COMPASS

Cardinal Orientation Manipulation and Pattern-Aware Spatial Search

ACM SIGSPATIAL GEOSEARCH WORKSHOP

Kent O'Sullivan | Nicole Schneider | Hanan Samet

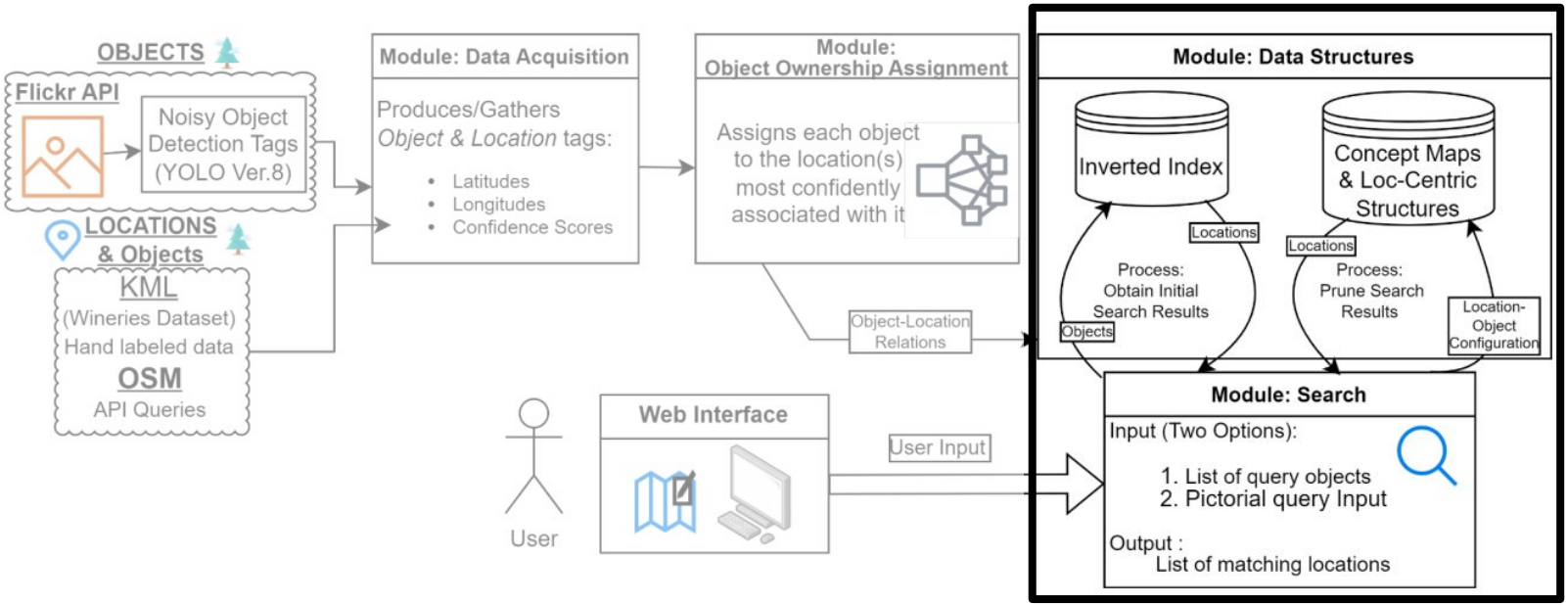
13 Nov 2023

Presentation Scope

1. Overview.
2. Background and current limitations.
3. Location-centric spatial pattern matching.
4. Object-centric spatial pattern matching.
5. Demo of COMPASS algorithms and data structures.
6. Conclusion and future directions.

GESTALT Architecture

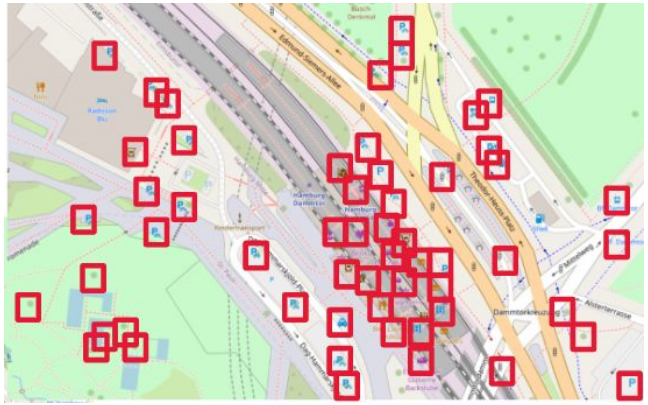
Data Structures & Search



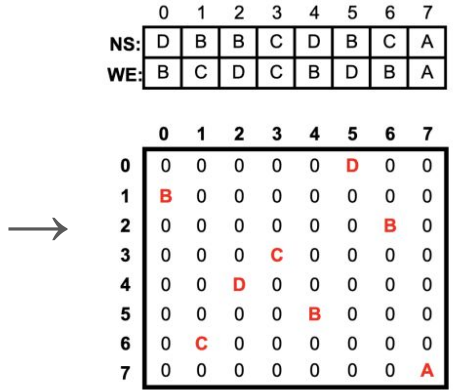
COMPASS provides scalable Spatial Pattern Matching (SPM)

Enables spatial search over objects and locations

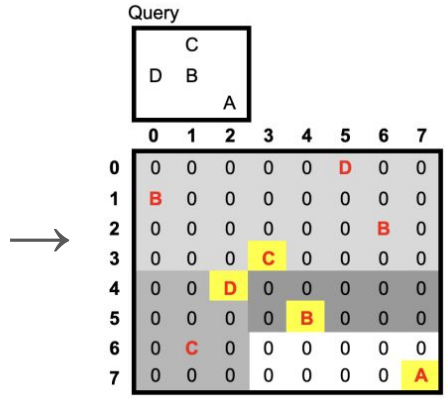
- **Data structure**: Matrix-based encoding of relative object positions
- **Search**: Recursively prunes the matrix until a match is identified



Collect.



Encode.



Search.

Most approaches to SPM are **at least cubic** in complexity

Keyword, **metric**, and **topological** constraints:

- Ignore critical spatial information

Directional constraints:

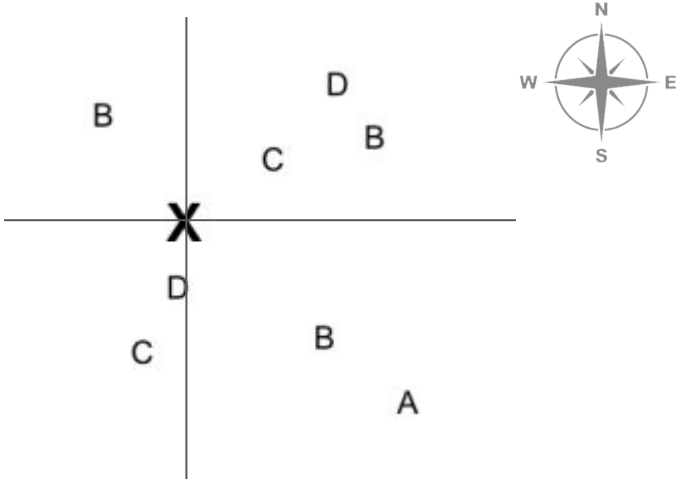
- Encode spatial patterns as *pairwise* constraints

Algorithm	Implementation			Relationship Constraints				Search Features			Complexity
	Encoding	Search	Objects	Keyword	Metric	Topological	Directional	Fuzzy	Negation	Card. Inv.	
SKECa+ [13]	N/A	SKQ	**P**	X	X				X	N/A	$O(rn^Q)$
PQL [8]	Set	SI	P,L,R	X	X	X	X	X	X		Unclear
McheckSsl [21, 22, 24]	Set	SI	P	X	X				X		$O(n'^2 + 2^{n'})$
GESTALT$_{SI-Basic}$ [18]	Set	SI	P	X						N/A	$O(Gn)$
GESTALT$_{SI-Ranked}$ [18]	Set	SI	P	X						N/A	$O(G(n + n'Q))$
GESTALT$_{SI-Fuzzy}$ [18]	Set	SI	P	X				X		N/A	$O(QGn)$
PQIS [12]	Link	SGM	P	X	X		X		X		$O(m^m)$
Spacekey$_{MPJ}$ [10, 11]	Link	SKQ & SGM	P	X	X			X	X		$O(m\zeta^2 + \xi)$
Spacekey$_{SPJ}$ [10, 11]	Link	SKQ & SGM	P	X	X			X	X		$O(n^4 + mn^2 + \xi)$
ESPM [5]	Link	SKQ & SGM	P	X	X			X	X		$O(n'^n)$
MSJ$_{MSJ}$ [19]	Link	CSP	P,L,R		X	X	X	X			$O(n^Q)^\star$
MSJ$_{WR}$ [19]	Link	CSP	P,L,R		X	X	X	X			$O(n^m)^\star$
MSJ$_{JWR}$ [19]	Link	CSP	P,L,R		X	X	X	X			$O(n^m)^\star$
STARVARS [16]	Segment	CSP	P				X			X	$O(m^n)$
SketchMapia [15, 20]	Link	SGM	P,L,R	X		X	X	X		X	Unclear
OSS [17]	Segment	Other	P,R		X	X	X			X	$O(n)^\star$
SRQL [6, 7]	Segment	Other	R	X		X	X		X		Unclear
COMPASS$_{LO}$ [ours]	Set	SI	P	X			X		X		$O(G(Q + n))$
COMPASS$_{OO}$ [ours]	CM	RGS	P	X			X				$O(G(Q + n^2))$
COMPASS$_{CI}$ [ours]	CM	RGS	P	X			X			X	$O(G(Q^2 + Qn^2))$

Table 2: Summary of related work.
Where the authors do not provide worst-case complexity, we estimate (denoted with *). n is the number of spatial objects in the database, m is the number of relations, G is the number of object collections (locations) to search over, Q is the number of query objects, n' is the subset of objects matching a keyword query, ζ is a sampling threshold in $[0, 1]$ and ξ is the maximal number of partial matches to a query

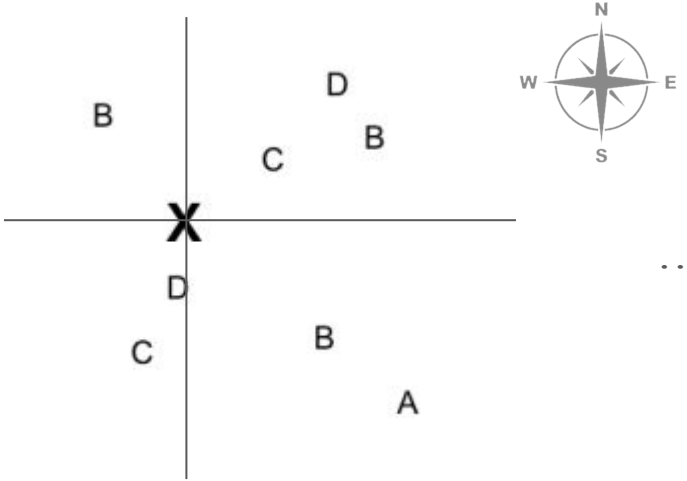
Location-Centric Spatial Pattern Matching

Given a known set of objects and how they each relate to a central location…



Location-Centric Spatial Pattern Matching

Given a known set of objects and how they each relate to a central location…



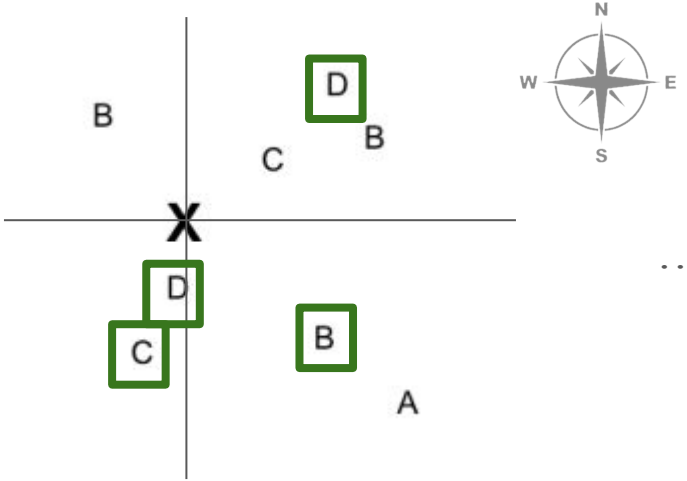
… and a sketch map or pictorial query…

Query

E	|	D
-	X	-
C,D	|	B

Location-Centric Spatial Pattern Matching

Given a known set of objects and how they each relate to a central location…



… and a sketch map or pictorial query…

Query

E	|	D
-	X	-
C,D	|	B

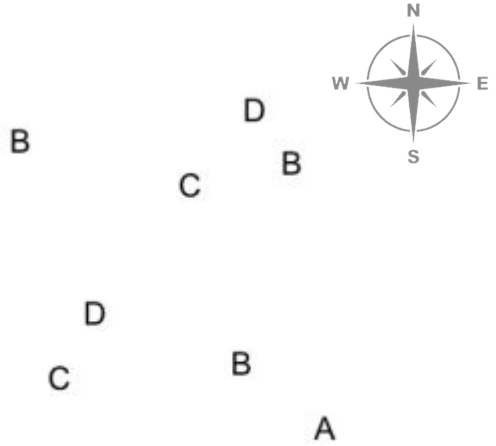
… determine which known locations are a match for the query.

COMPASS: Cardinal Orientation Manipulation and Pattern-Aware Spatial Search

Searching for **objects** by their directional relations to their associated **location**

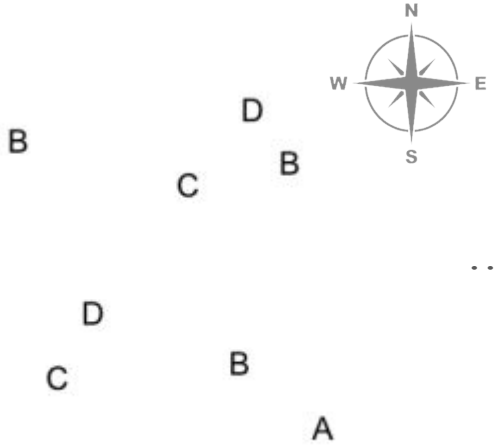
Object-Centric Spatial Pattern Matching

Given a known set of objects arranged in a spatial pattern…

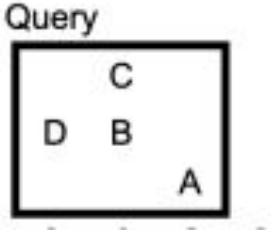


Object-Centric Spatial Pattern Matching

Given a known set of objects arranged in a spatial pattern…

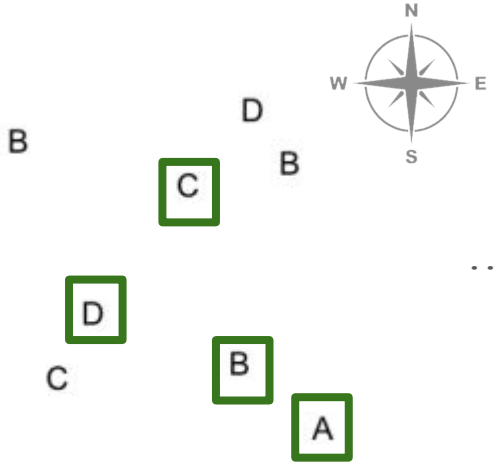


… and a sketch map or pictorial query…

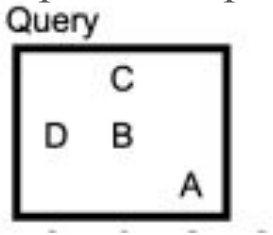


Object-Centric Spatial Pattern Matching

Given a known set of objects arranged in a spatial pattern…



… and a sketch map or pictorial query…



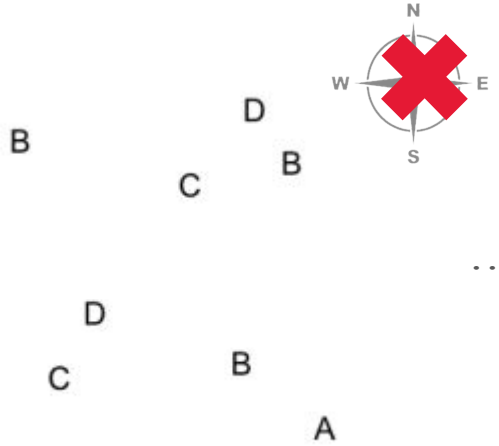
… determine if the query matches at least one set of known objects.

COMPASS: Cardinal Orientation Manipulation and Pattern-Aware Spatial Search

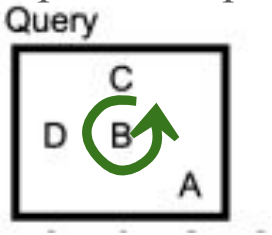
Searching for **objects** recursively by their directional relations to other **objects**

Cardinality-Invariant Object-Centric Spatial Pattern Matching

Given a known set of objects arranged in a spatial pattern…



… and a sketch map or pictorial query…



… determine if ***any orientation*** of the query matches at least one set of known objects.

COMPASS: Cardinal Orientation Manipulation and Pattern-Aware Spatial Search

Searching for **objects** by their directional relations to other **objects**, *regardless of cardinal orientation of the query*

Summary

- We present COMPASS, a suite of data structures and scalable search algorithms that enable spatial pattern matching over sets of objects associated with a location

Future directions

- Extend COMPASS to find ***all*** instead of ***any*** match to the query pattern.
- Extend our theoretical analysis of COMPASS with an empirical comparison against related works.
- Investigate if the COMPASS matrix-based embedding can be extended to support line and region data.

Questions

Kent O'Sullivan osullik@umd.edu

Nicole R Schneider nsch@umd.edu

Hanan Samet hjs@cs.umd.edu