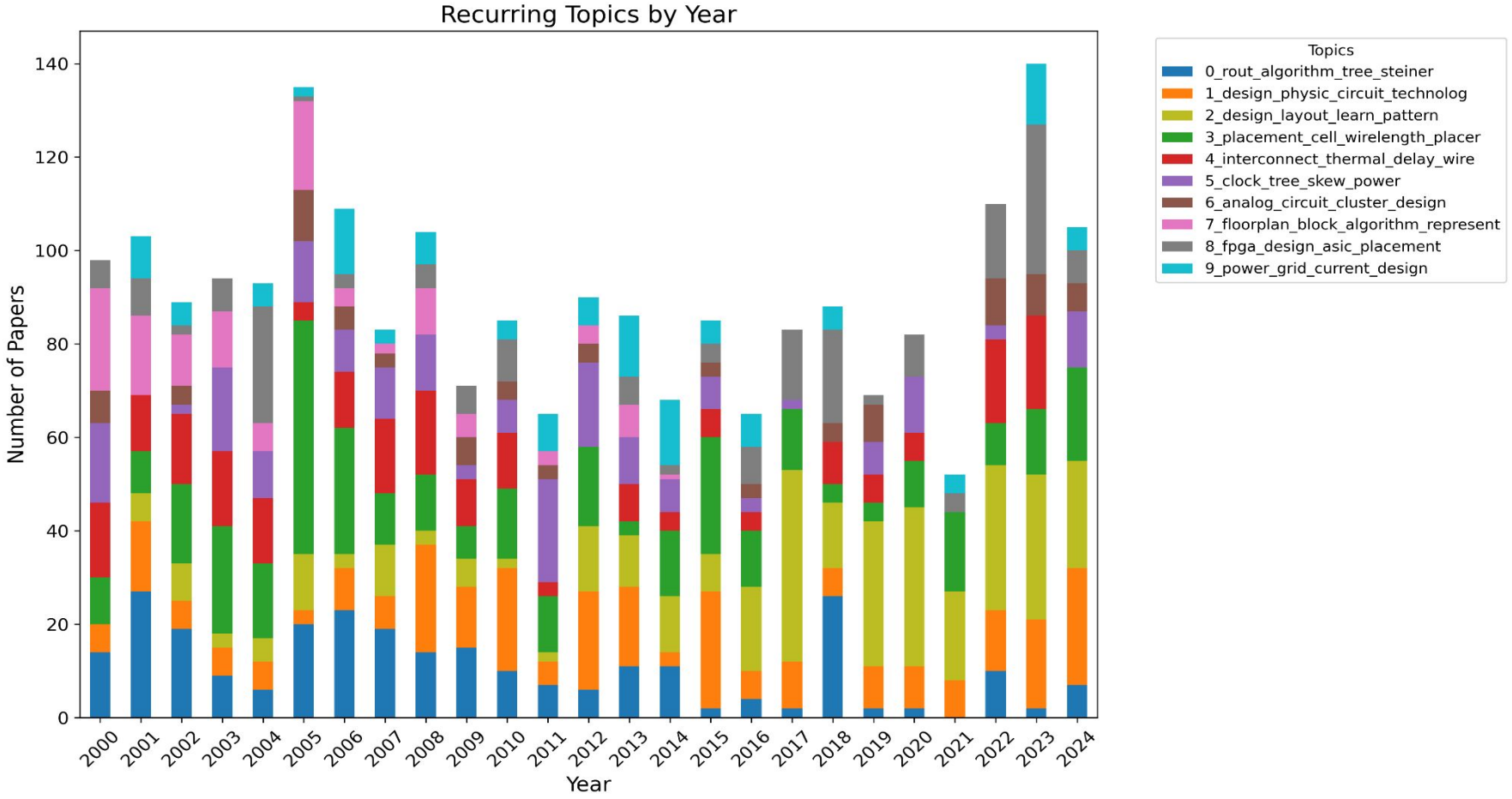



Recurring Topics by Year
Number of Papers
Year
0
20
40
60
80
100
120
140
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
Topics
0_rout_algorithm_tree_steiner
1_design_physic_circuit_technolog
2_design_layout_learn_pattern
3_placement_cell_wirelength_placer
4_interconnect_thermal_delay_wire
5_clock_tree_skew_power
6_analog_circuit_cluster_design
7_floorplan_block_algorithm_represent
8_fpga_design_asic_placement
9_power_grid_current_design

Modeling Communities: Citation Map

1️⃣ Identifying Research Communities (Community Detection)

✔ Built a Citation Network Graph

- Nodes = **Research papers**, Edges = **Citation relationships**

  ✔ Applied Louvain Algorithm

  ✔ Node size = Citation count (**bigger = more cited**).

- Grouped papers into **research clusters** based on citation connections
- Identified **major clusters** (e.g., placement, routing, AI-driven design)

  ✔ Tracked Cluster Evolution Over Time

- Examined how research communities **grew, and ..**

2️⃣ Extracting Key Topics in Each Community

✔ Applied BERTopic & LDA on Each Cluster

- Extracted **dominant research topics** within each community
- Mapped key **themes driving ISPD research**

  ✔ Analyzed Topic Evolution

- Some topics remained **core** (e.g., placement, routing)
- Others **emerged** (e.g., AI & machine learning in EDA)
- Certain areas **declined** (e.g., early partitioning techniques)

  ✔ Compared Topic Distribution Across Clusters

- Showed how topics **intersect and evolve** within research fields

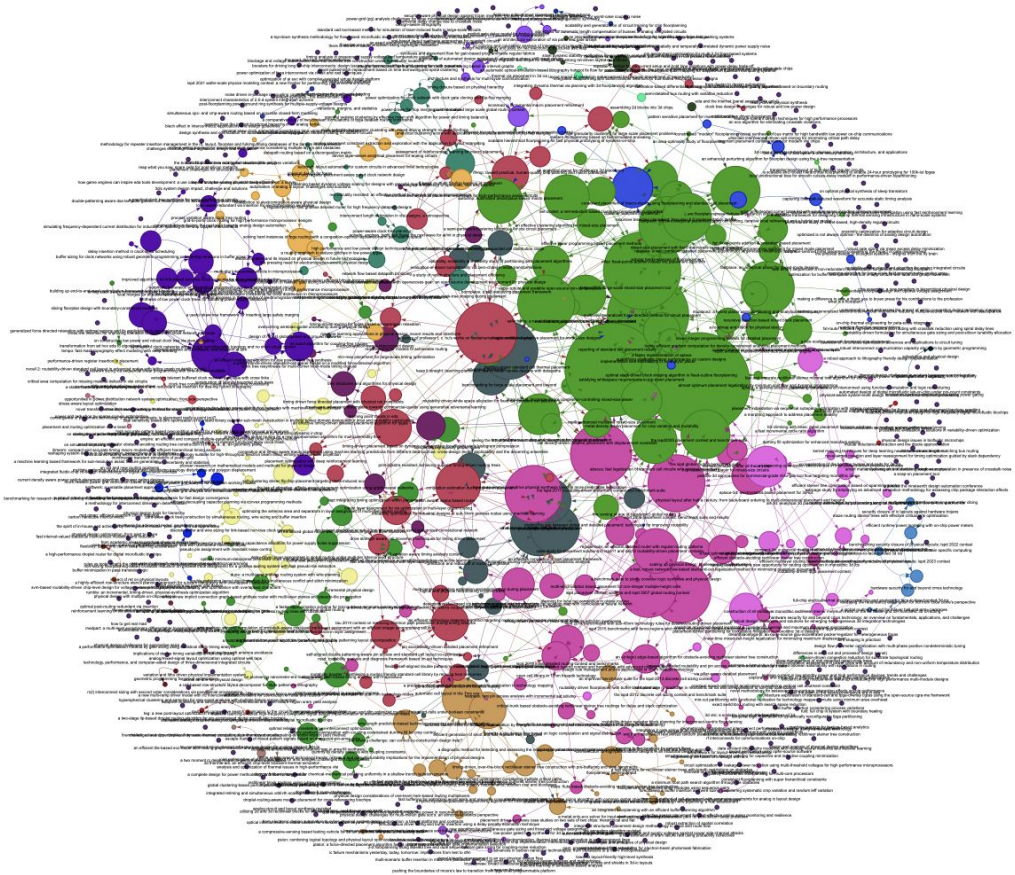
Citation Map

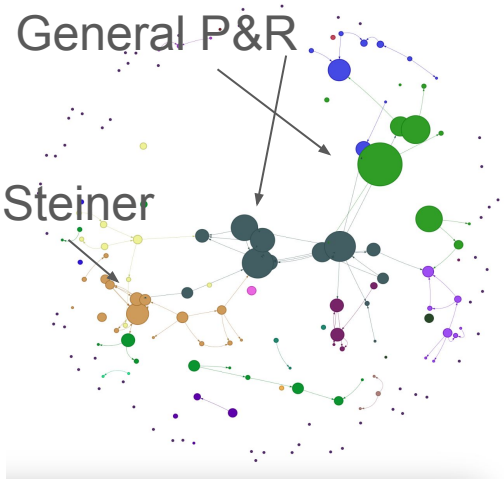
By first identifying research communities and then applying topic modeling, we uncovered the key themes driving ISPD research, mapped their evolution.

📌 **Highly cited papers act as catalysts**—they define research directions and influence future work.

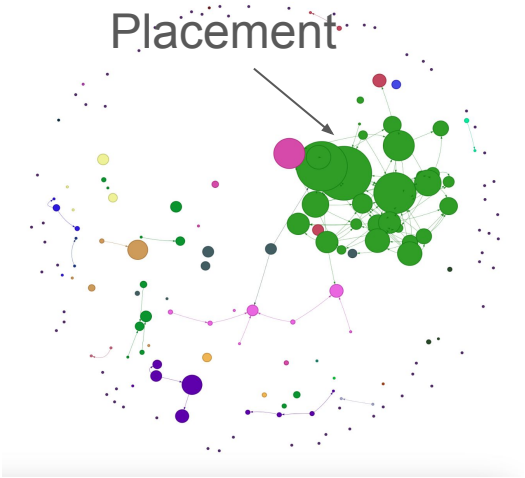
📌 **Strong collaboration networks** lead to higher-impact research.

📌 **Mapping citations reveals how ISPD research has evolved**, what ideas drive the field, and where the next big breakthroughs may come from.



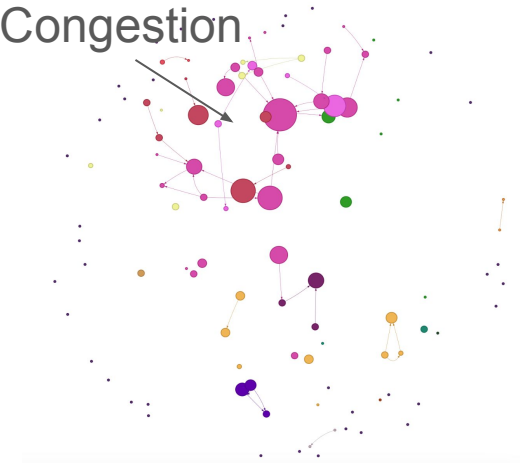


2000-2004

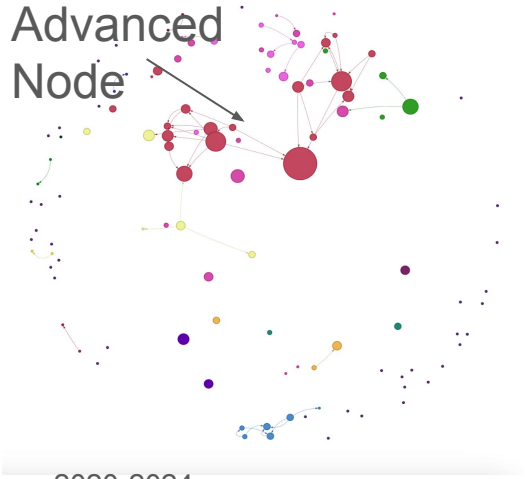


2005-2009

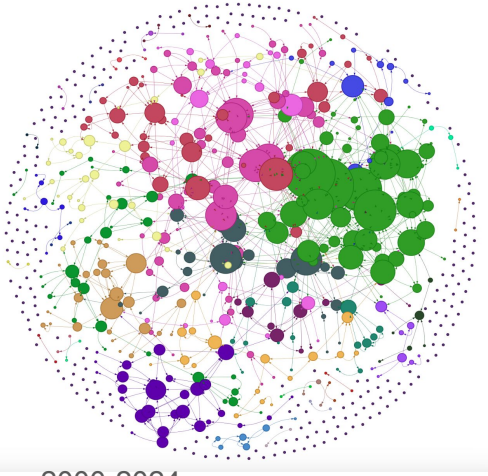
2010-2014



2015-2019



2020-2024



2000-2024

Modeling Co-Authorship

We analyzed how ISPD research contributions have evolved geographically over the past 25 years by mapping author affiliations and collaborations.

✔ Steps to Analyze Geospatial Trends

1️⃣ Data Collection & Processing

✔ Extracted **author affiliations** from ISPD papers.

✔ Geocoded locations (universities, institutions) to **map research hubs**.

2️⃣ Trend Analysis Over Time

✔ Examined **shifts in key research hubs** from **2000 to 2024**.

✔ Identified **new contributors** from emerging regions.

3️⃣ Collaboration Networks

✔ Mapped **international co-authorships** to track **global research partnerships**.

✔ Analyzed **how collaboration intensity** has changed over time.

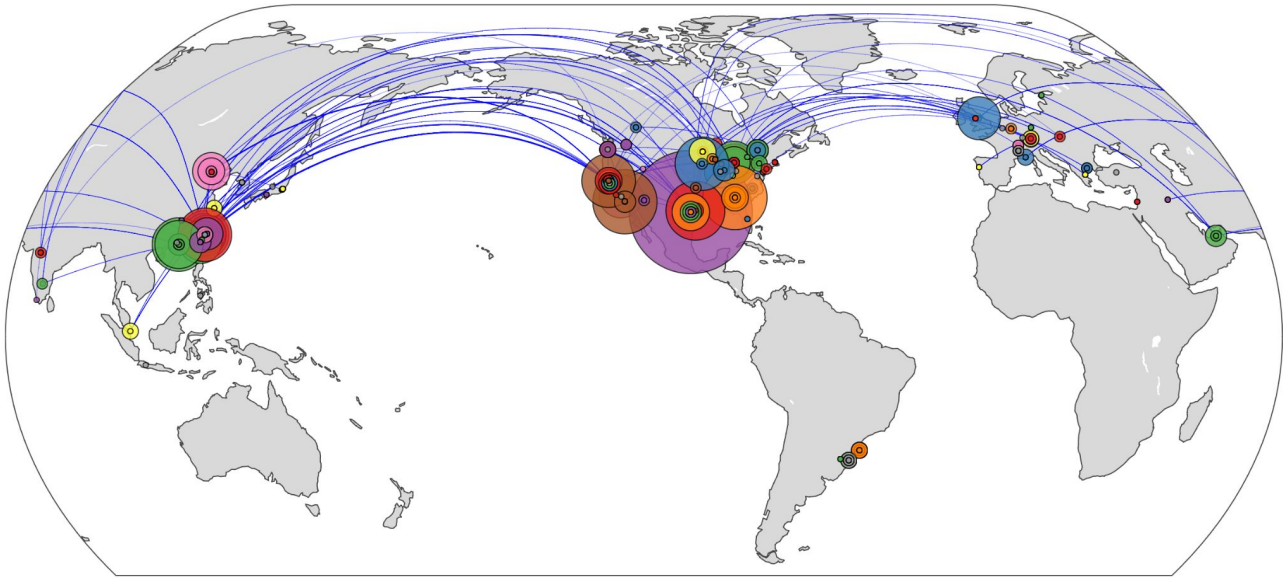
Geospatial Visualization

ISPD research is no longer regionally concentrated—innovation is now driven by a global network of contributors.

📌 **Early dominance (2000-2010)**: ISPD research was primarily concentrated in the **U.S. & Western Europe**.

📌 **Expansion (2010-Present)**: Significant growth in contributions from East Asia (China, South Korea, Taiwan).

📌 **Stronger global collaborations**: More **cross-region co-authorships** in AI-driven design and machine learning applications.



Conclusions

📌 **We should be strategic about contests**

Many repeat contests, but what are other roadblocks?

Challenges to contests are also what impedes research in those areas – open benchmarks!

📌 **ISPD papers don't cite ISPD papers enough**

How can we build on this?

📌 **Working with “dirty data” is hard**

Author aliasing

Author’s with multiple institutions

📌 **We still can't predict the future**

But if you tell me the next contest…

https://vlsida.github.io/ISPD25/