The Use of Graph Theory in Forensic Footwear Analysis

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Outline

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  - Often have distinctive features — sole patterns, wear, imperfections
- Current practices are subjective

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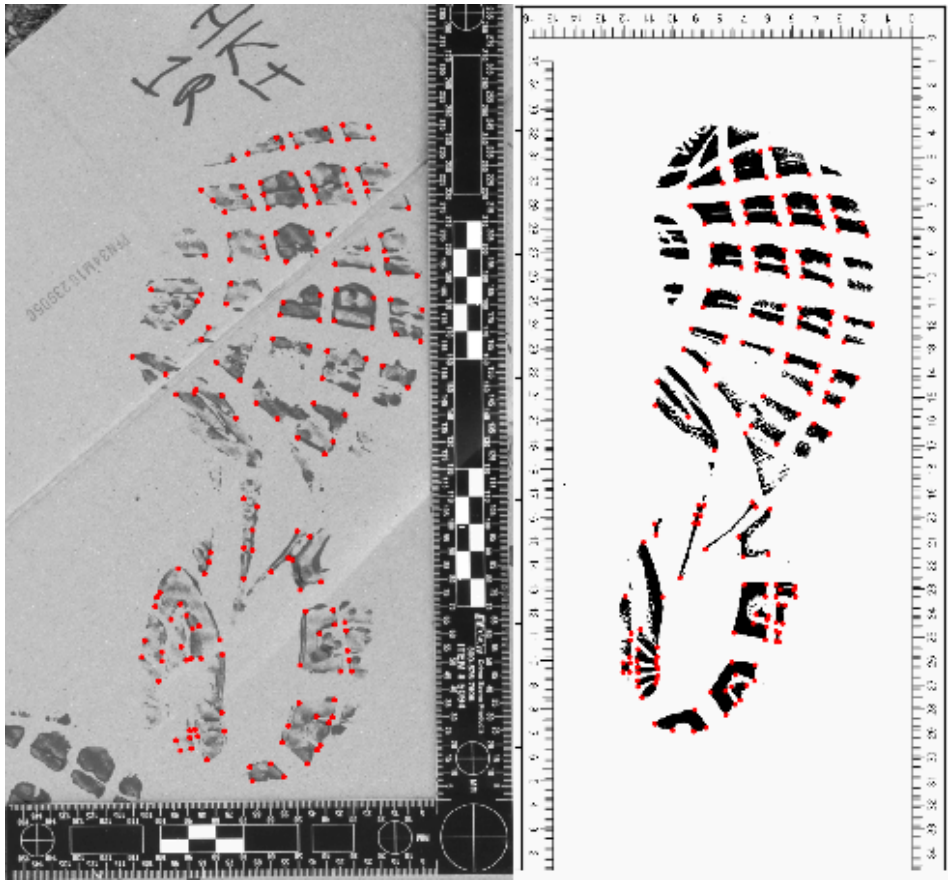
2. **Develop methods for computing high performance comparison scores**
3. Build database of impressions for testing and training algorithms

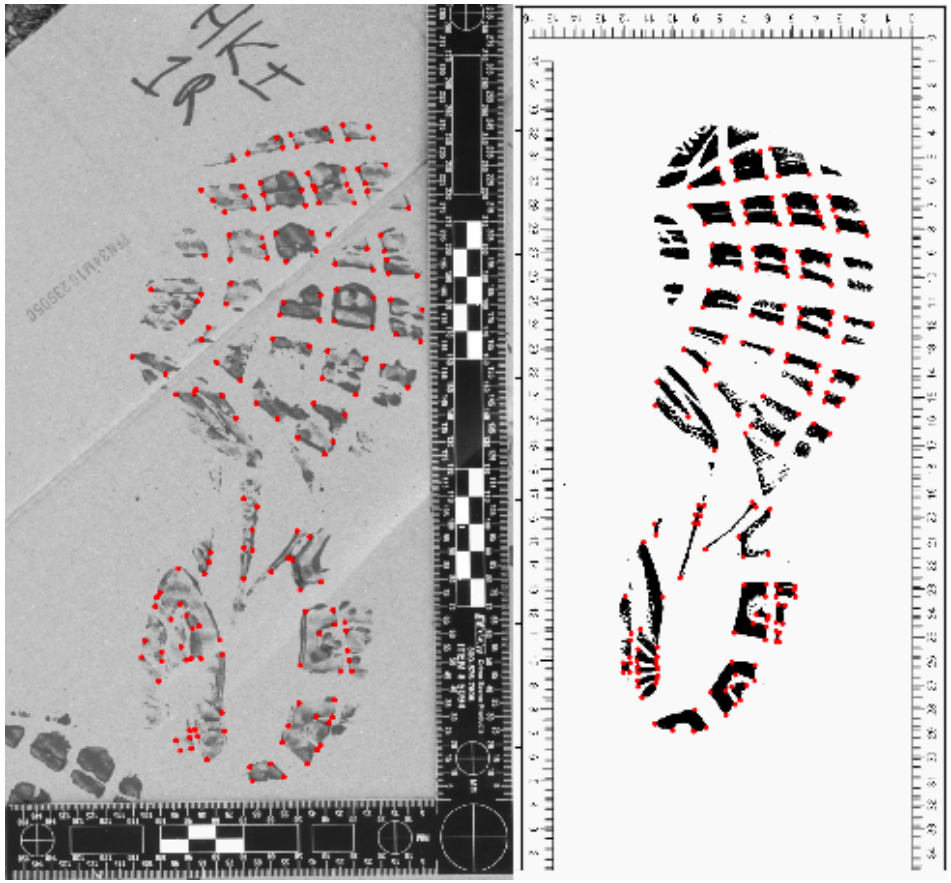
A Comparison Score — Distance

How to compute distance measure:



A Comparison Score — Distance

1. Find features common in both impressions.



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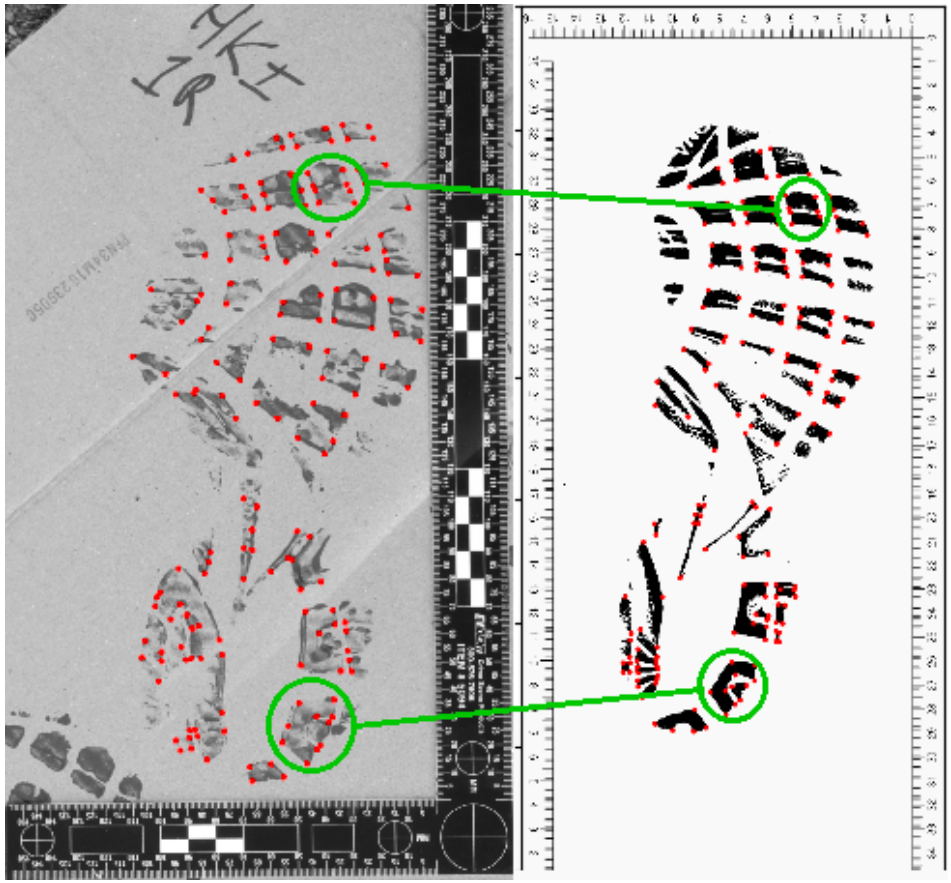

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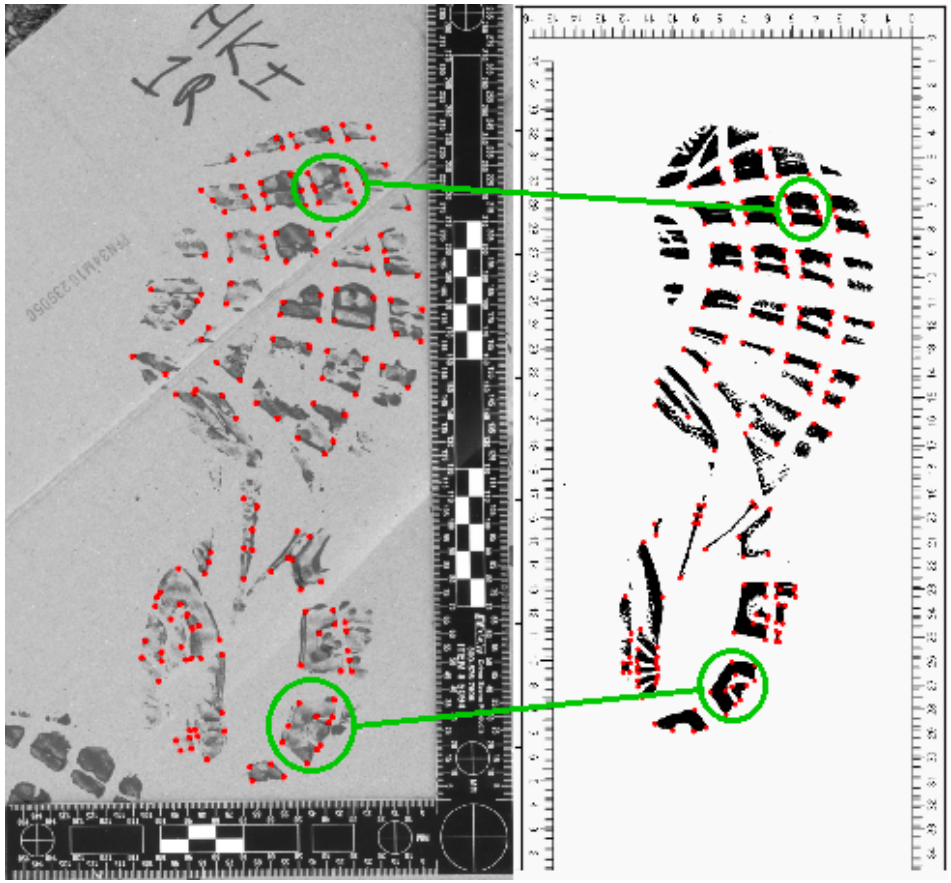
2. Use these features to align the prints.



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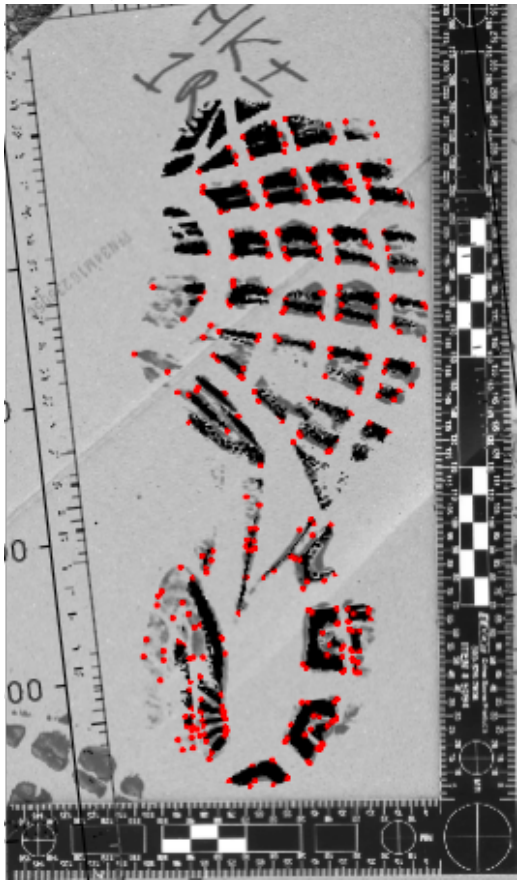

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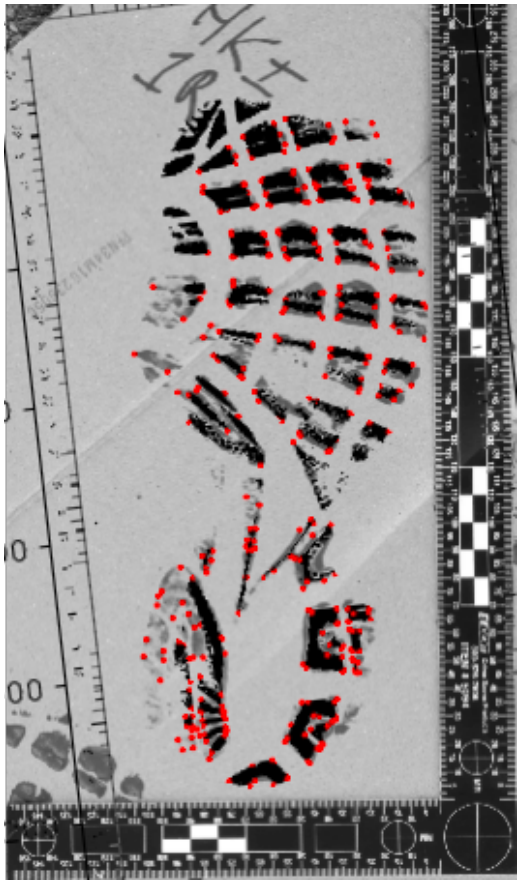
3. Calculate distance between features after alignment.



A Comparison Score — Distance

But remember, this process needs to be accurate, repeatable, and reproducible!

That's where Graph Theory comes in!

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$V = \{a, b, c, d, e, f\}$
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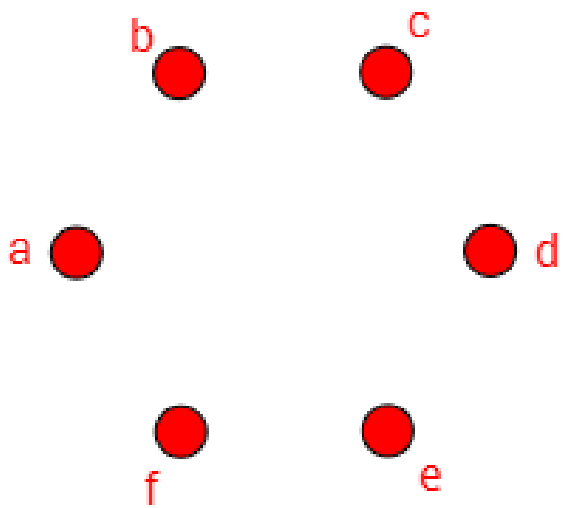

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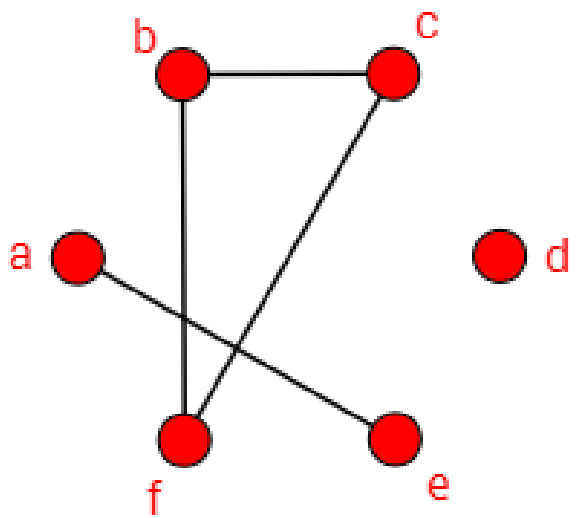

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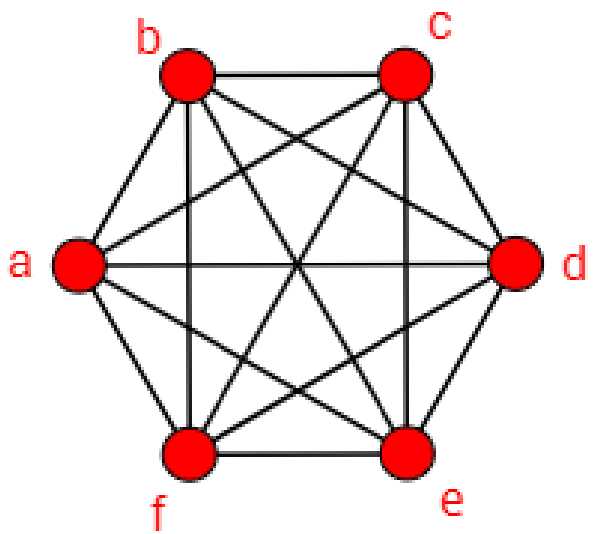

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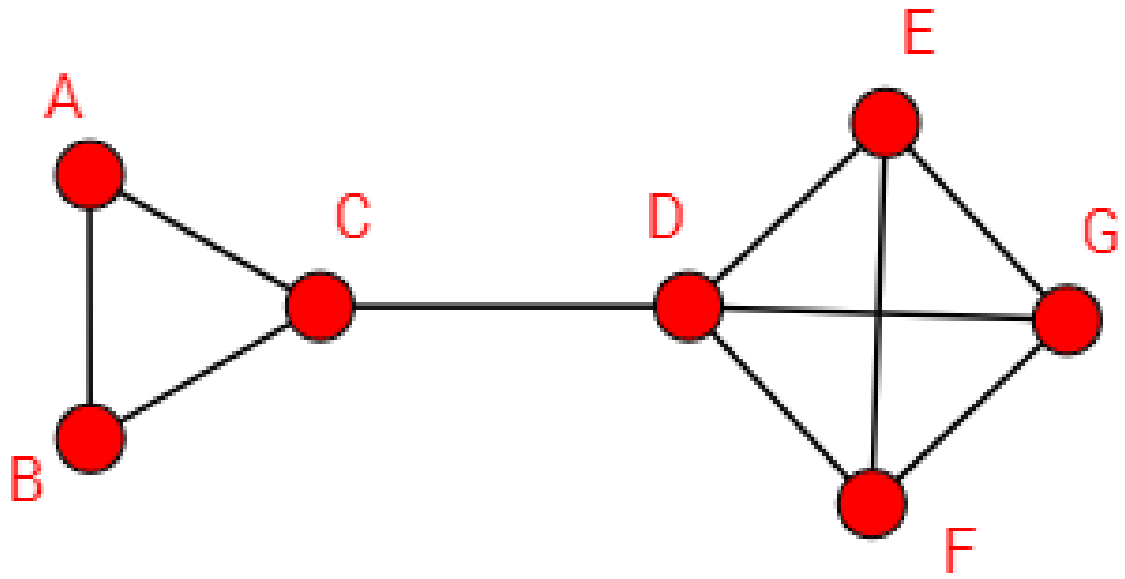
Example (Social Networks)

Let $V = \{Alice, Bob, Charlie, David, Eve, Fred, Grace\}$ and let uv be an edge if and only if person u and person v are friends.



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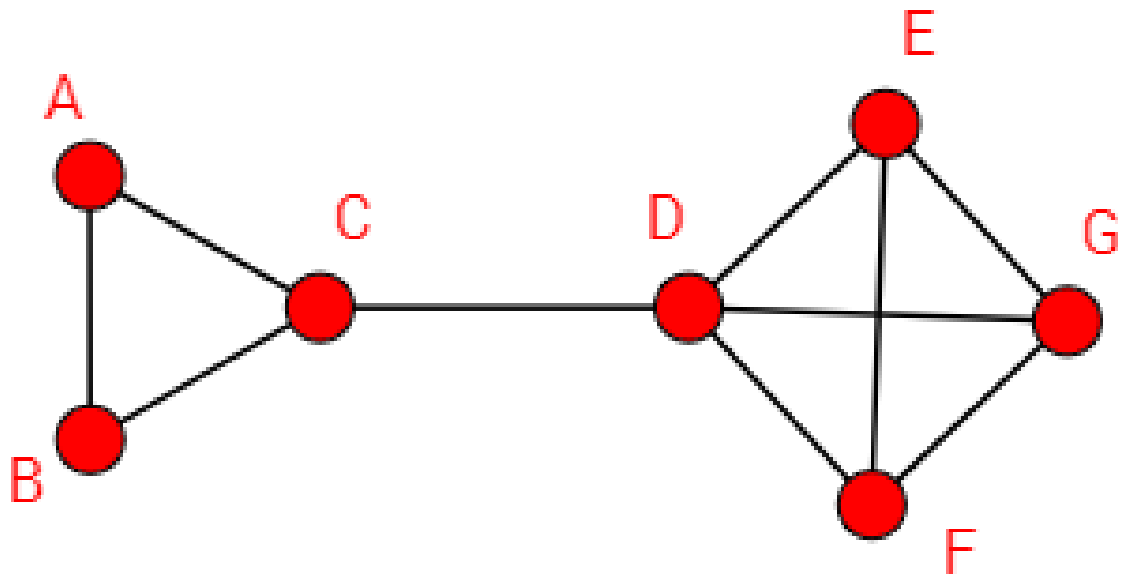
Definition

A *clique* is a subset of vertices in which each pair of distinct vertices are adjacent.



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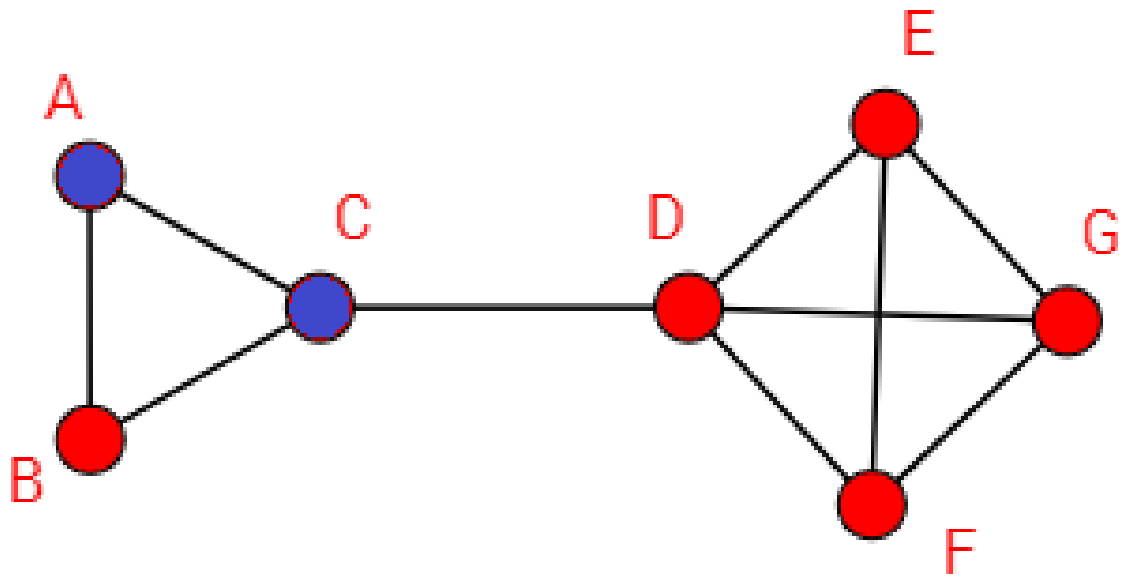

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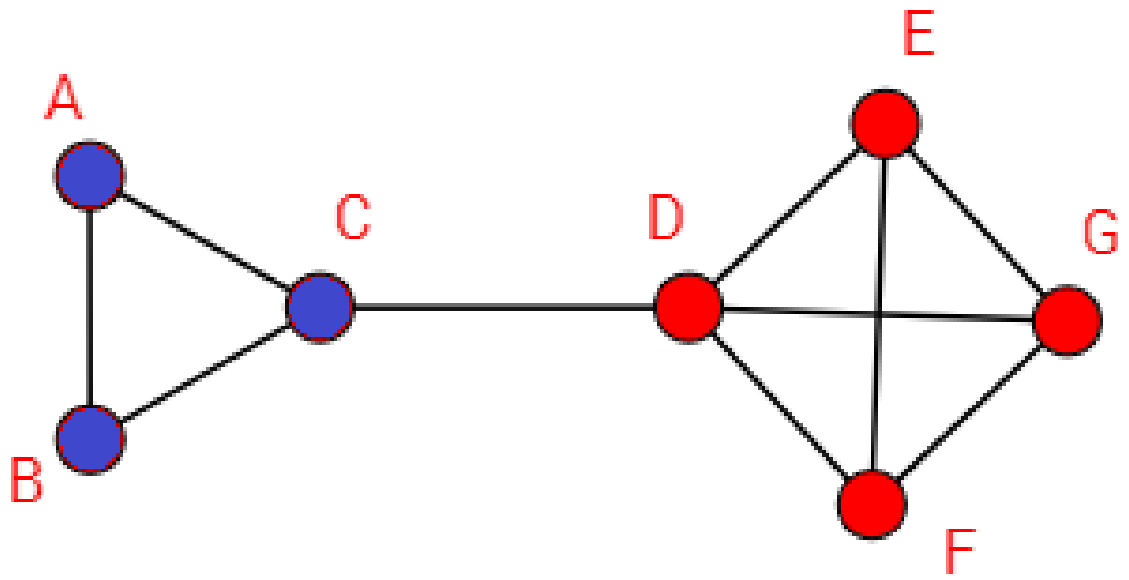

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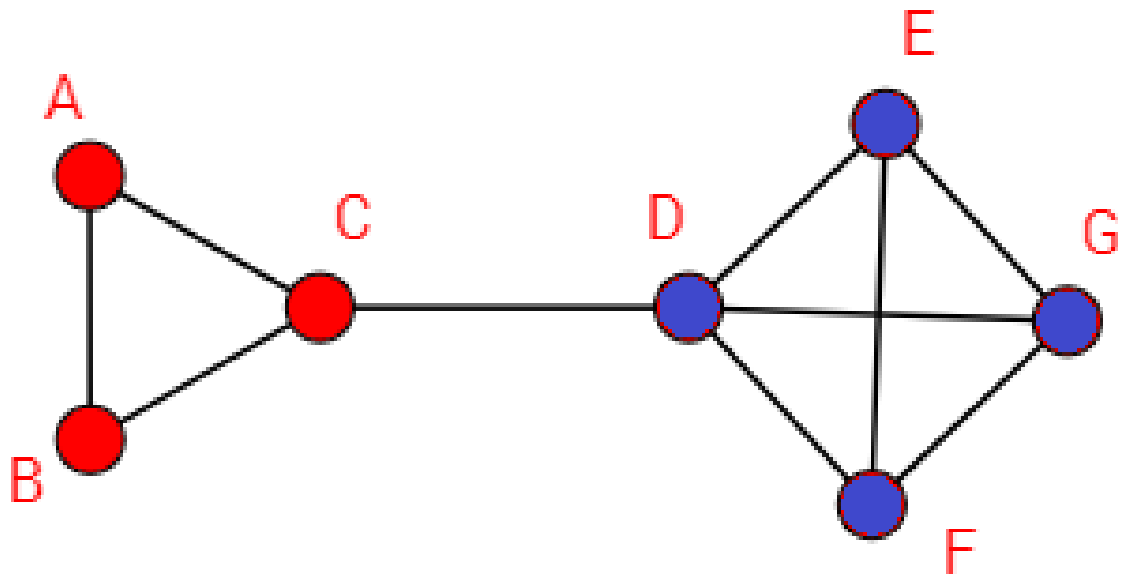

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How does this apply?

Definiton - Product Graph:

Given two configurations of features,

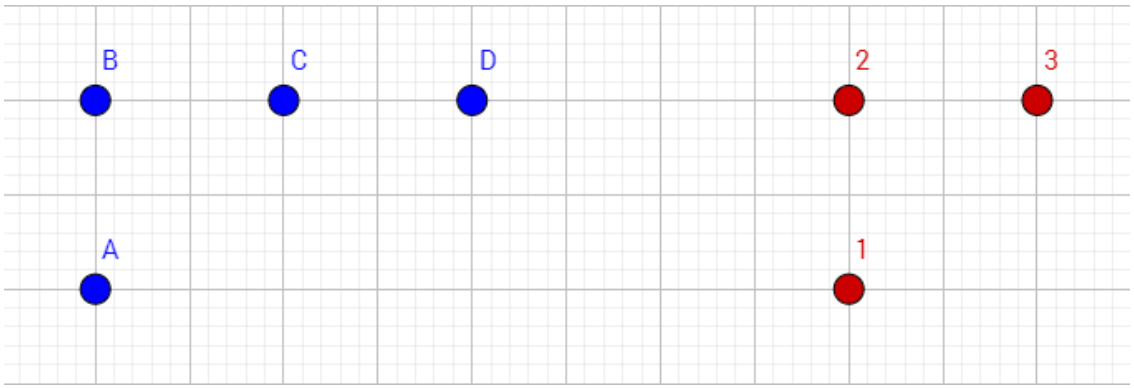
$$P = \{p_1, ..., p_n\} \quad \text{and} \quad Q = \{q_1, ..., q_m\},$$

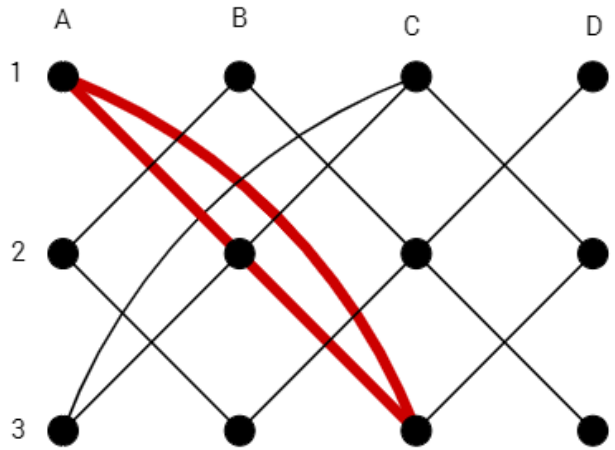
we construct a *product graph* with vertex set

$$V = \{p_1q_1, ..., p_1q_m, ..., p_nq_1, ..., p_nq_m\}.$$

Two vertices p_iq_j and p_kq_ℓ are connected if and only if the distance between points p_i and p_k is equal to (within a margin of error) the distance between points q_j and q_ℓ.

A Small Example





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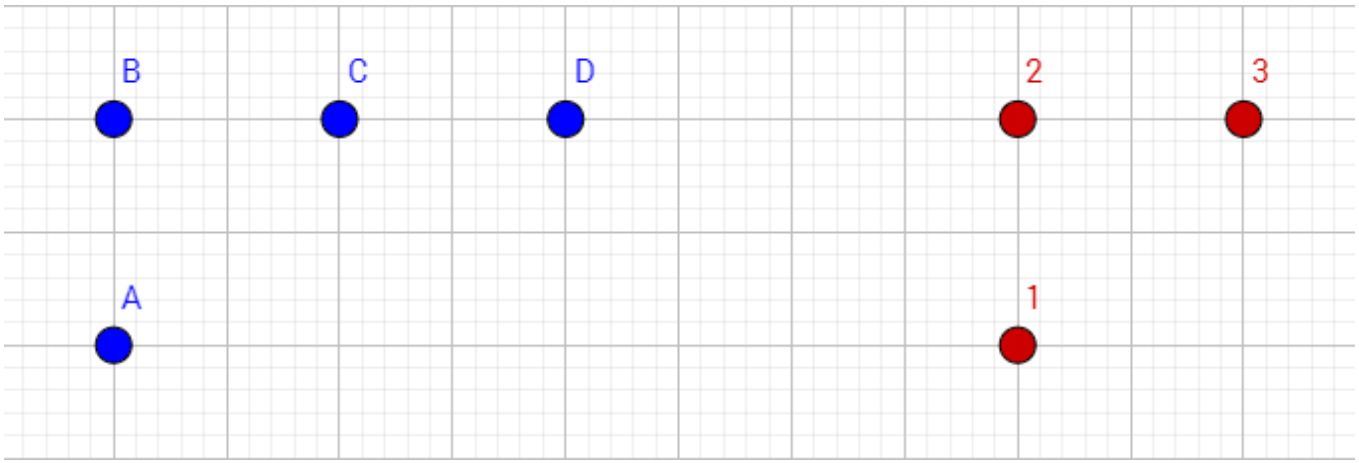
A set of features in P that are congruent to a set of features in Q.



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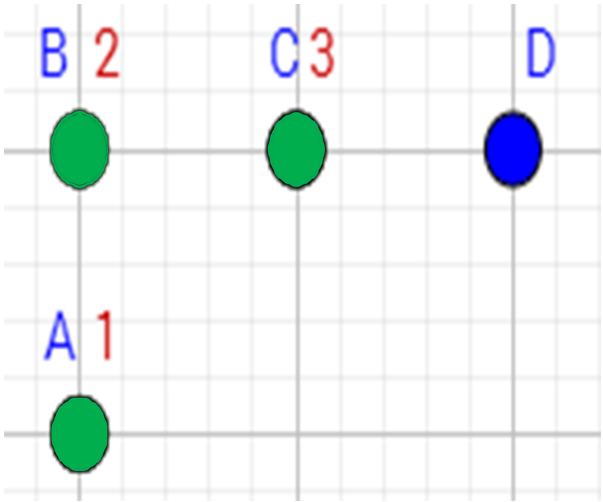
What does a clique in the product graph represent?
A set of features in P that are congruent to a set of features in Q.
We can then align the impressions by this congruence.



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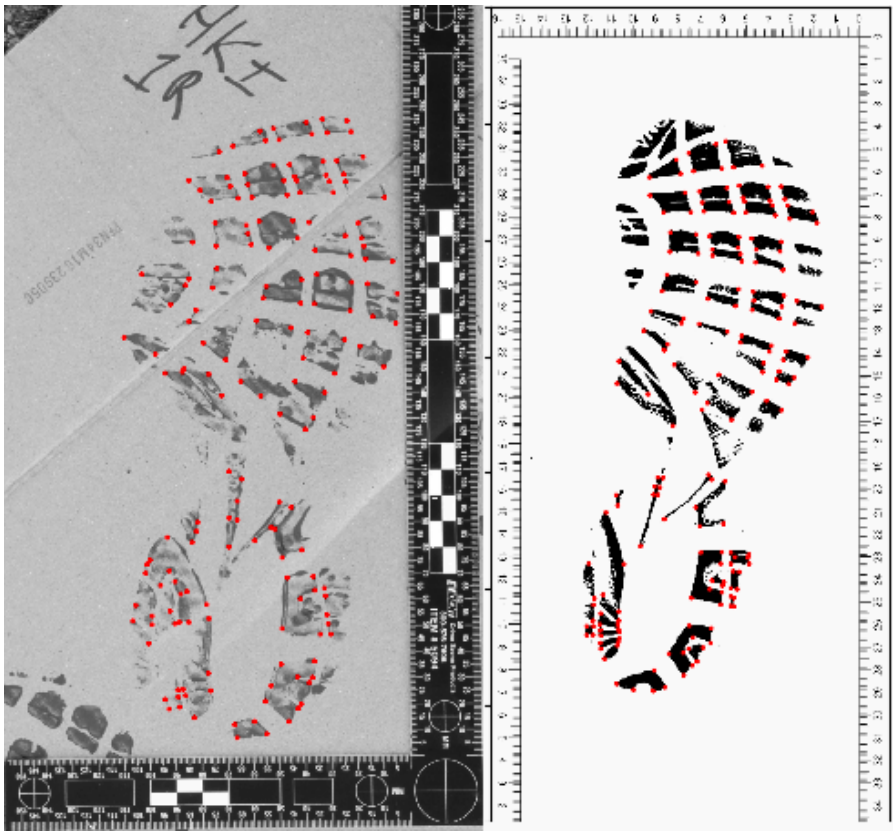
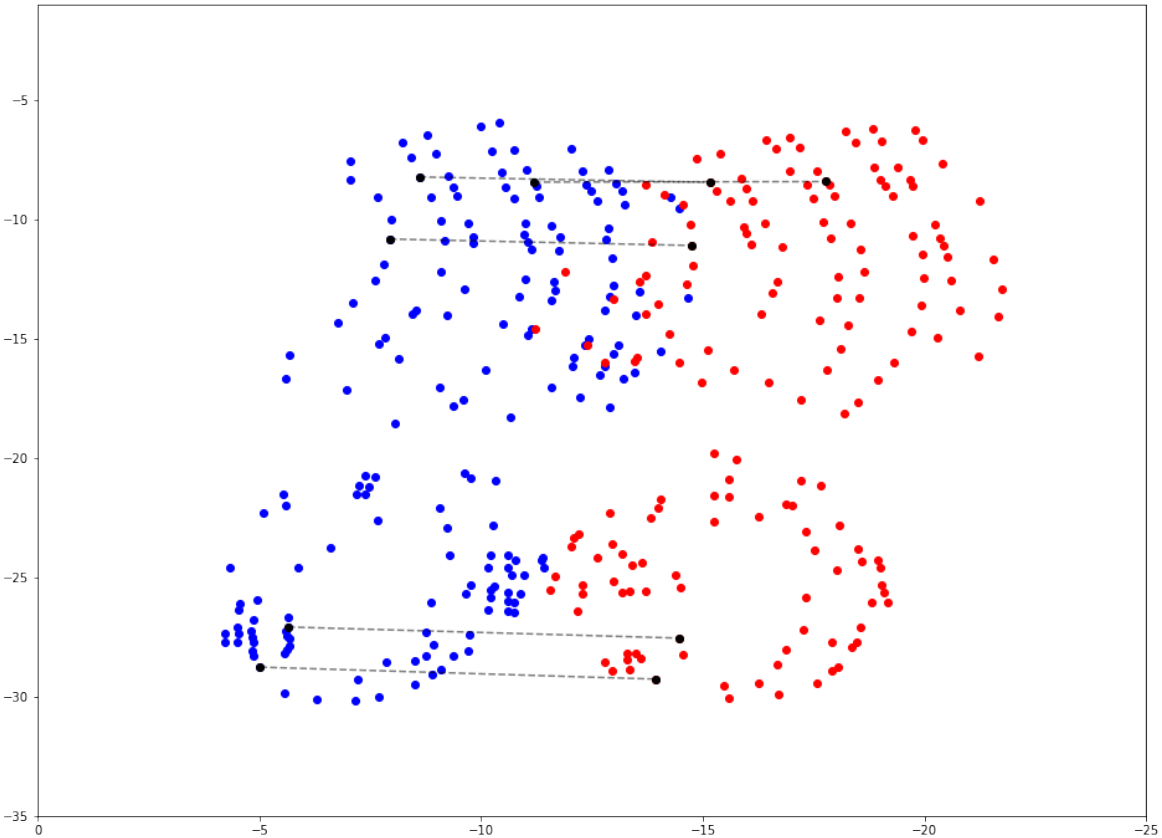
Shoe Example

0. Create product graph.



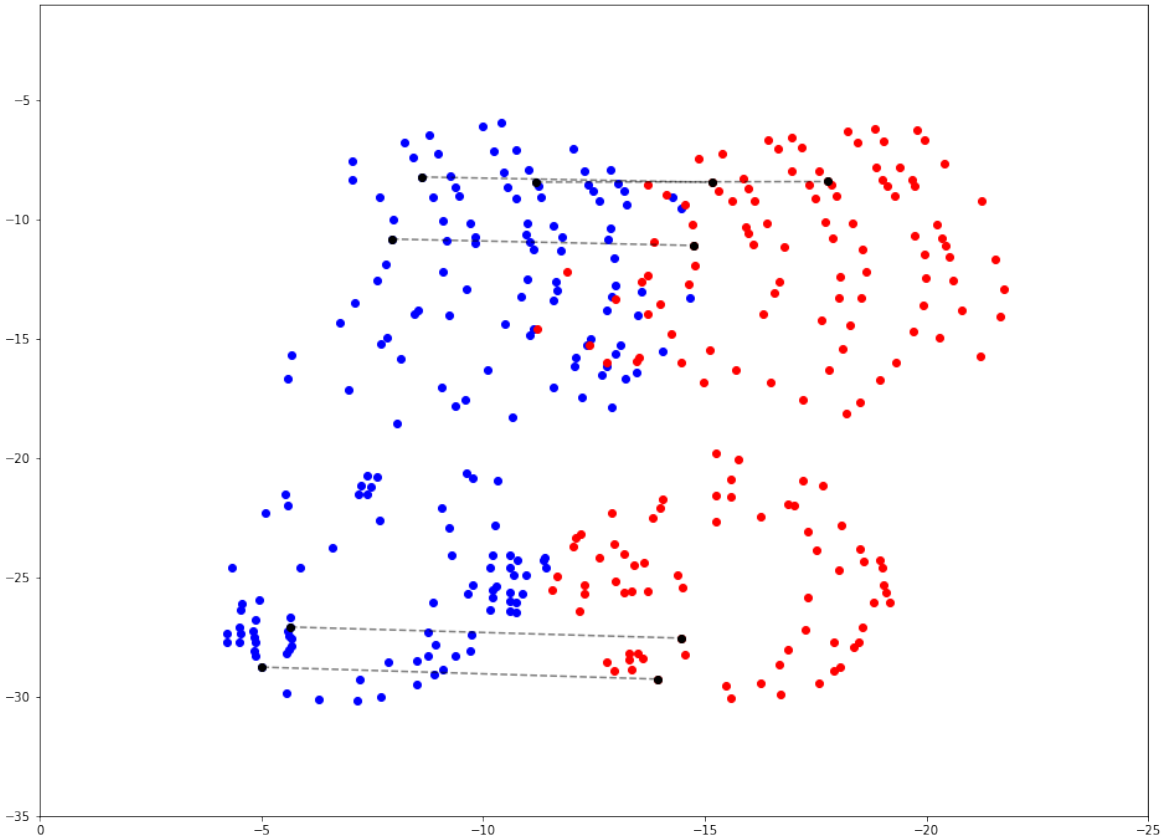
Shoe Example

1. Find a large clique in the product graph.



Shoe Example

2. Align the impressions by the clique correspondence.



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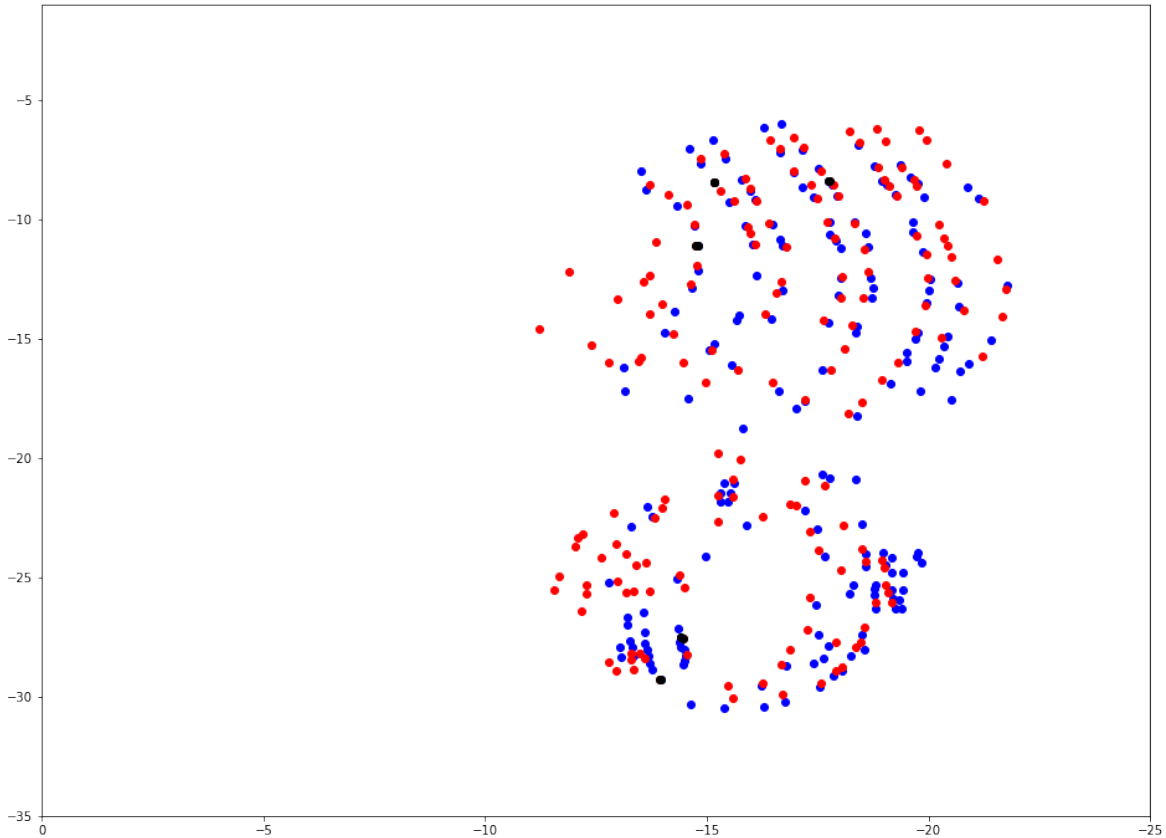
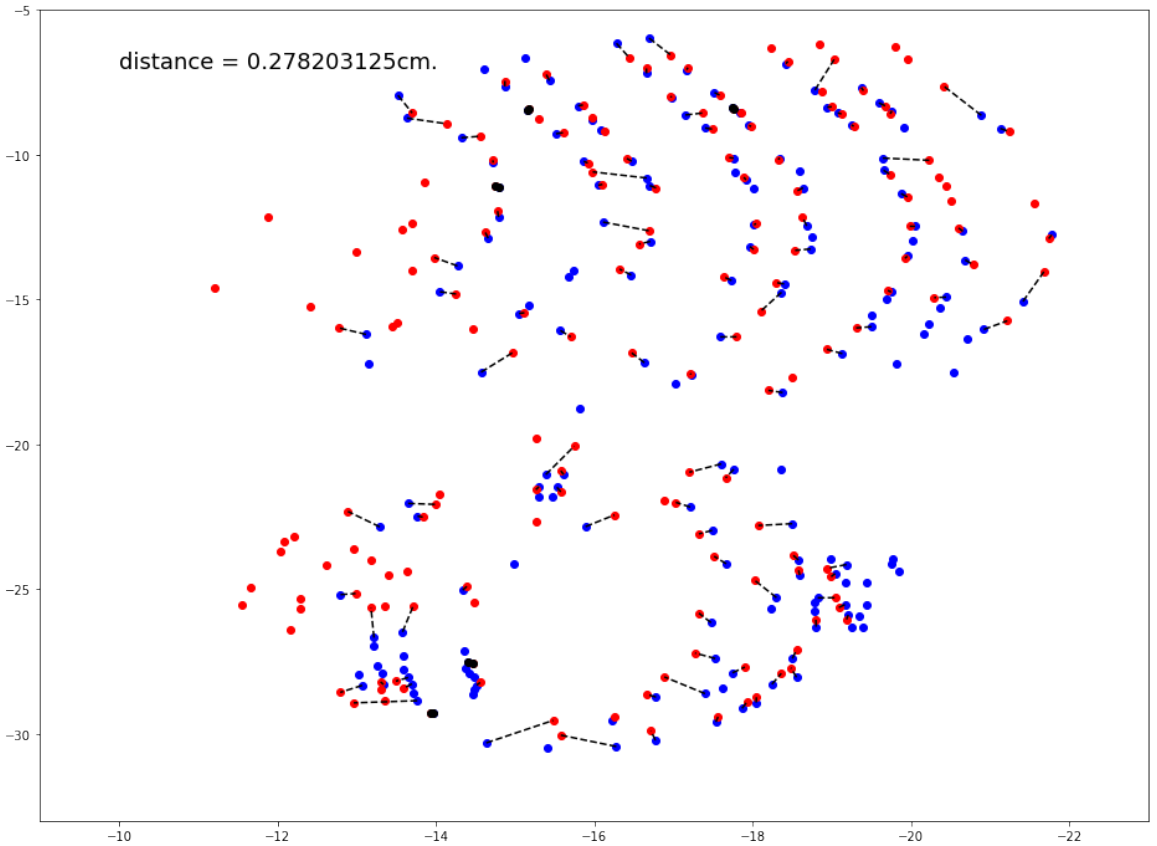


Shoe Example

3. Compute distance between features.



Improvements and Future Work

- Normalize distance score for comparison
- Investigate other similarity scores
- Allow for error in classifying characteristics
- Implement machine learning to test and develop scoring systems

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Summary

- There is a need for forensic footwear comparisons to be objective and reproducible.
- The distance between impressions is just **one** similarity measure.
- But Graph Theory is a helpful tool in computing this (and other!) scores.

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Questions?

Special Thanks to:

Dr. Martin Herman
Dr. Hari Iyer

and to you for listening!

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