IMPROVED AND VISUALLY ENHANCED CASE-BASED RETRIEVAL OF ROOM CONFIGURATIONS FOR ASSISTANCE IN ARCHITECTURAL DESIGN EDUCATION (2020)

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Problem?

Early conceptual design phase

Manual search for design ideas in academia

Proposed solution

Retrieval – CNN & CBR

UI

Based on

Metis-I & Metis-II

Design retrieval & autocompletion projects

CONCEPTS & FOUNDATIONS

RELATED WORK; CASE-BASED REASONING

- Related CBR approaches:
  - **ARCHIE** – Excel-*ish* representation (Goal, Plan, Outcome)
  - **PRECEDENTS** – Design Issues, Design Concepts, & Forms (semantic connections)
  - **CBArch** – Vectors & Human similarity percentages (latter used as heuristics)
  - **VAT** – Topology, Ontology (relationship between rooms/areas), Visualization
- Metis-I & Metis-II
  - Attribute-value-based
  - Graph-based

ROOM CONFIGURATION

- Type of room + connection
- Graph-based
- *Semantic Fingerprints (FP)*
  - Based on dividing spaces into concepts
  - Identifies and separates different buildings

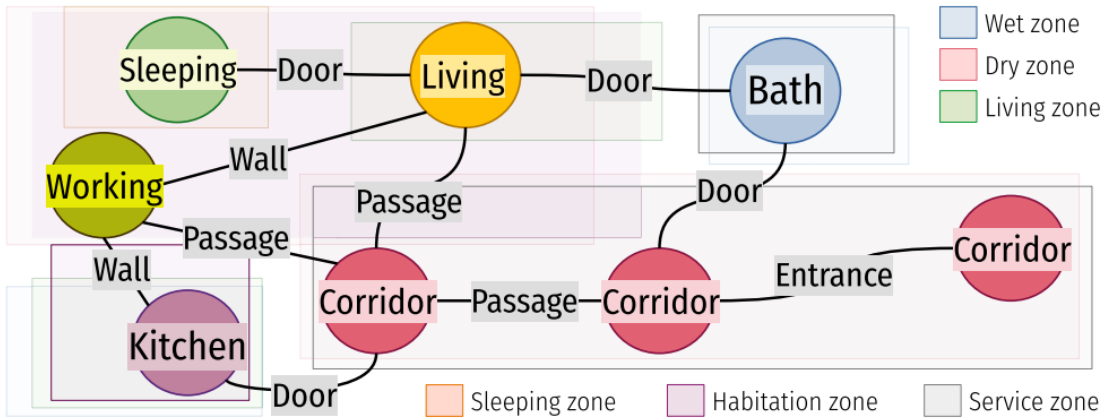


Fig. 1. An example of a room configuration graph and ARZ assignment.

Concepts	Level	Unit	Zone	Room
Entities	Attic Floor	Circulation	Circulation Zone	Bedroom
	Upper Floor	Apartment	Living Zone	Workroom
	Ground Floor	Terrace	Function Zone	Bathroom
	Basement	Balcony	Sleeping Zone	Kitchen
				Corridor
				Staircase

Fig. 3. Taxonomy – Example of entities

Fig 1: https://link.springer.com/chapter/10.1007/978-3-030-58342-2_14
Fig 3: https://www.researchgate.net/publication/230675749_Sketch-based_Methods_for_Researching_Building_Layouts_through_the_Semantic_Fingerprint_of_Architecture

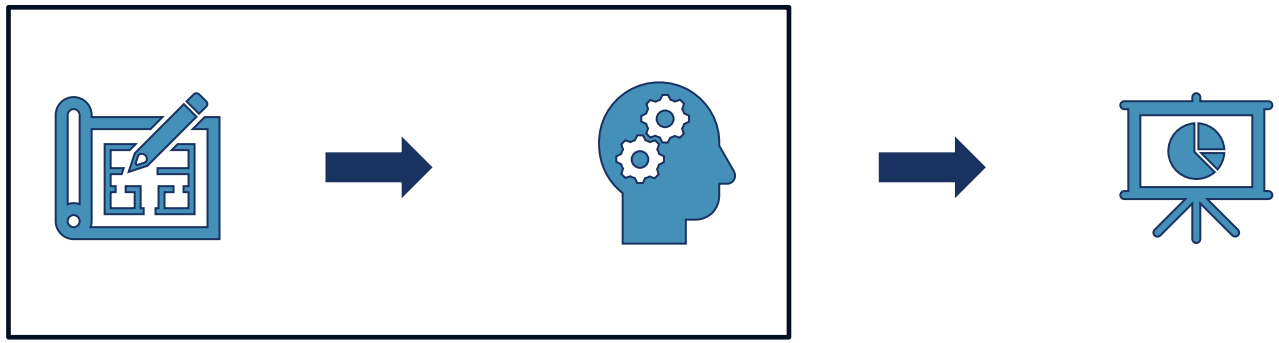
ARCHITECTURAL ROOM ZONES (ARZ)

- Dividing floor plan sections into zones
- Additional information on top of types & connections
- Established in earlier papers, however..
  - Combination of zones & room configuration + FP is new
  - Maybe it will help?

Table 1. Architectural room zones with the corresponding room types.

ARZ name	Description	Room types
Wet zone	Frequent contact to water	KITCHEN, TOILET, BATH
Dry zone	No frequent contact to water	LIVING, SLEEPING, WORKING CORRIDOR, CHILDREN
Living zone	Social + free time activities	LIVING, KITCHEN
Sleeping zone	Rest + relax activities	SLEEPING
Habitation zone	Frequent human contact	LIVING, SLEEPING, WORKING KITCHEN, CHILDREN, EXTERIOR
Service zone	Rare presence of humans	CORRIDOR, TOILET, BATH STORAGE, PARKING, BUILDINGSERVICES

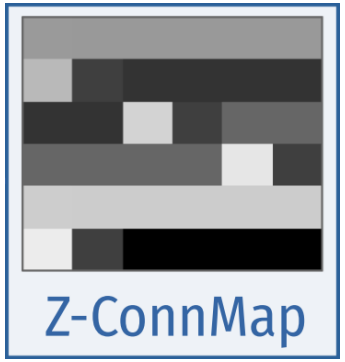
GRAPH → AI → RESULT; HOW?

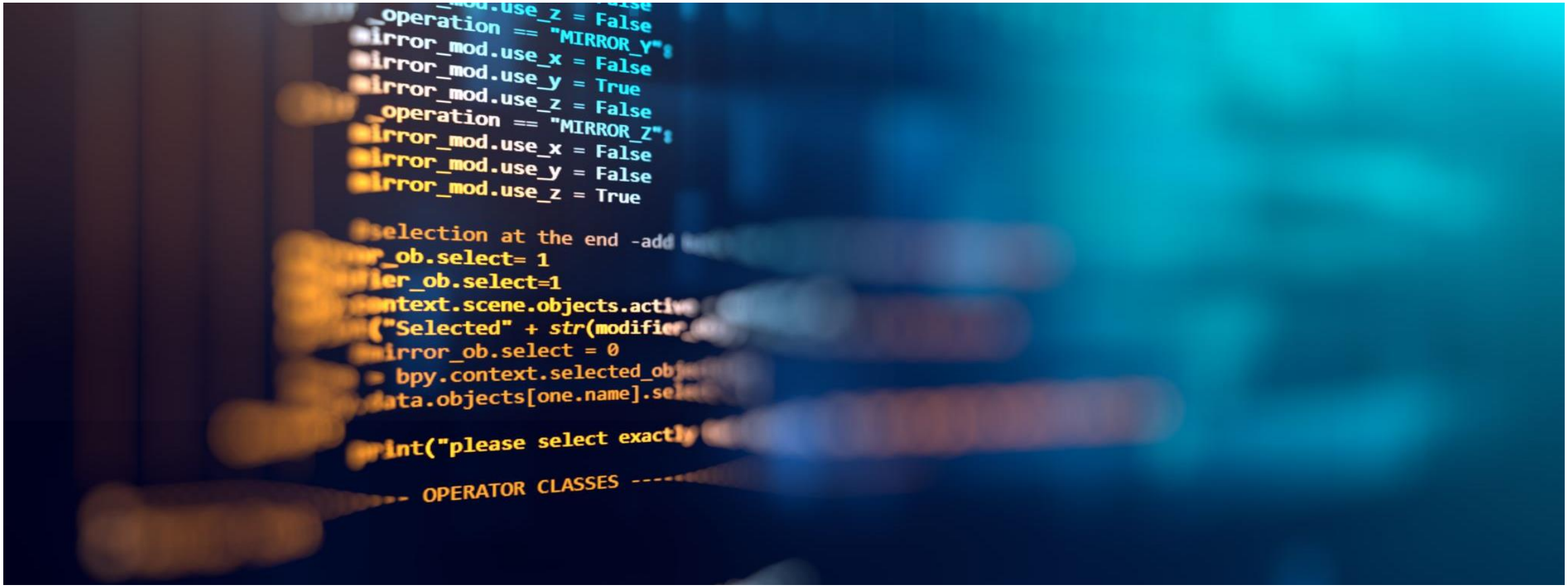


THE ANSWER IS (ALWAYS) TENSORS

- ConnMap
  - Numerical codes – relations
  - Example: 542
    - 5 – Kitchen
    - 4 – Corridor
    - 2 – Passage
- Downsides:
  - Many repeats;
  - Not sufficiently distinguishable (for ML)

- Z-ConnMap
  - Same as before, however…
  - Each room type associated with a zone
  - Example: 51422
    - 5 (Kitchen) + 1 (Wet zone)
    - 4 (Corridor) + 2 (Dry zone)
    - 2 (Passage)
- More sparsity – more happiness

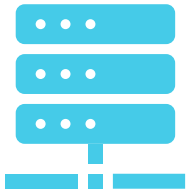




COMBINED RETRIEVAL + UI

DATA AUGMENTATION

Problem: Lack of data



Solution: GAN

CNN-based

Used Z-ConnMap

Restrictions in generation:

Rooms could only be replaced with others from the same zone

CONTEXT-BASED PRESELECTION OF CASES

- "Warm-up" before similarity search;
  - ***Pre****selection*
- MetisCBR – graph-based retrieval; slow for larger dataset
- Turned to Z-ConnMap-based retrieval
- Specific CNN to assign labels (Table 2)
- Retrieval:
  - Use CNN to fetch cases with similar labels

Table 2. Currently implemented design contexts.

Type	Contexts	Explanation	×
Structural	`SparseConnections` `RoomTypeDominance`	*Number of edges < number of rooms A room type dominates the configuration*	`OR`
Temporal	`PreDesign` `FullDesign`	*Different states of the room configuration during the early design phases*	`XOR`
Typological	`SocialHousing` `StandaloneHousing` `UnknownHousing`	*Housing category of the room configuration*	`XOR`

SEARCH CONTINUES - GRAPH MATCHING

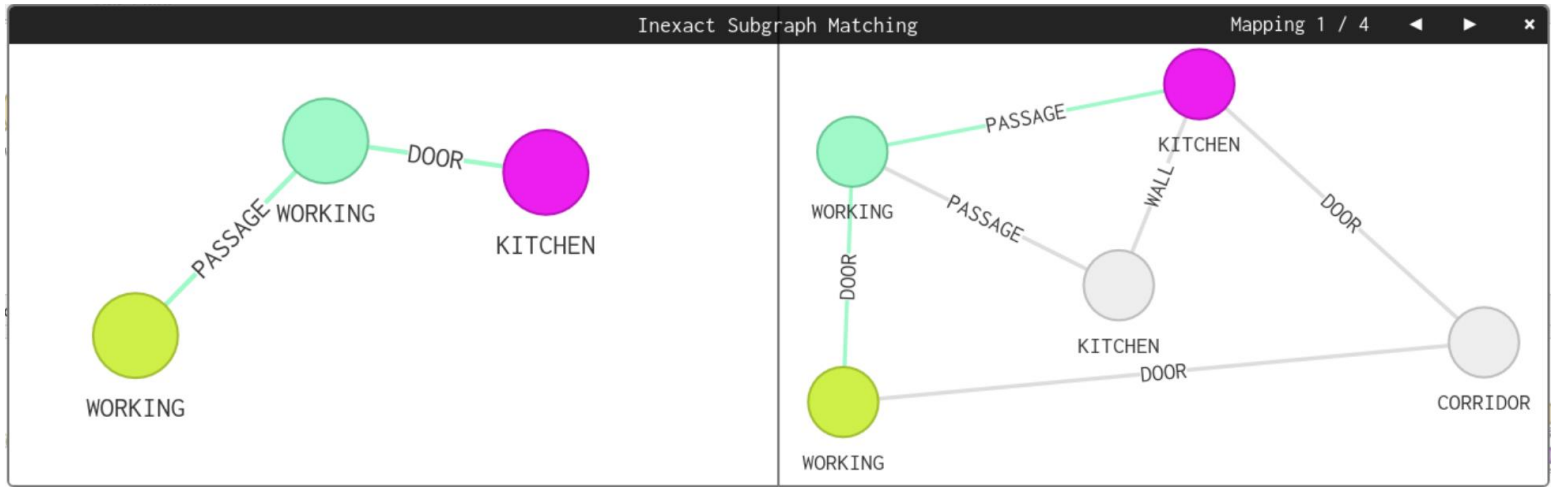
- After preselection
- Graph matching/*isomorphism*
- VF2 & CRI
  - Applied to rooms, adjacency, accessibility respectively
  - ..and all combined

Table 3. Currently implemented graph matching methods and semantic FPs.

Sem. Fingerprint	Algo.	Matching types	Features
`Room Graph`	CRI	Exact graphs w/o preselection	*Matches exact structure only* All semantics are ignored
`Adjacency`	VF2	Exact and inexact graphs and subgraphs	Semantics of edges are ignored *Matches rooms semantics only*
`Accessibility`	VF2	Exact and inexact graphs and subgraphs	Semantics of rooms are ignored *Matches edges semantics only*
`Full Room Graph`	VF2	Exact and inexact graphs and subgraphs	*Matches rooms as well as edges semantics*

EXACT VS. INEXACT MATCHING

- Exact
  - Room types (living, sleeping) + semantics (door, passage)
  - Exact match
- Inexact
  - Replacement strategies;
  - Similar rooms are interchangeable
  - Similar semantics are interchangeable



UI: ROOMCONF EDITOR

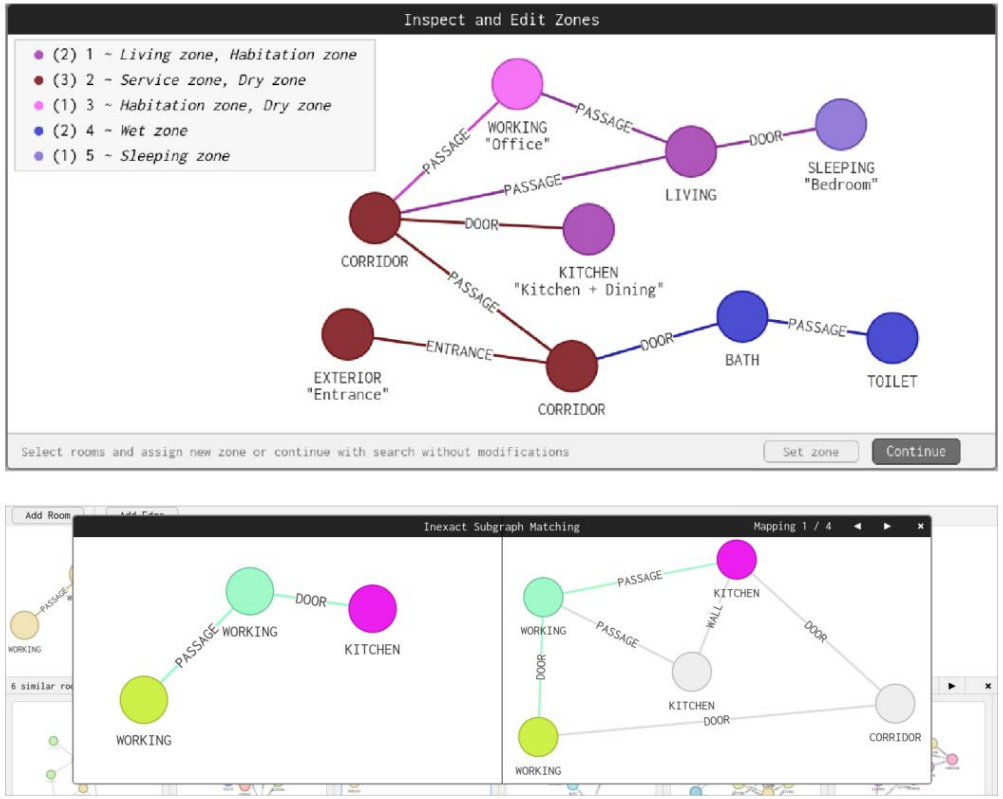


Fig. 3. RoomConf Editor. *Above:* Pre-search zone modification window. *Below:* The mapping between query (left) and case (right), where the room color codes indicate matched rooms and the edge colors show the connection direction. The user can click through different exact and inexact mappings. These are the mapping differences to Metis-WebUI that used arrows for rooms and the per-FP visualization. In the background, the query and the search results can be seen. (Color figure online)

COMPLETE SYSTEM

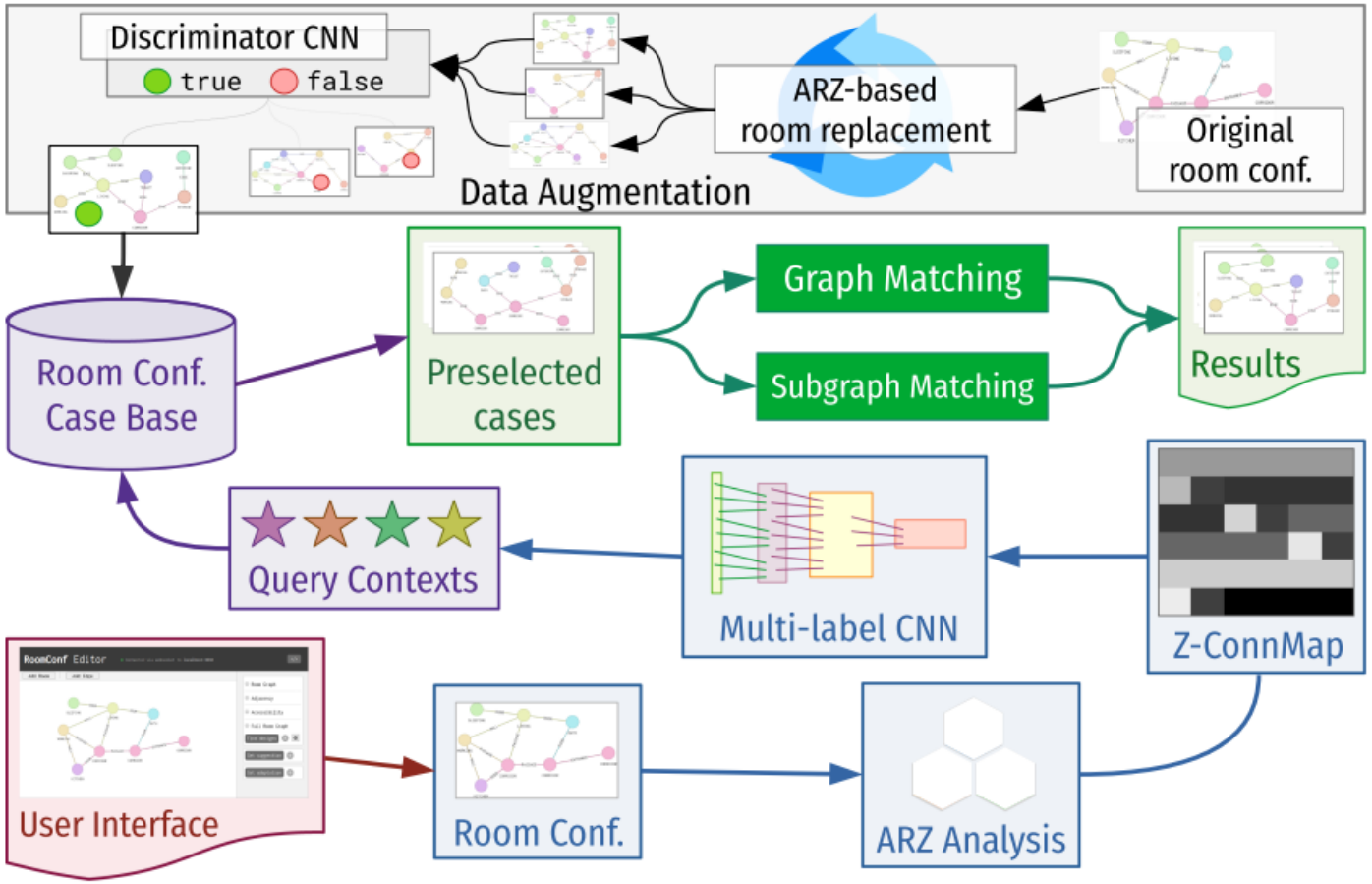
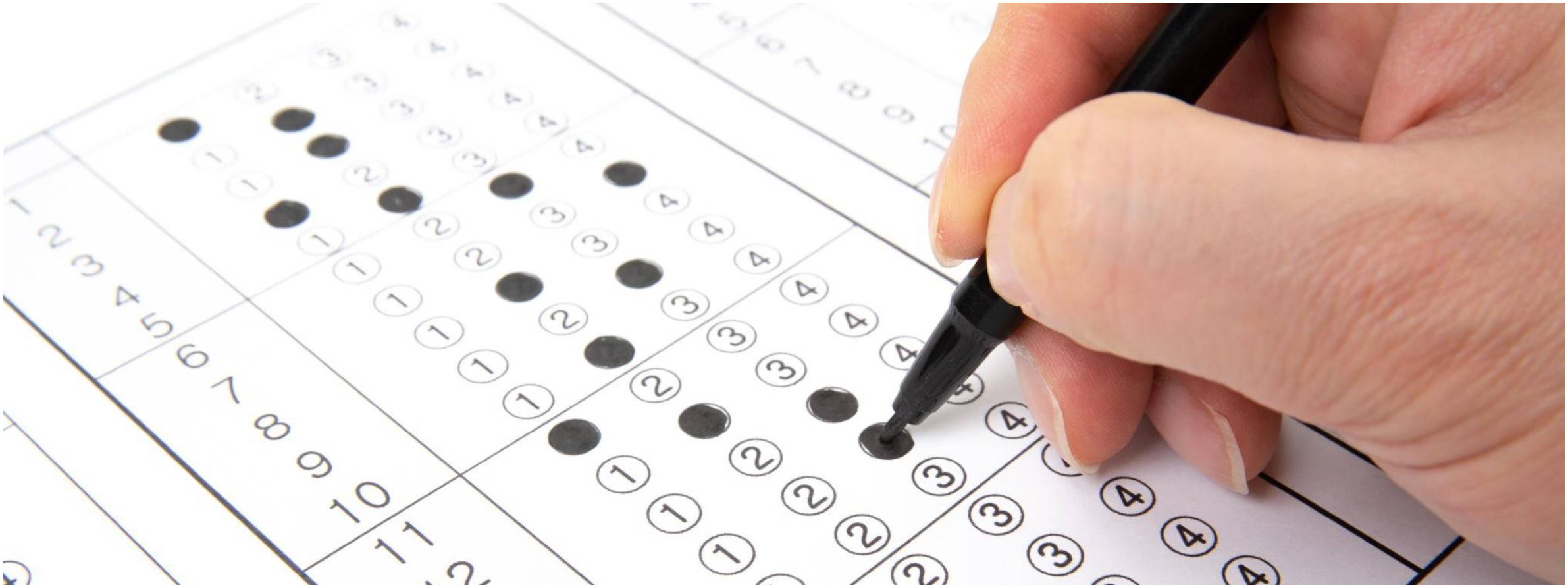


Fig. 2. Overview of the retrieval process of the combined system.



EVALUATION

WHAT ARE WE CHECKING?

Improvement of retrieval process by:

Adding zones	Using zoned connection maps	..for context-based preselection	..combined with exact & inexact (sub)graph matching

Combine the above with the UI

ANALYSIS STATISTICS

2852 room configuration cases

- 250 manually created
- 2602 generated

For preselection:

- CNN labeller trained on 250 original cases
- Labelled the rest (prediction)
- ..then trained on them afterwards

QUANTITATIVE ANALYSIS

- Complexity calculated as $|N_{edges}| \cdot |N_{nodes}|$
- 20 queries of varying complexities
- Retrieval ***time*** predominant metric

PRESELECTION RESULTS

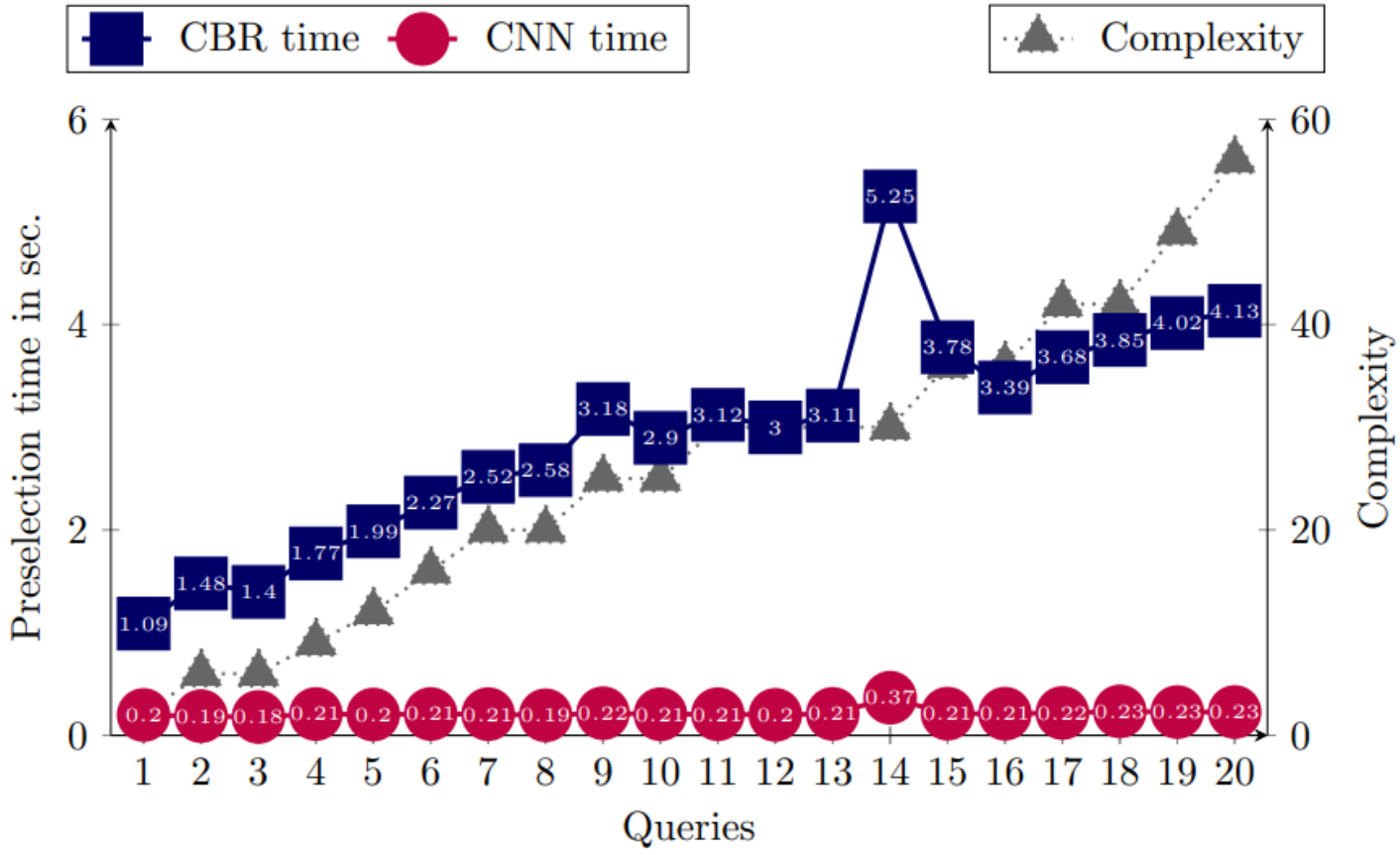
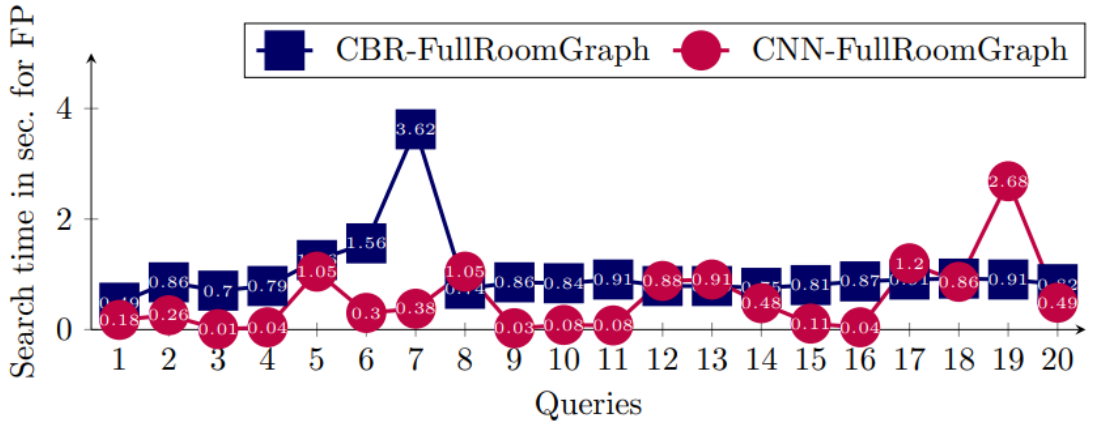
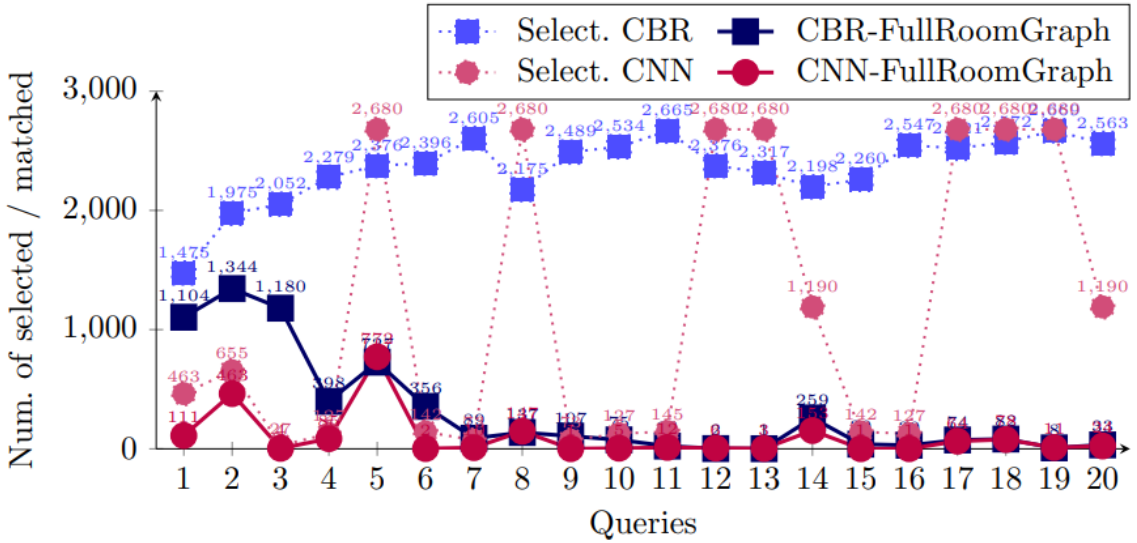


Fig. 4. Results of the preselection evaluation.

GRAPH MATCHING RESULTS





USER STUDY

8 people tested application

Thinking out loud – say what you are thinking

Tasks:

- Create room configuration
- Initiate search process
- Rate relevance of results using similarity examination

Finally – verdict; usable for education?

RESULTS

UI satisfactory, however..	Semantic FPs were unknown to users, caused confusion Bubbles (nodes) should scale with room area
Zones:	Some required more explanation
Some stretched the system – created deliberate bad designs	System self-corrected after zone changes
Conclusions?	All were positive – none completely declined All could see potential use in education at different levels

CONCLUSIONS

Created an AI-based digital assistance system for **education**

Specific interface

CNNs and graph matching to find similar reference of room configurations

Evaluated through quantitative experiment and user study

Future work – use user feedback to further develop application

REFLECTIONS

DISCLAIMER: I MIGHT BE STUPID

REFLECTIONS

- Overall idea very cool
- Inspiring to see educational angle
- Z-ConnMap confusing
  - Matrix structure unclear
- Preselection phase – why?
  - Didn't really understand the point
- Interesting to see combination with additional generative AI for complete floor plan generation