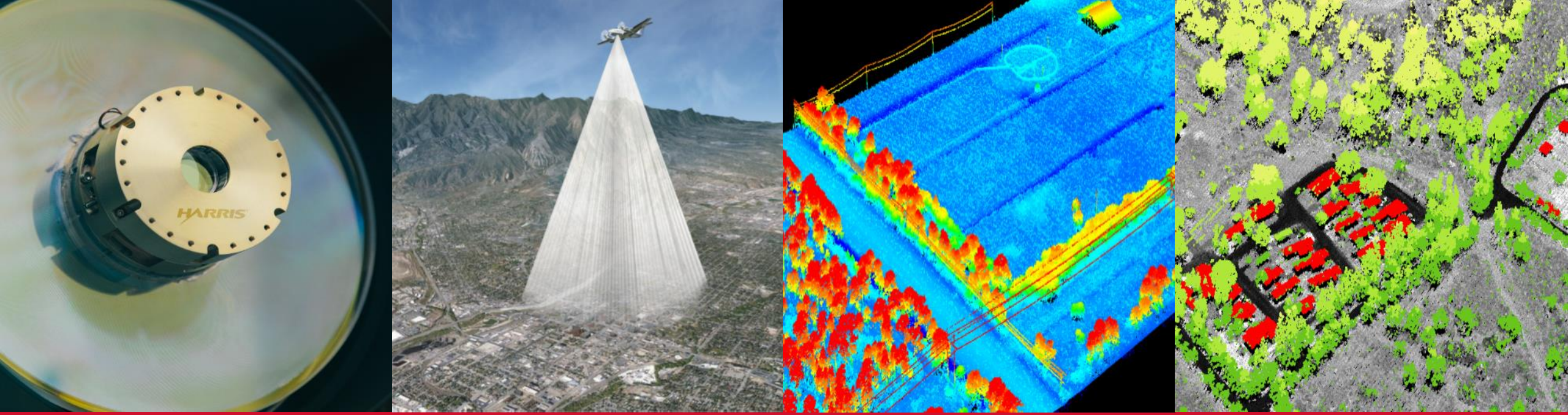


BASIC COINCIDENCE PROCESSING

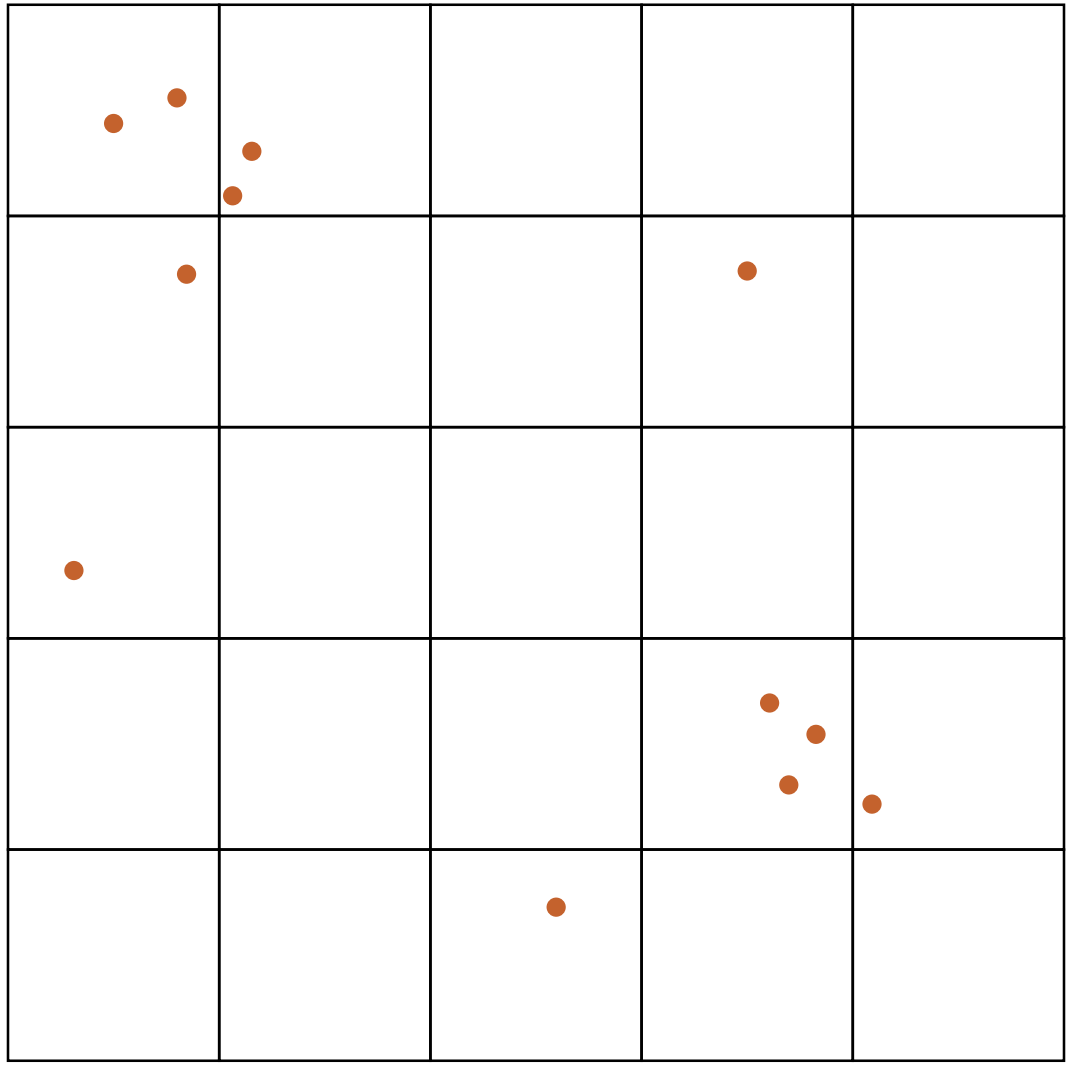
KRISTIAN DAMKJER

Manager, Software Engineering

Contents

SCENARIO OVERVIEW

Frame 1



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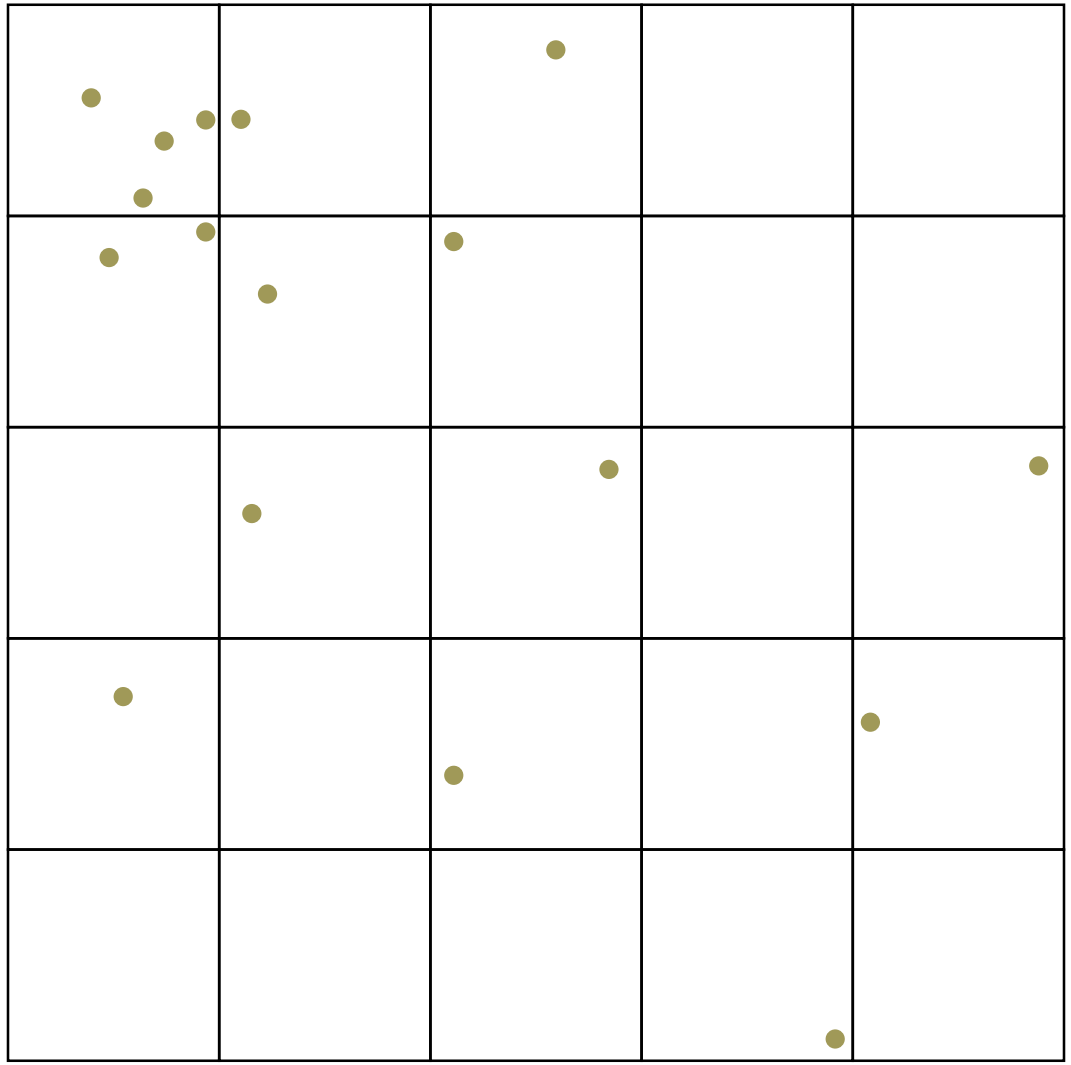
●	2	1	100.01
●	101	2	1004.5

Frame 2



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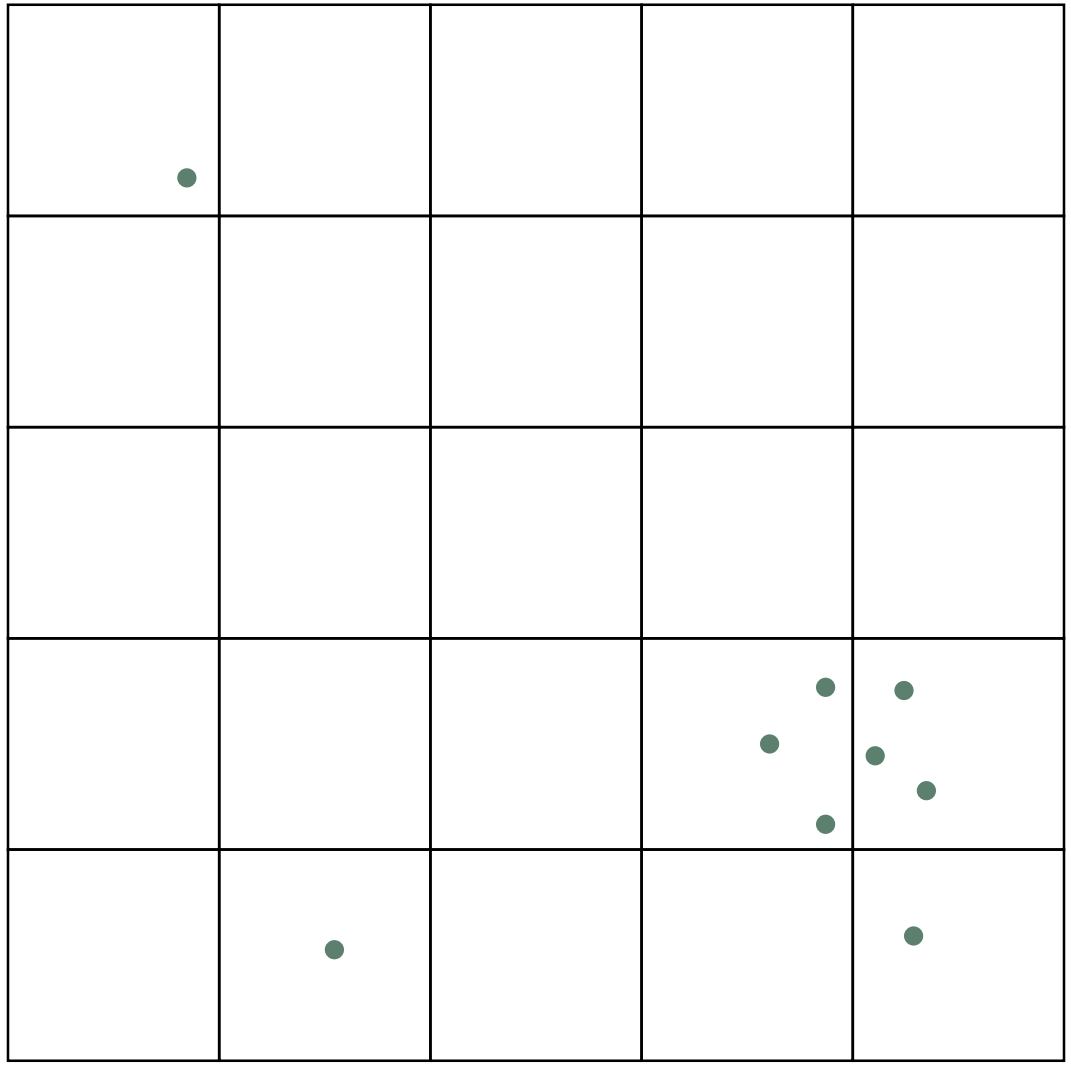
2	1	100.01
101	2	1004.5

Frame 101



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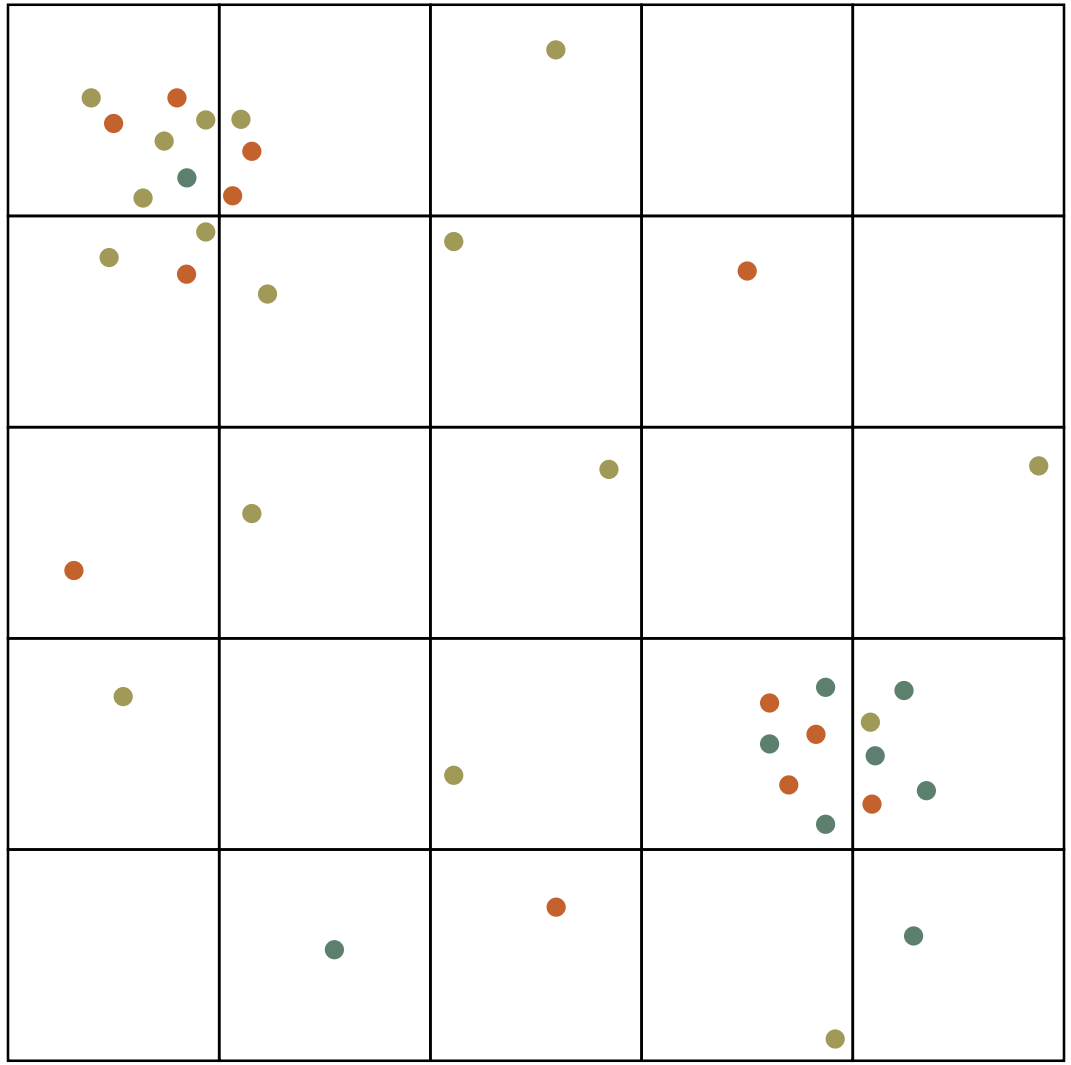
2	1	100.01
101	2	1004.5

Aggregate — What is Signal vs. Noise?



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2	1	100.01
101	2	1004.5

1-D COINCIDENCE

Identify Signal above Noise Threshold

	Frame	Source	Time
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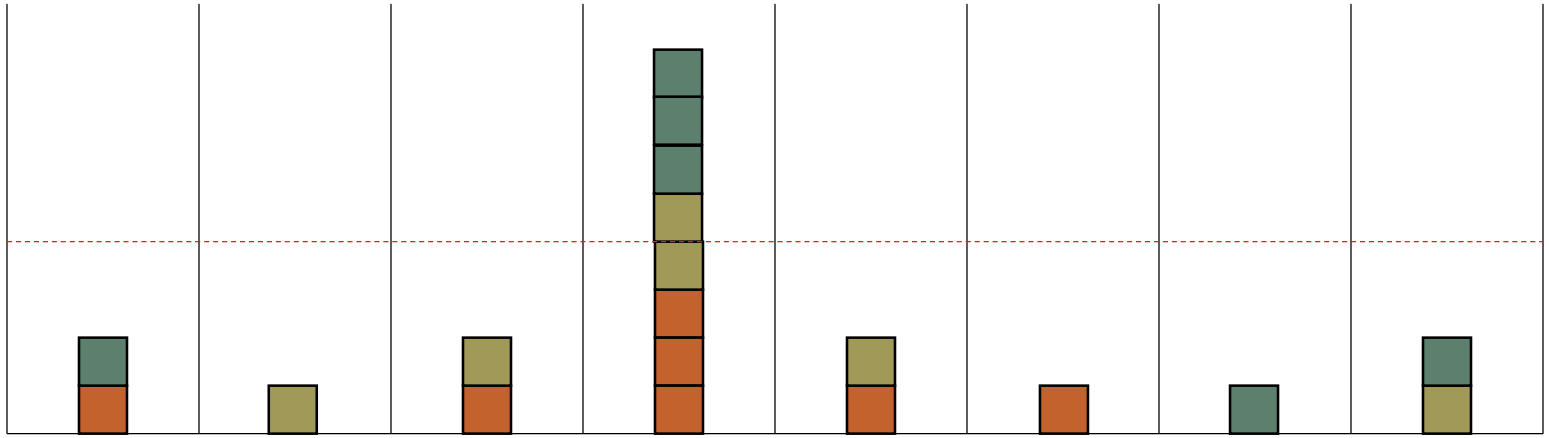
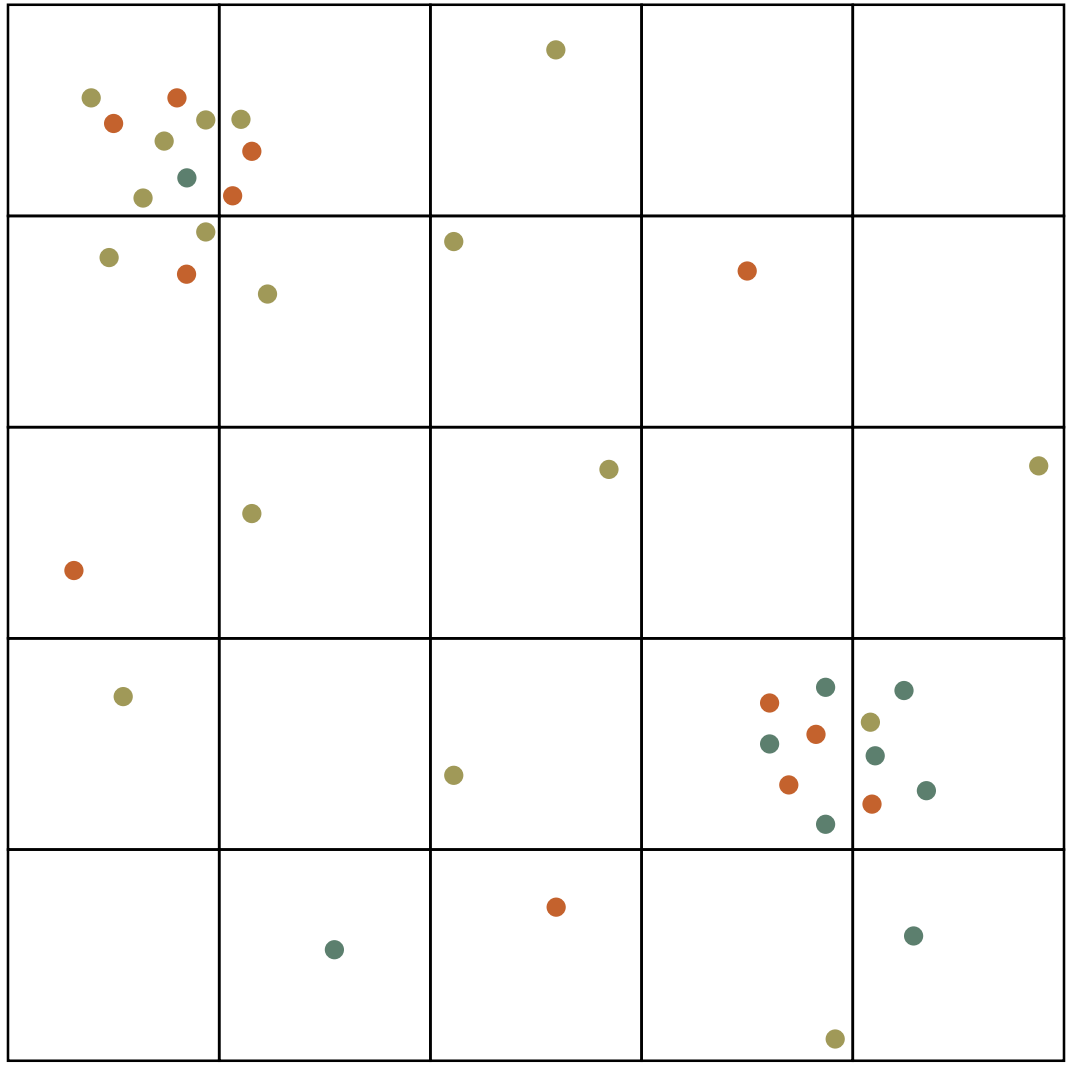
●	2	1	100.01
●	101	2	1004.5



2-D COINCIDENCE

How to Extend 1-D Coincidence?

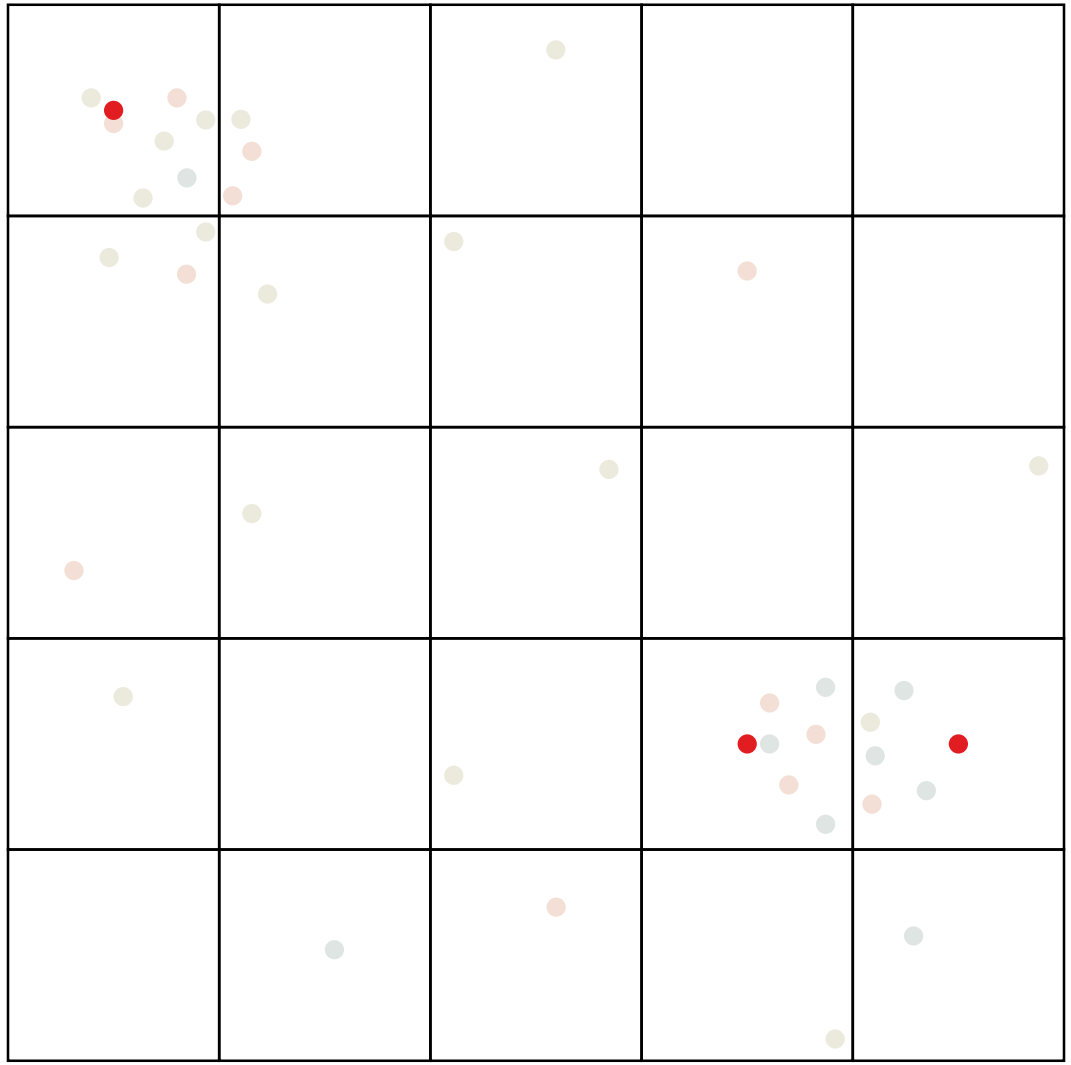


	Frame	Source	Time
●	1	1	100.00
●	2	1	100.01
●	101	2	1004.5

Threshold Hits in Each Pixel?

7	3	1		
3	1	1	1	
1	1	1		1
1		1	6	5
	1	1	1	1

Where to Place Consensus Points? What Metadata?



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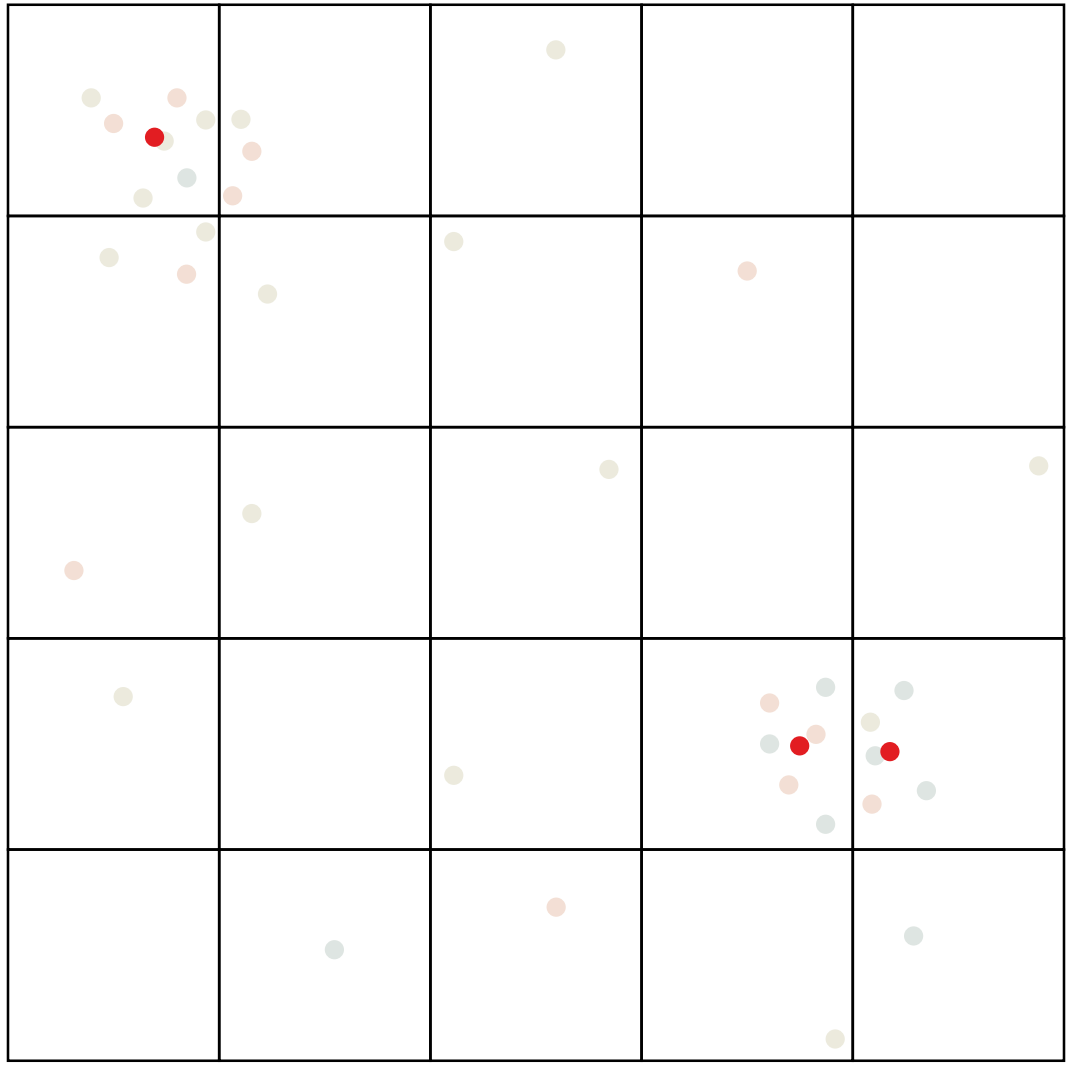
●	2	1	100.01
●	101	2	1004.5
●	?	?	?

Center of Mass in Each Pixel? Metadata?



	Frame	Source	Time
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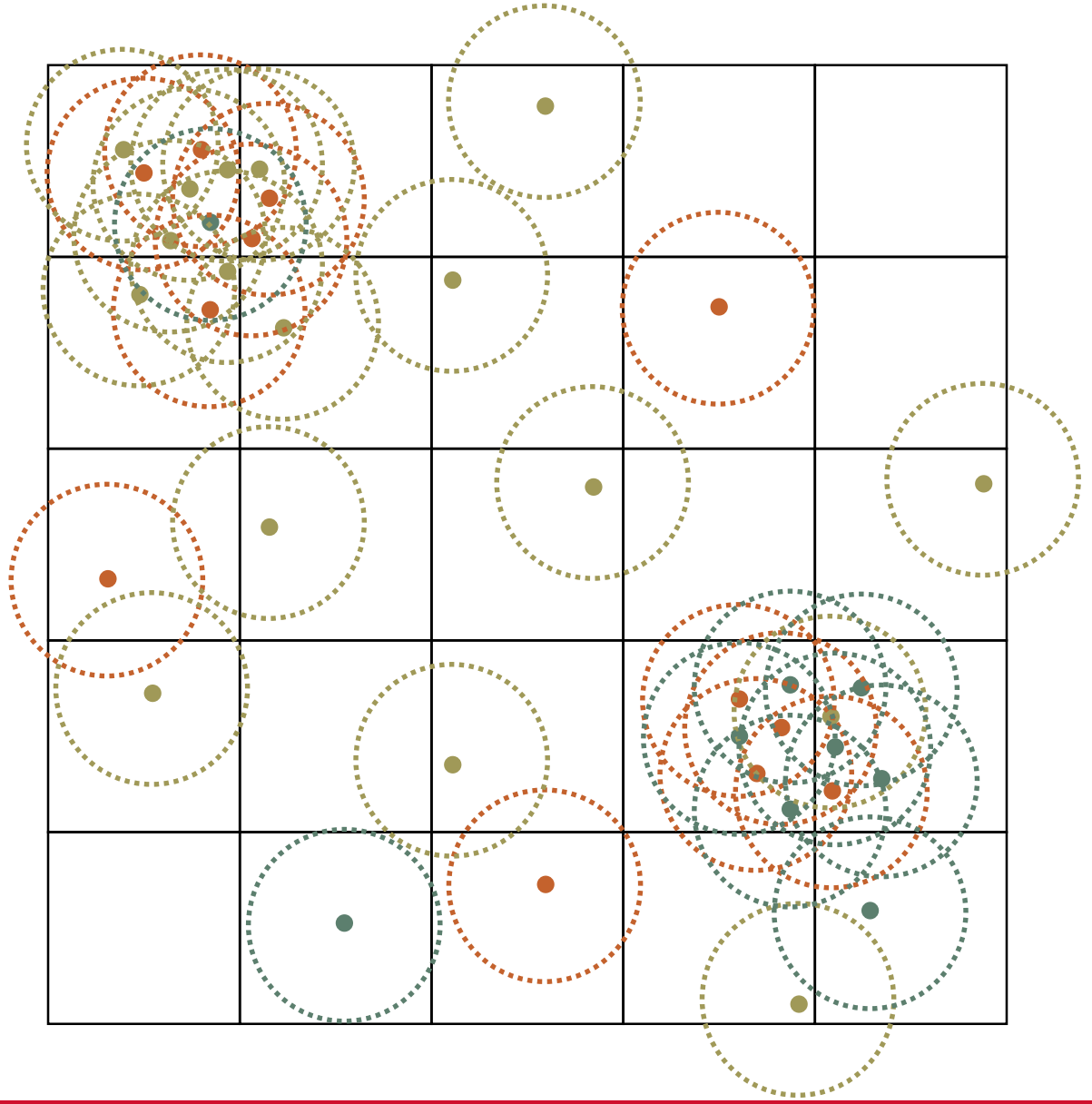
●	2	1	100.01
●	101	2	1004.5
●	?	?	?

2-D RADIAL COINCIDENCE

Check for Coincidence Everywhere — Euclidian Metric



Frame	Source	Time
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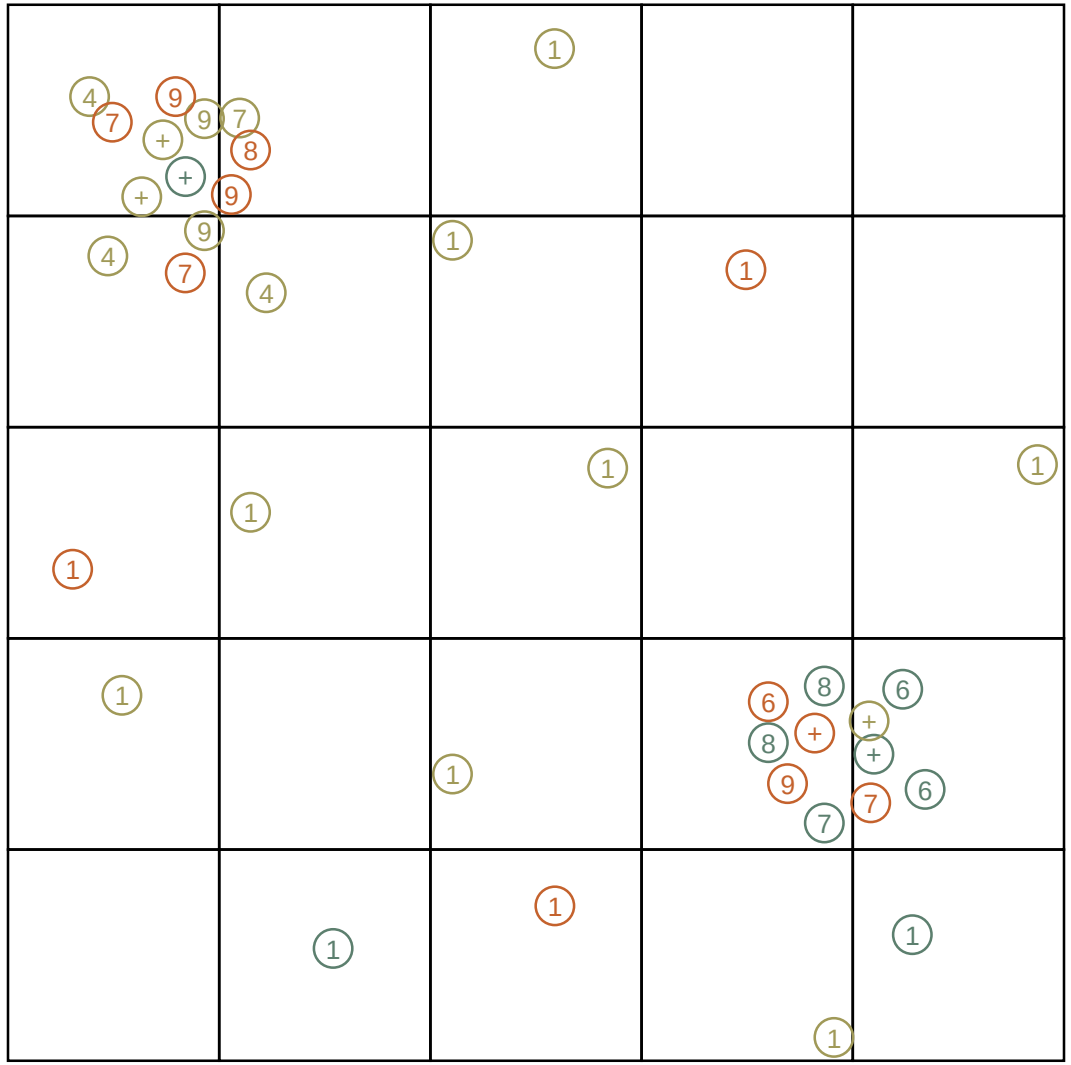
2	1	100.01
101	2	1004.5

Count Neighbors — i.e., Points Coincident within Threshold



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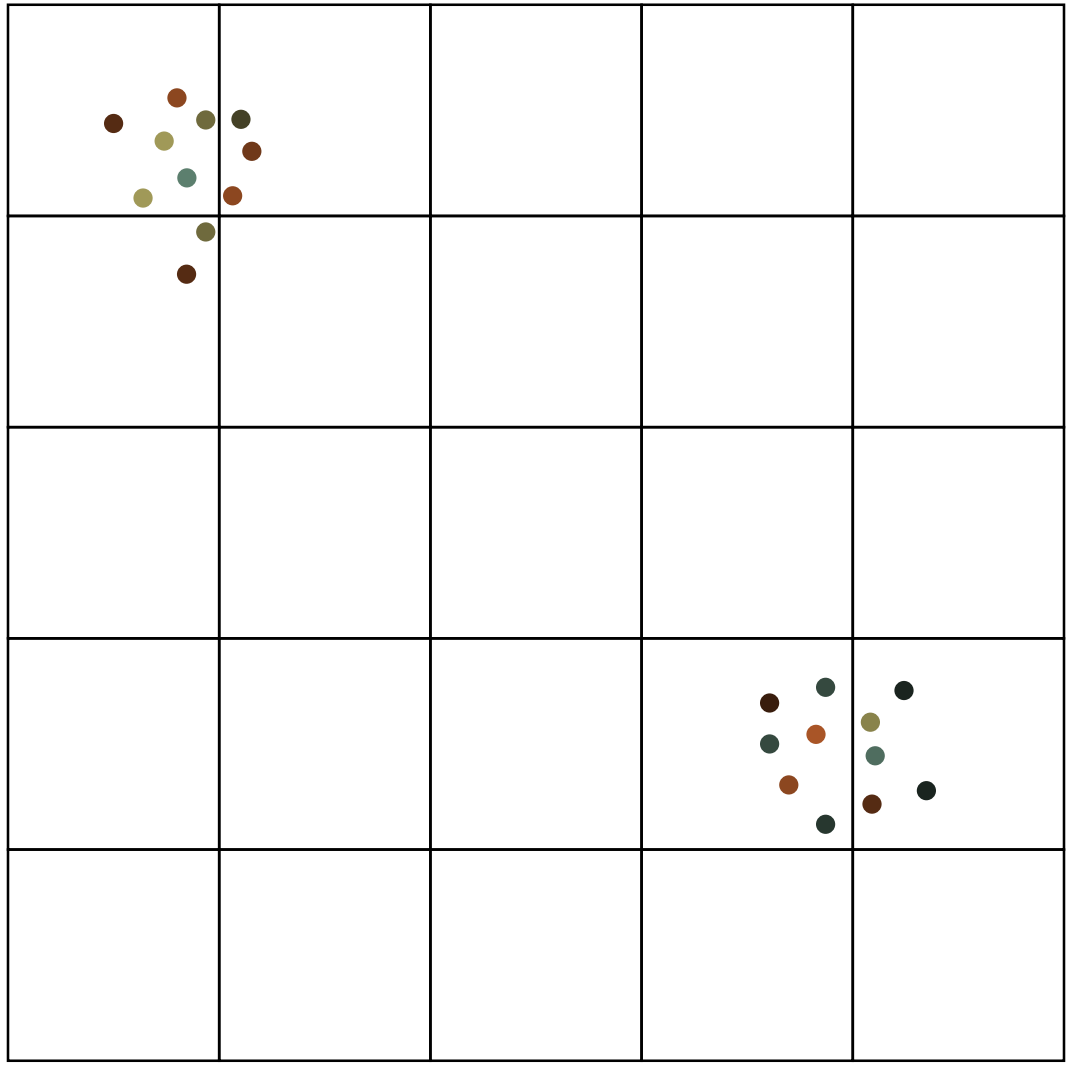
●	2	1	100.01
●	101	2	1004.5

Eliminate Points Lacking Neighbors — Final Consensus?

- **Pick strongest return in each sample volume?**
- **What to do in case of a tie?**



	Frame	Source	Time
●	1	1	100.00
●	2	1	100.01
●	101	2	1004.5

Other Types of Simple Coincidence

Alternative Metric Spaces

- **Manhattan Distance vs. Euclidean Distance equates to “box” volumes instead of “ball” volumes.**
- **Other metric spaces possible.**

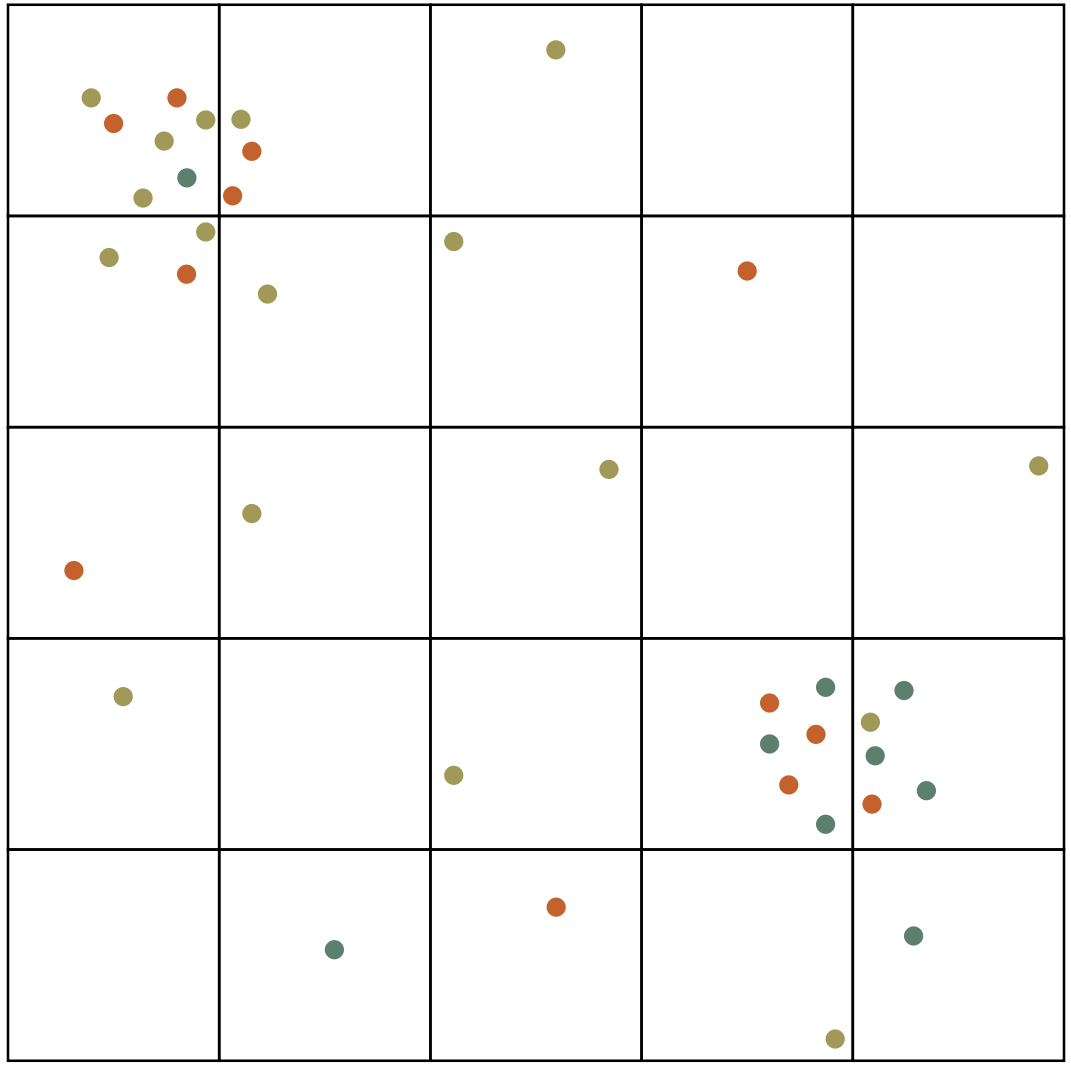
Count-Based Neighborhood

- **Inverts coincidence relationship. Threshold based on reach required to envelop a fixed number of neighbors vs. number of neighbors observed within a fixed reach.**

BASIC QUERY POINT STRATEGIES

Avoid Synthetic Points: Partition Raw Data

- **Select a single point per sample volume to act as a representative**
- **Remaining points act as support for coincidence processing**
- **Final points are always direct measurements**
- **Metadata association is straight-forward**
- **Avoids unnecessary computational complexity**



	Frame	Source	Time
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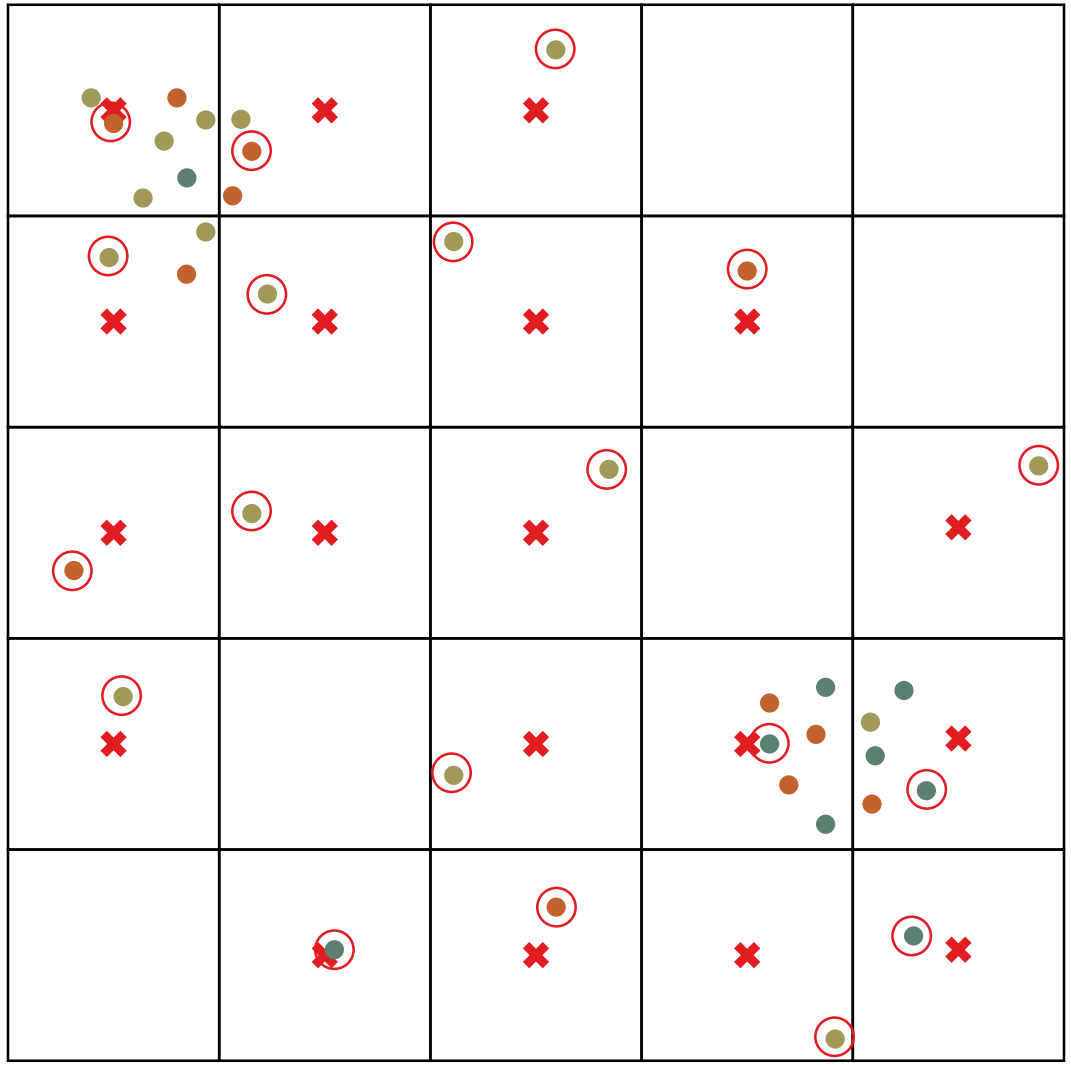
●	2	1	100.01
●	101	2	1004.5

BASIC QUERY POINT STRATEGIES: NEAREST CENTER

Nearest Center Queries



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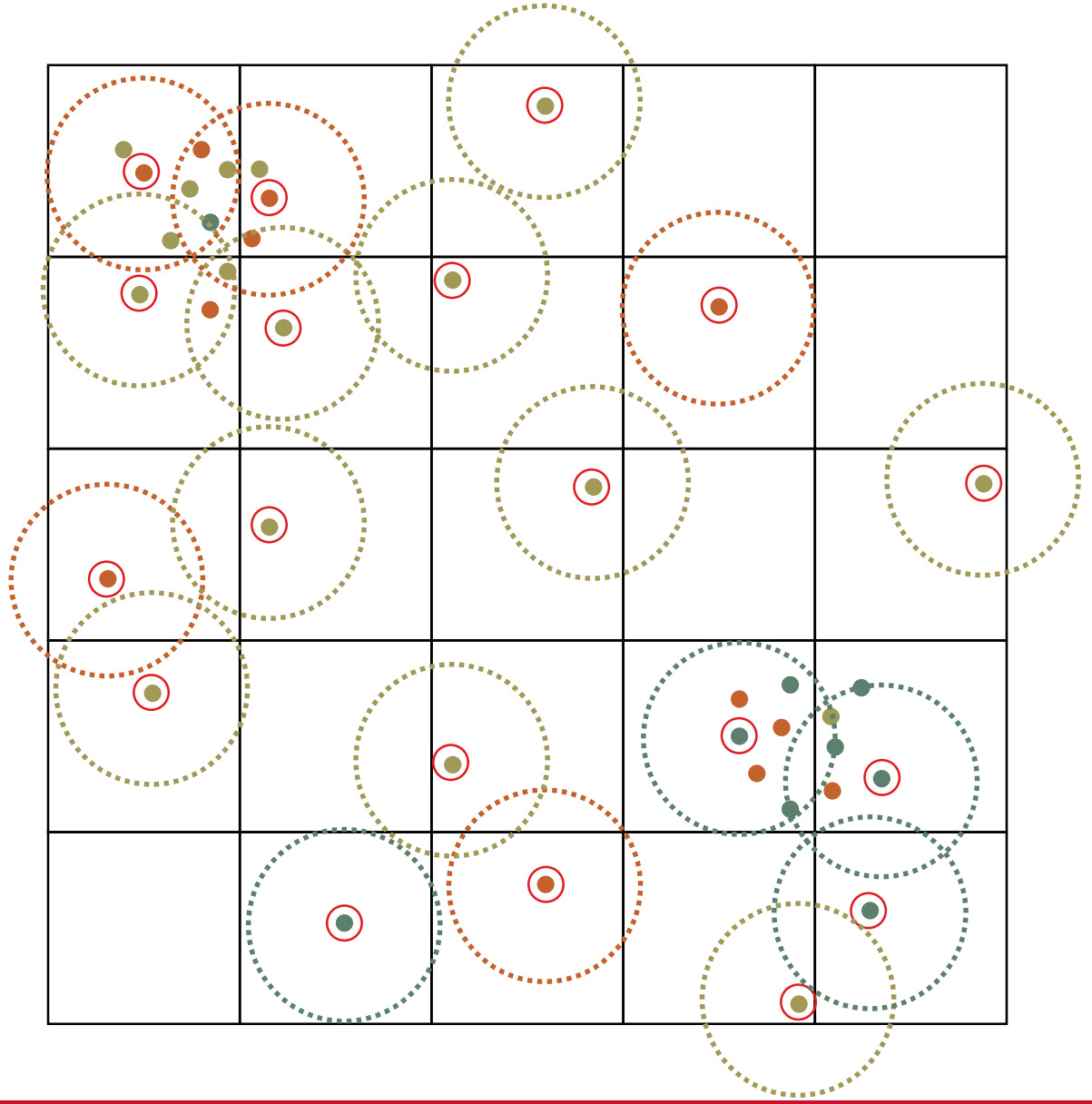
●	2	1	100.01
●	101	2	1004.5

✖ Pixel Center

○ Selected Query Point

Establish Coincidence at Queries

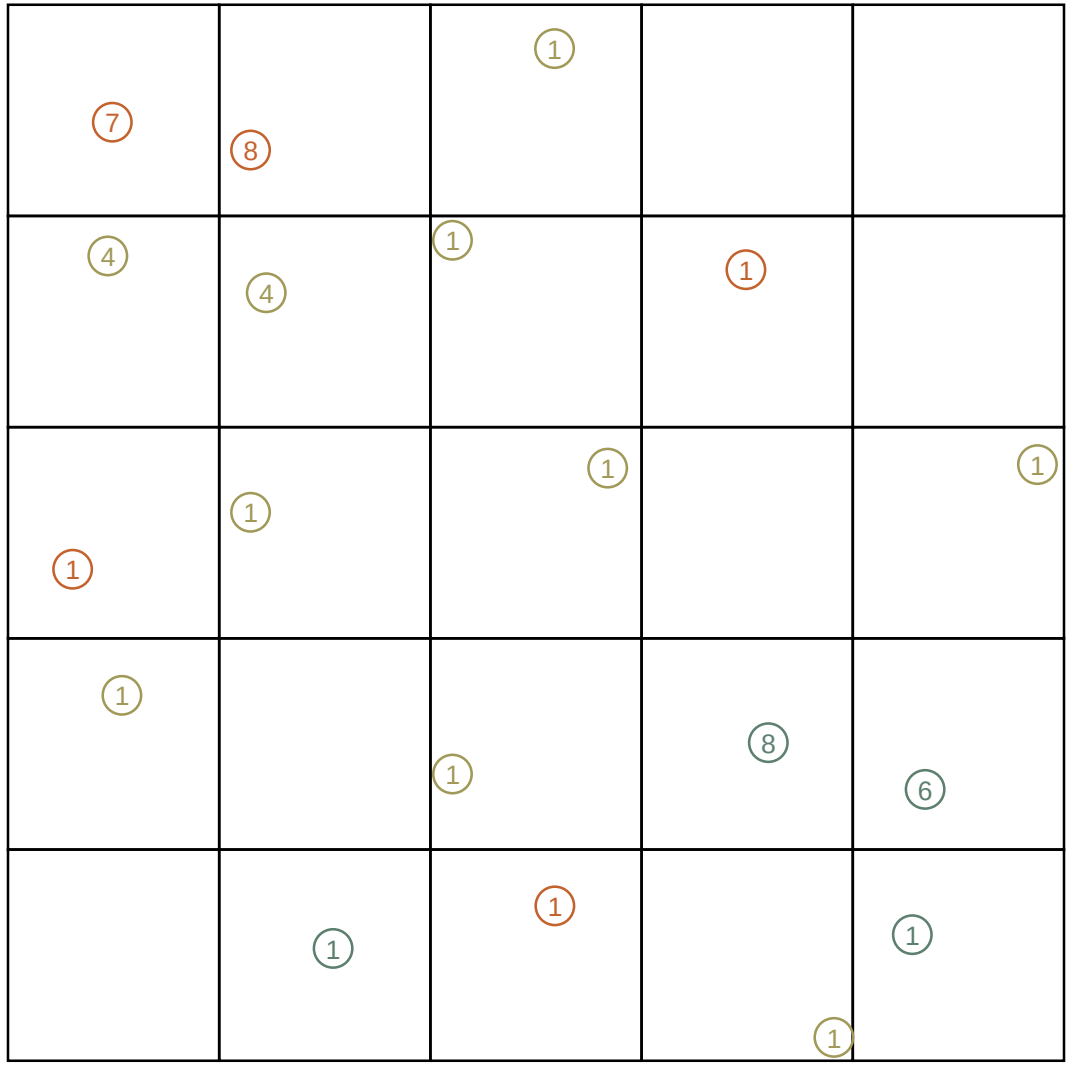


	Frame	Source	Time
●	1	1	100.00
●	2	1	100.01
●	101	2	1004.5

✖ Pixel Center

○ Selected Query Point

Count Neighbors — i.e., Points Coincident within Threshold



	Frame	Source	Time
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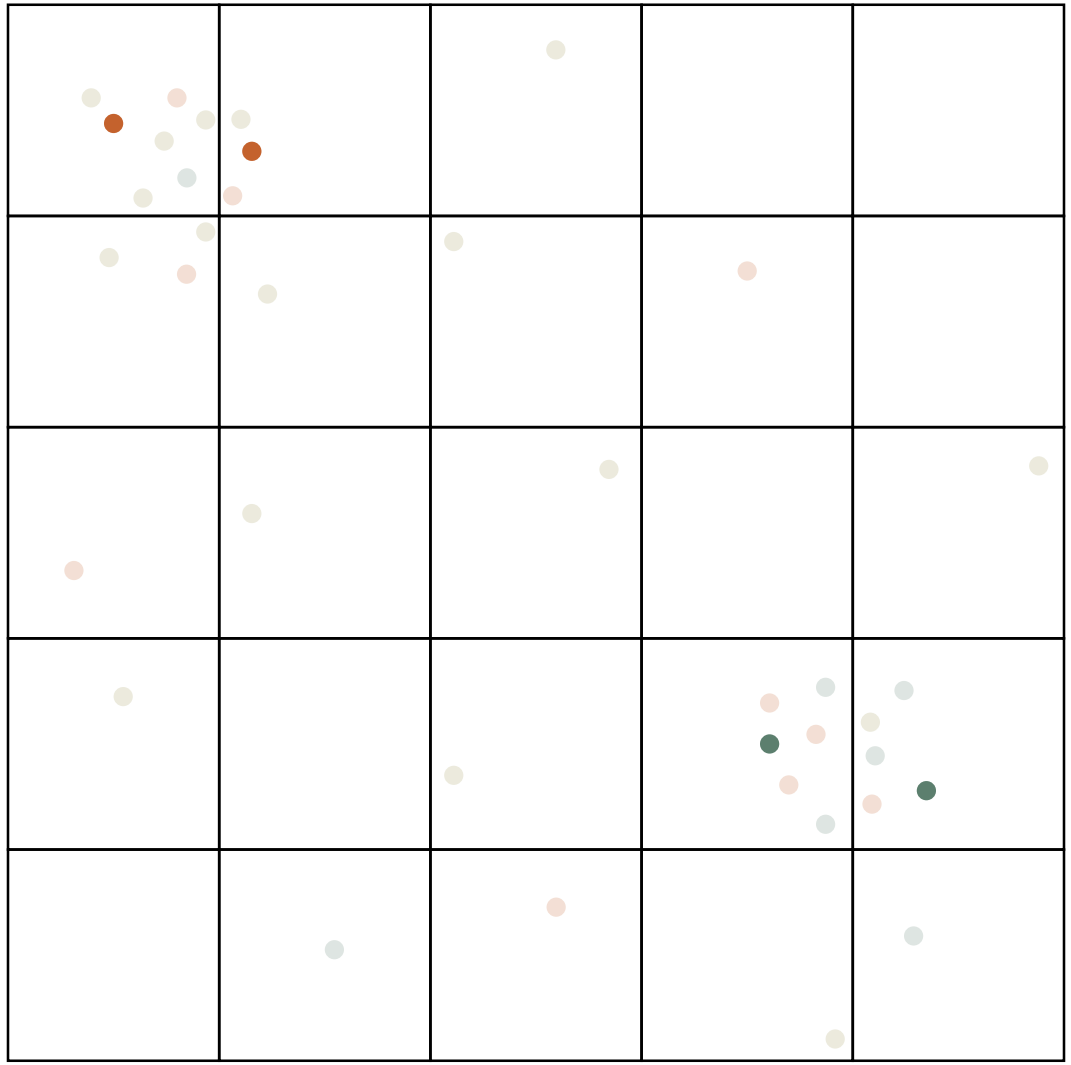
●	2	1	100.01
●	101	2	1004.5

Eliminate Support and Queries Lacking Coincident Neighbors



	Frame	Source	Time
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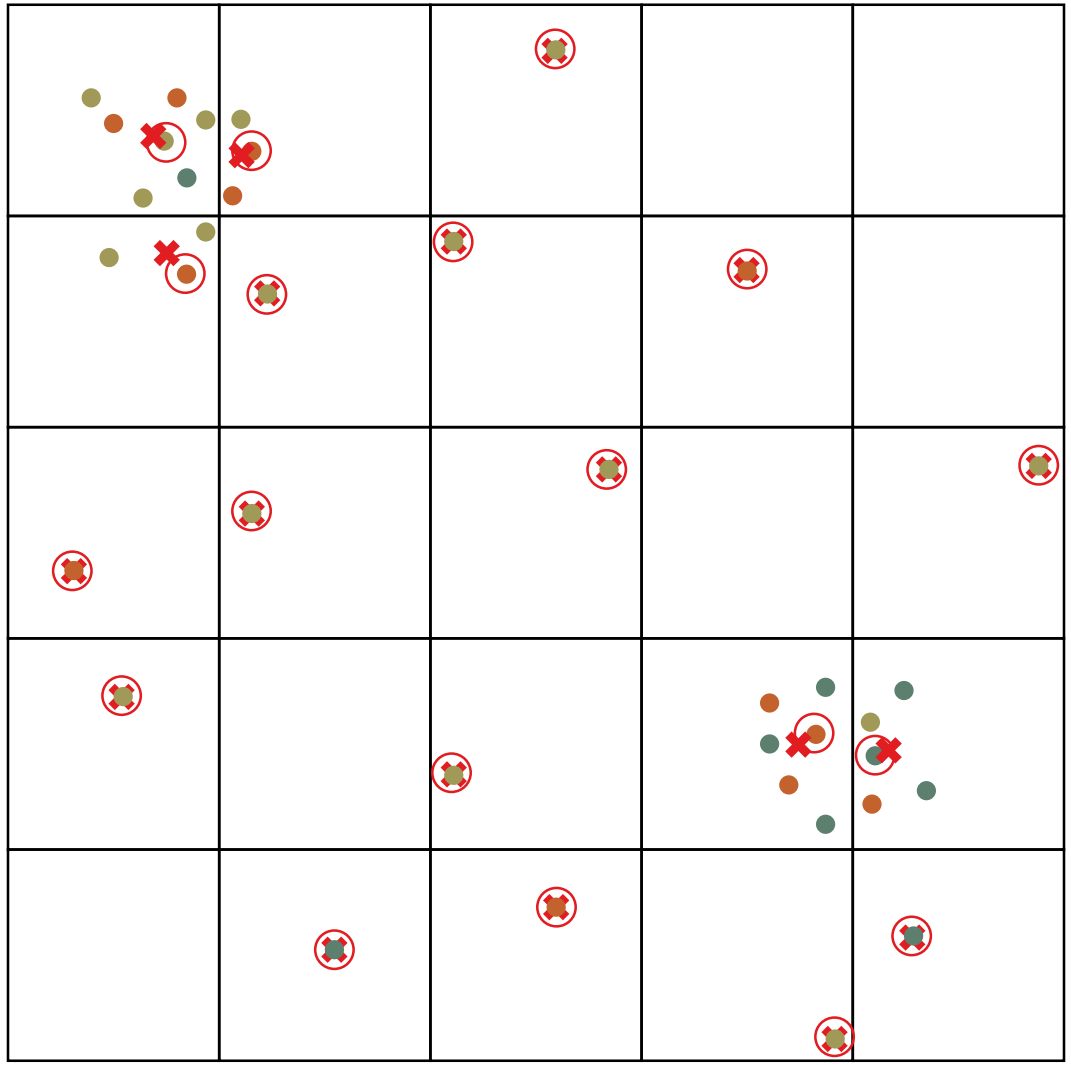
●	2	1	100.01
●	101	2	1004.5

BASIC QUERY POINT STRATEGIES: MASS POINT

Mass Point Queries

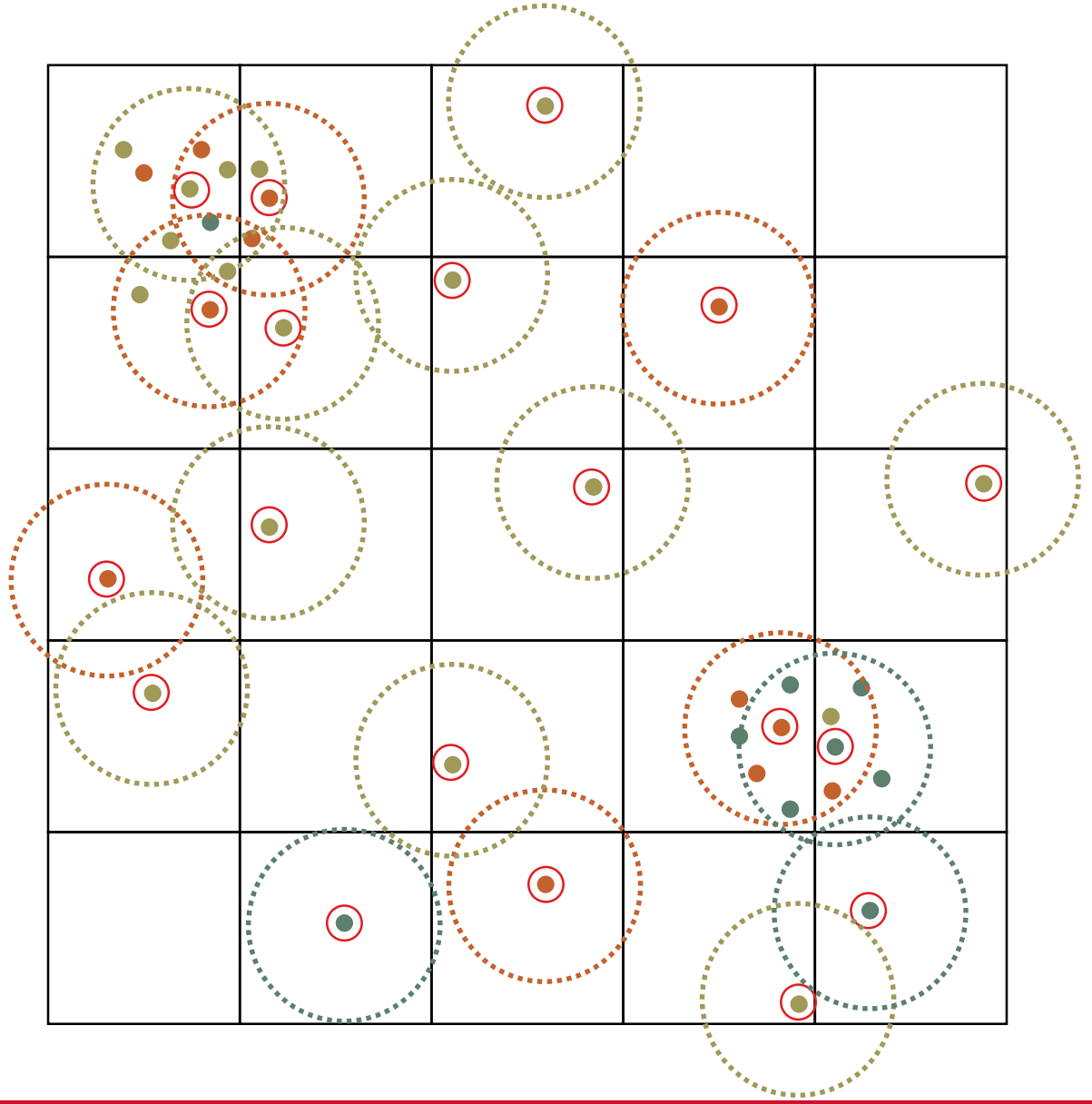


	Frame	Source	Time
●	1	1	100.00
●	2	1	100.01
●	101	2	1004.5

✖ Pixel Center of Mass

○ Selected Query Point

Establish Coincidence at Queries

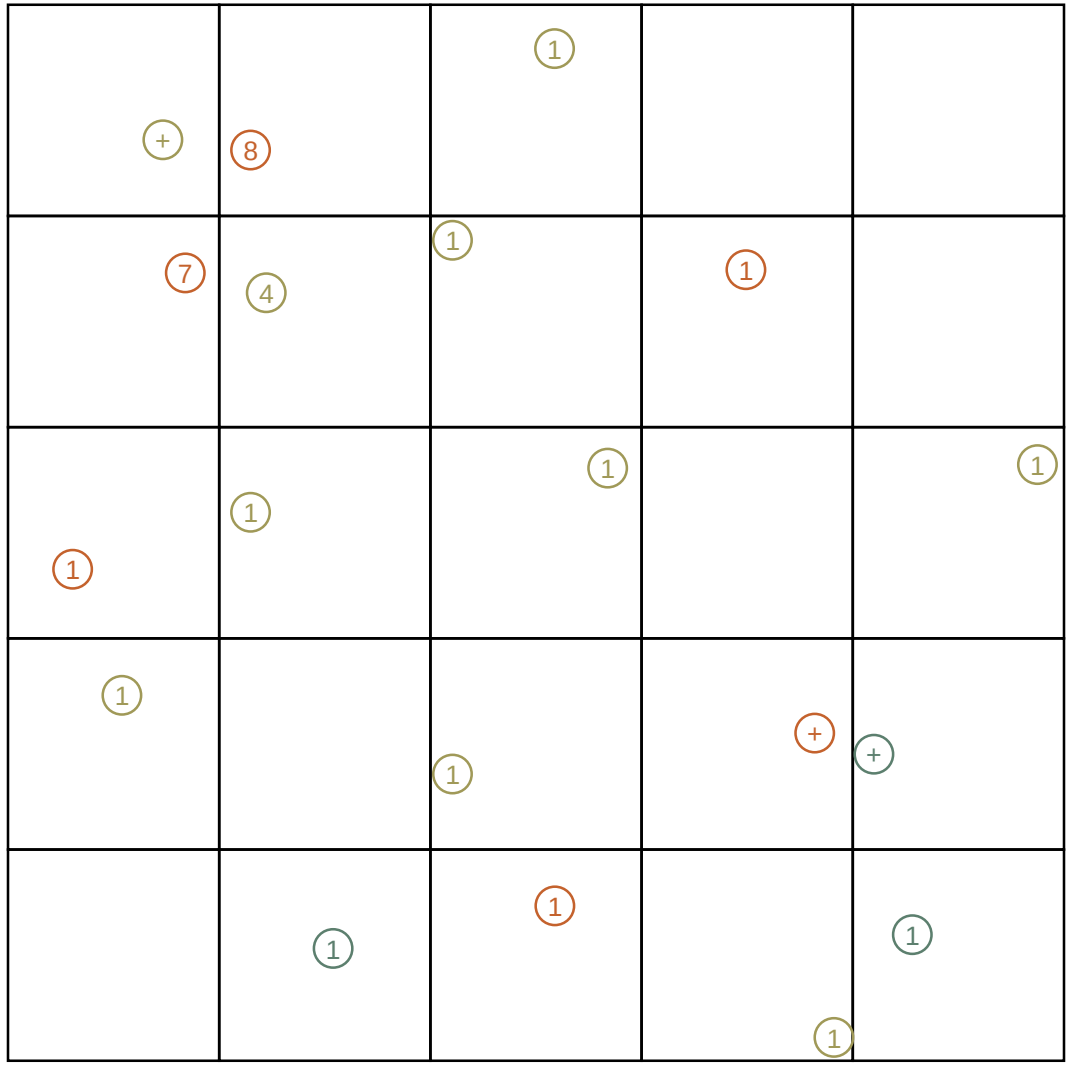


	Frame	Source	Time
●	1	1	100.00
●	2	1	100.01
●	101	2	1004.5

✖ Pixel Center

○ Selected Query Point

Count Neighbors — i.e., Points Coincident within Threshold



	Frame	Source	Time
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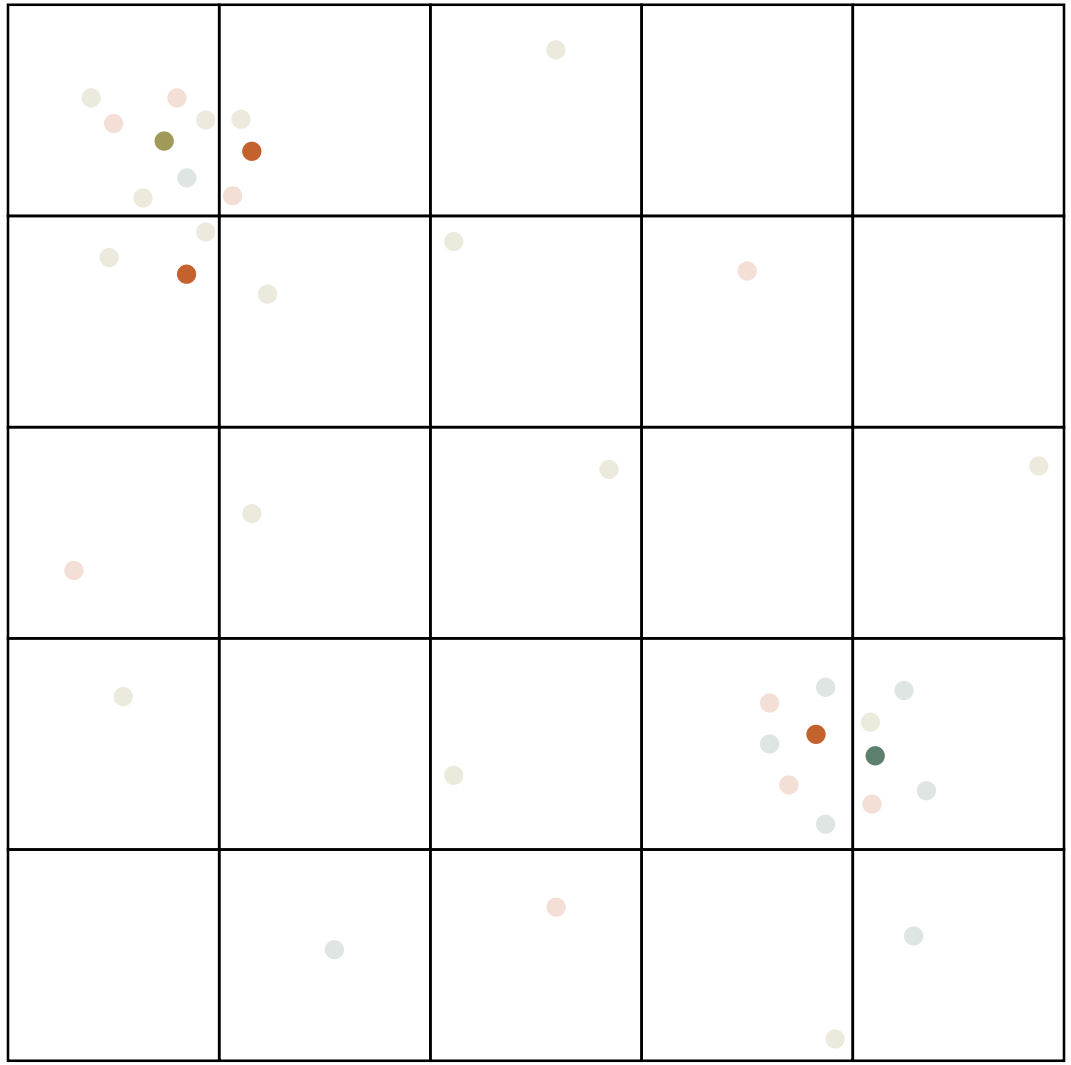
●	2	1	100.01
●	101	2	1004.5

Eliminate Support and Queries Lacking Coincident Neighbors



	Frame	Source	Time
●	1	1	100.00
●	2	1	100.01
●	101	2	1004.5

FINAL CONSIDERATIONS

Final Considerations

- This presentation has focused on the very basics for a specific technique to make a determination of signal vs. background for products derived from raw Geiger-mode APD LiDAR measurements.
- There are approaches other than coincidence processing that are used to filter raw GmAPD LiDAR data. They are not covered here, but have similar issues with respect to synthetic points and metadata attribution.
- This presentation covers several approaches that have been used by various data providers to create point clouds from Geiger-mode APD LiDAR data. While we believe there is a lot of value to populating products with directly measured points, there is no guarantee that products derived from raw GmAPD LiDAR are produced in this way.
- While the information presented here may lead to a lot of discussion on what could be captured for GmAPD LiDAR, it is critical that we establish what constitutes a well-formed LAS 1.4 file for GmAPD LiDAR Data.
- In my opinion, it is not appropriate to require Extra Bytes or VLR data for a specific technology to constitute well-formed LAS 1.4. If metadata fields do not make sense for a specific technology, there should be a mechanism to notify data consumers. We should not populate metadata fields with incomplete or confusing entries. I believe that it is more damaging to provide bad or misleading metadata than no metadata.