

Bloodstain Pattern Analysis and Artificial Intelligence

Philip Joris (CEO – Forentrics)



FORENTRICS
BRINGING EVIDENCE INTO FOCUS.



Who are we?

- Engineer specialized in Artificial Intelligence
 - PhD in forensic image computing
 - Co-founder of Forentrics
- Forentrics develops cutting edge technology for law enforcement and forensic professionals.



HemoVision

Faster Analysis. Sharper Insights.

HemoVision is the future of Bloodstain Pattern Analysis (BPA). It combines unparalleled performance with incredible ease of use. Readily integrating into existing workflows, assisting you every step of the way.

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Vision-3D

Courtroom-Ready 3D Crime Scene Visualizations.

With Vision-3D, you can transform your crime scene scans into interactive digital twins – shareable, annotated, and easy for investigators, attorneys, and juries to understand.

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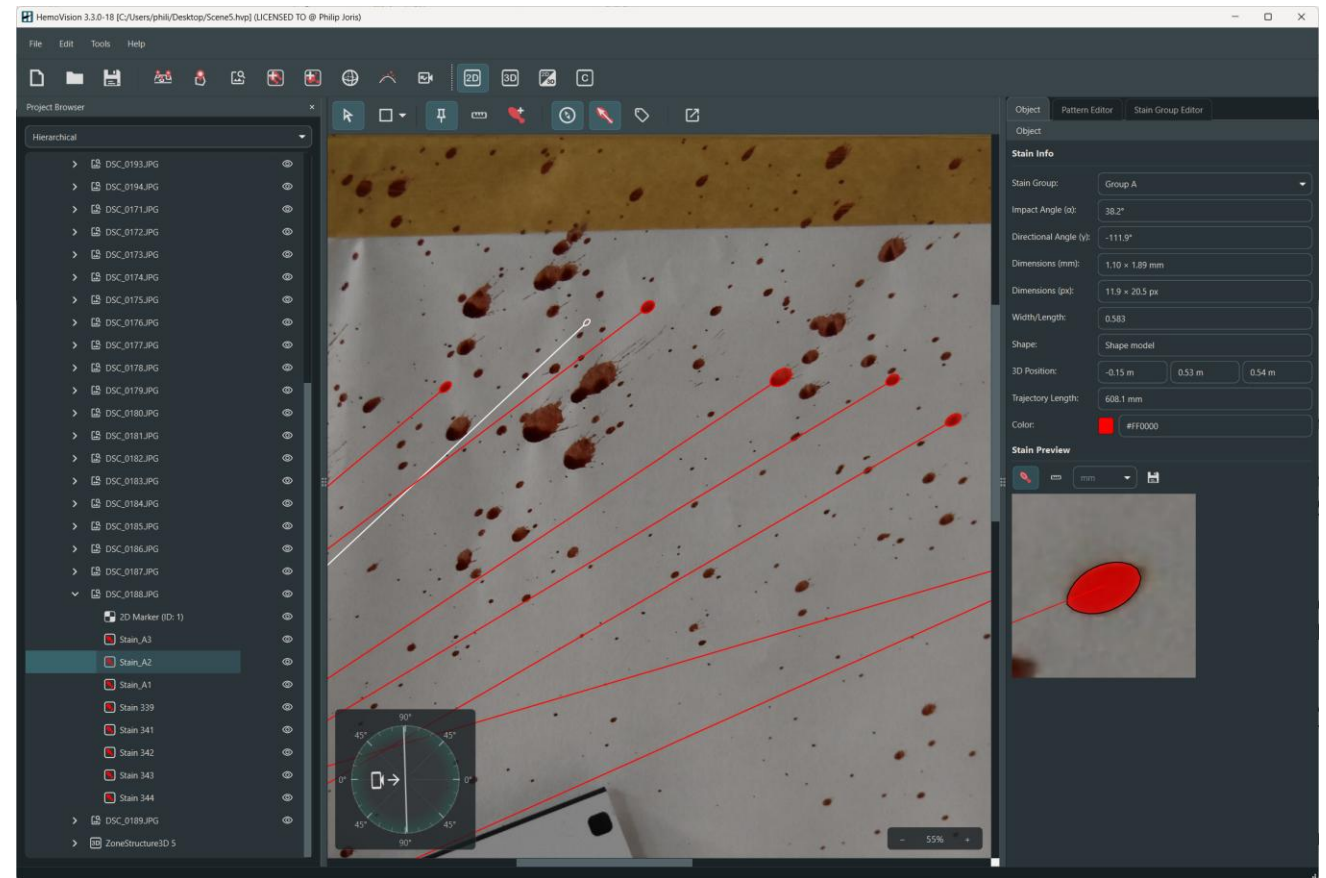
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Agenda

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Goal of today: “How can AI help bloodstain pattern analysts?”

1. What is Bloodstain Pattern Analysis?
2. Artificial Intelligence for BPA
3. Examples



HemoVision 3.3.0

Part 1: What is BPA?

What is BPA

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- Bloodstain patterns are often encountered on scenes of violent crimes.
- BPA involves documenting, analyzing, and reporting on bloodstain patterns.
- Artificial Intelligence (AI) can help
 - Let's focus on **projected** bloodstain patterns for this presentation.



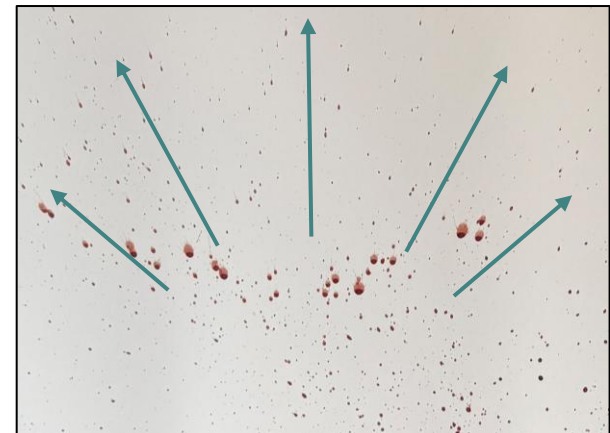
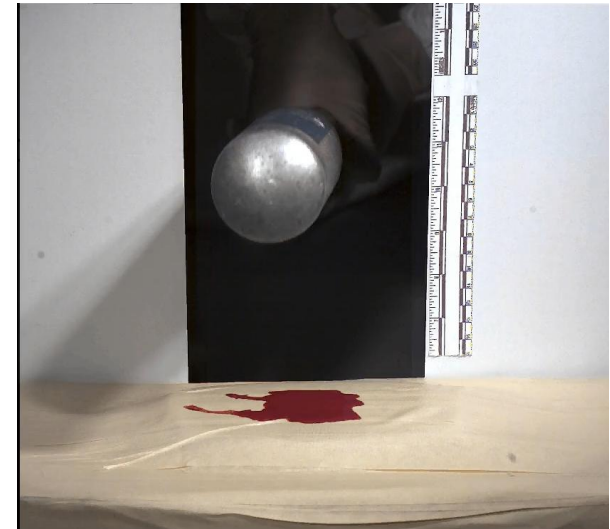
Projected Bloodstain Patterns

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<https://alvideo.ameslab.gov/archive/bpa-videos/>

- **Impact Pattern**

- Energy transfer into liquid blood
- Blood is projected onto surrounding surfaces and objects
- Typical V-shaped patterns
- Stains have circular / elliptical shape



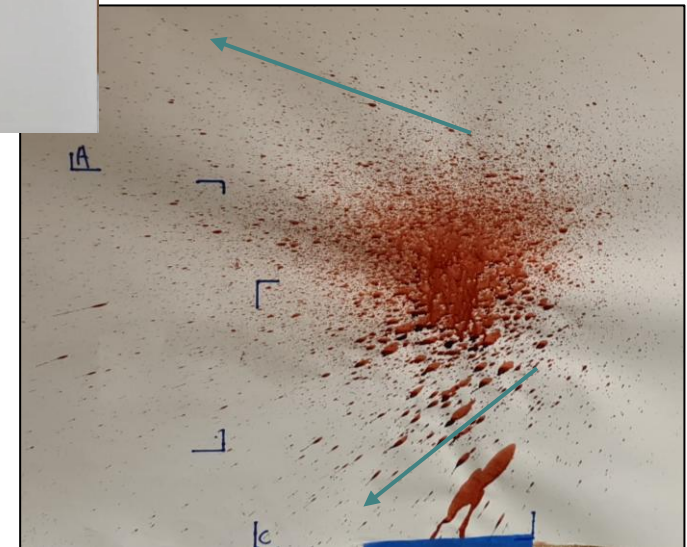
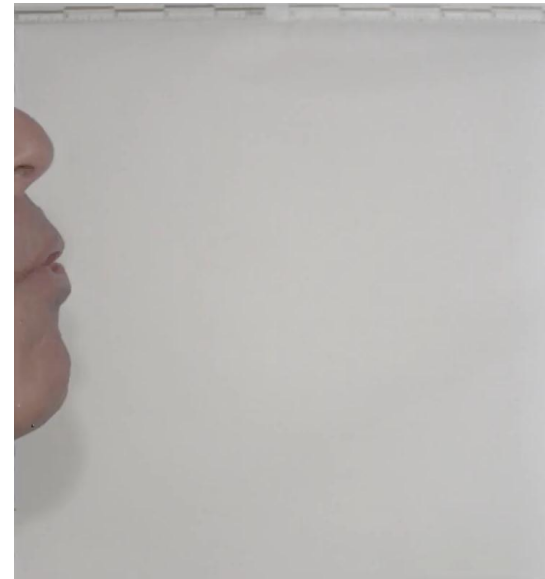
Projected Bloodstain Patterns

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- **Expired Pattern**

- Liquid blood is exhaled with force (coughing, sneezing)
- Blood is projected onto surrounding surfaces and objects
- Stains have circular / elliptical shape

<https://alvideo.ameslab.gov/archive/bpa-videos/>

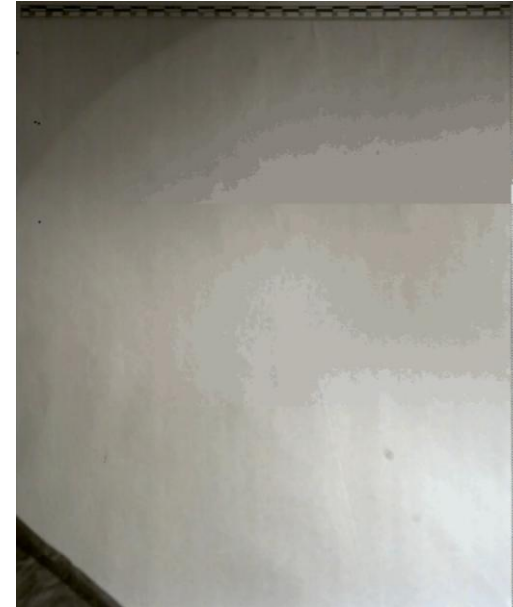


Projected Bloodstain Patterns

8

- **Cast-off Pattern**

- Blood is released from a swinging object
- Blood is projected onto surrounding surfaces and objects
- Typical (curvi-)linear distribution
- Stains have circular / elliptical shape



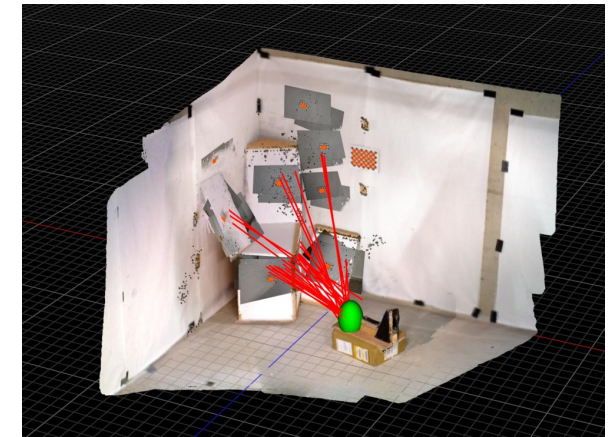
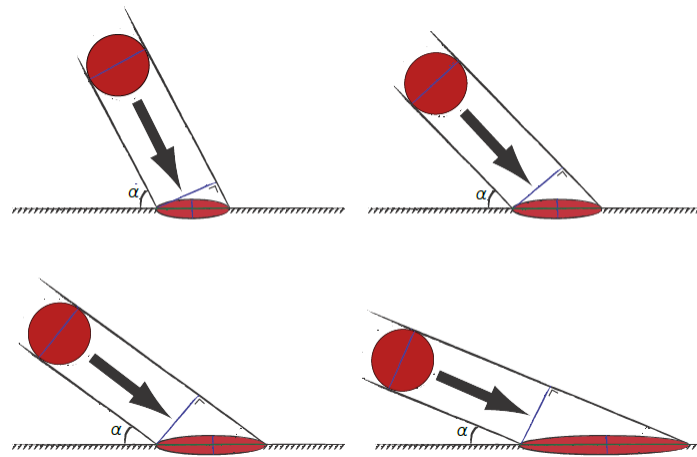
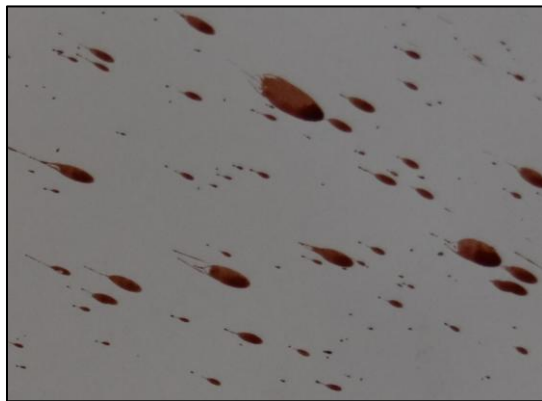
<https://alvideo.ameslab.gov/archive/bpa-videos/>



Projected Bloodstain Patterns

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- Common characteristics
 - Stains are elliptical (not perfect ellipses...)
 - Relationship between shape and impact angle
 - We can determine the **trajectories** of stains



$$\alpha = \sin^{-1}\left(\frac{\text{width}}{\text{length}}\right)$$

Projected Bloodstain Patterns

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- Analyze convergence of multiple trajectories to determine the spatial source.
 - Positioning of victim & suspect
 - Refute or corroborate statements

Dexter s01e01 (Showtime, 2006)



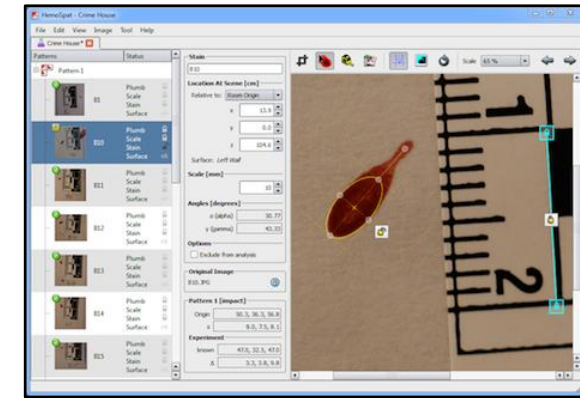
Stringing

<https://www.forzaforensics.com/bloodstain-pattern-analysis>



Manual calculations

https://hemospat.com/images/front_page/big/HemoSpat_Interface_Win7.png



Software

Tedious, time-consuming, risk of bias, risk of scene contamination, not repeatable, ...

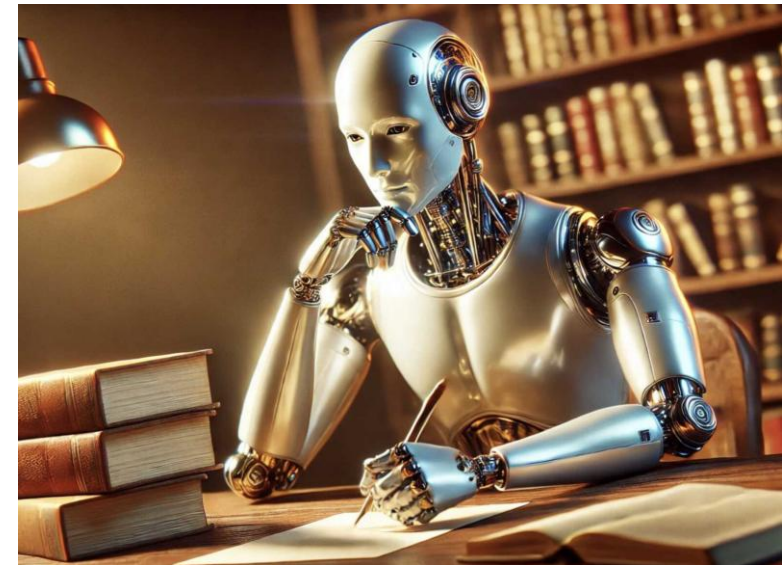
→ How can AI help us?

What is Artificial Intelligence?

What is “Artificial Intelligence”

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- Any system capable of performing tasks that normally require human intelligence, particularly tasks involving perception, reasoning, learning, problem-solving, and decision-making.
- It's an umbrella term for many different fields:
 - Rule-based / expert systems
 - Machine learning
 - Deep learning / neural networks
 - Computer vision
 - Natural language processing
 - Optimization and search algorithms
 - Robotics and autonomous systems
 - ...



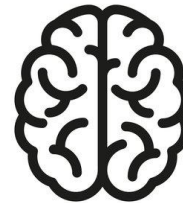
<https://www.rochester.edu/newscenter/artificial-general-intelligence-large-language-models-644892/>

What is “Artificial Intelligence”

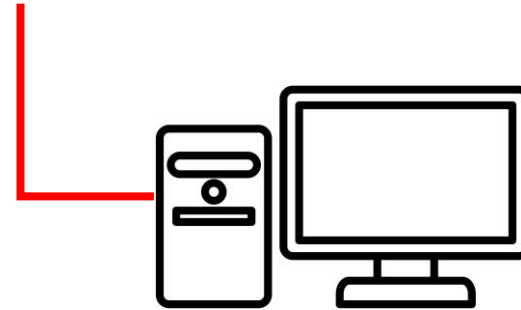
13

- Even very simple things can be considered to be “AI”

AI to improve work-life-balance



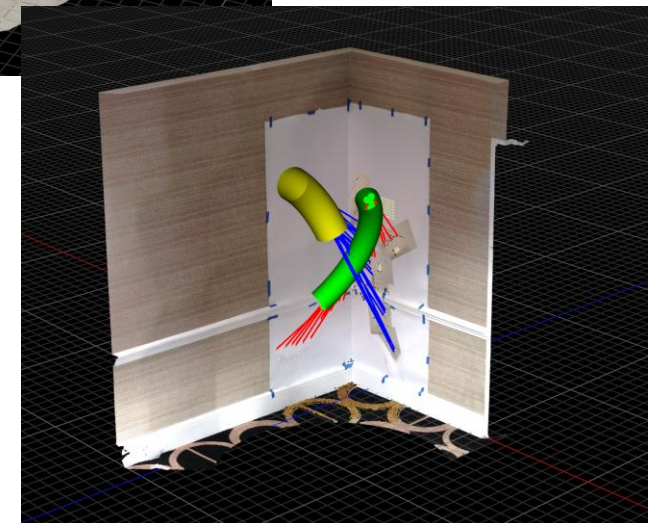
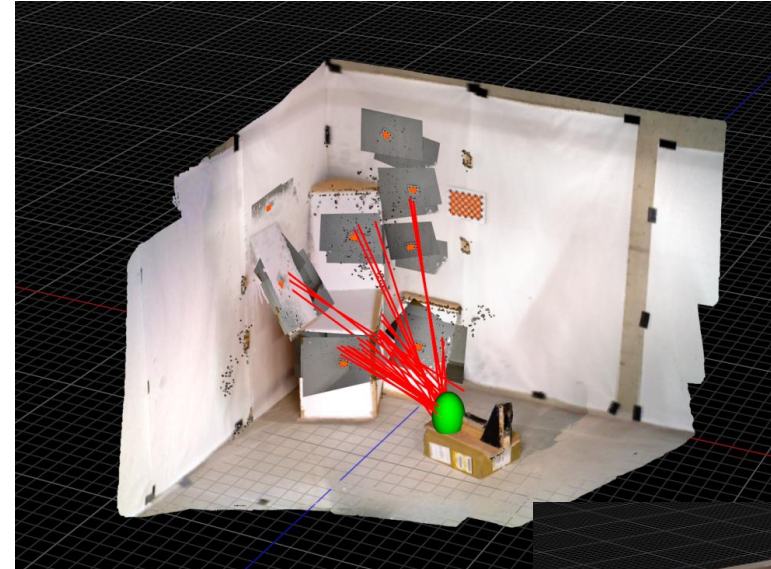
```
If( time > 17:00 )  
  then: turn off computer
```



What is “Artificial Intelligence”

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- We want to analyze complex projected bloodstain patterns.
- We will cover three forms of AI that we use:
 1. Computer vision for scene reconstruction
 2. Machine learning for stain trajectory calculation
 3. Optimization for convergence analysis

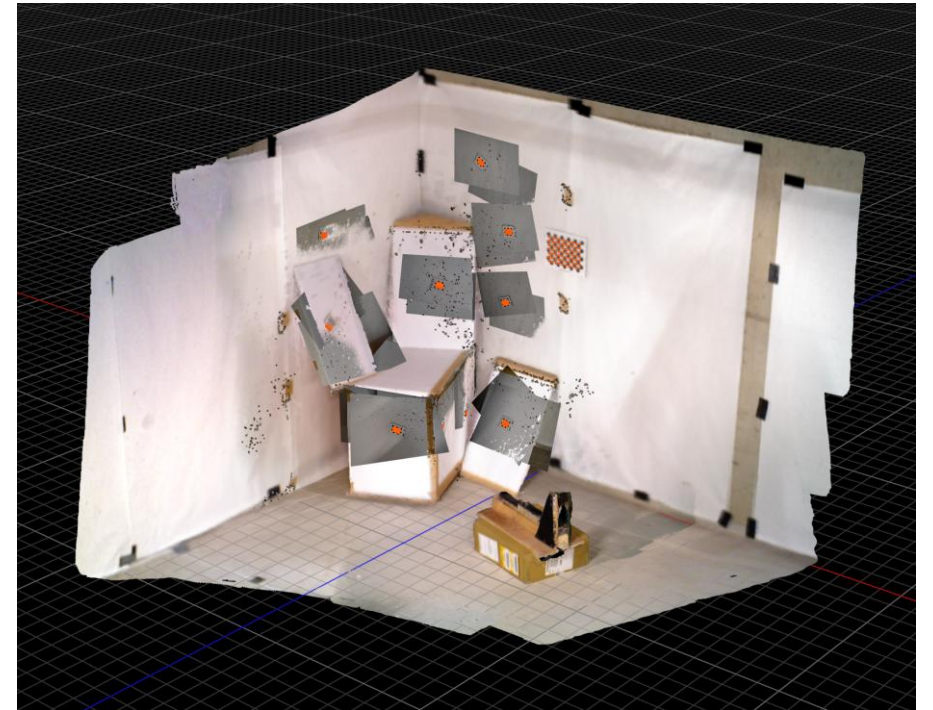


Step 1: Scene Reconstruction

Scene Reconstruction

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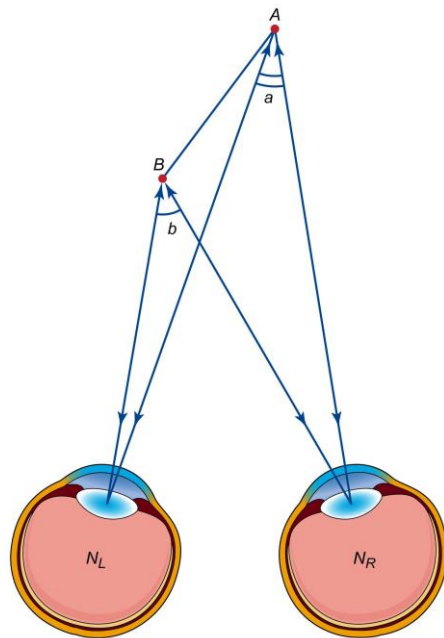
- **Problem**: we want to reconstruct our scene in 3D so that we know the coordinates of our bloodstains
 - We do not want to measure manually
 - We do not want to use expensive hardware
- **AI - Computer vision**: enabling computers to interpret, analyze, and extract meaningful information from images or video.



Scene Reconstruction

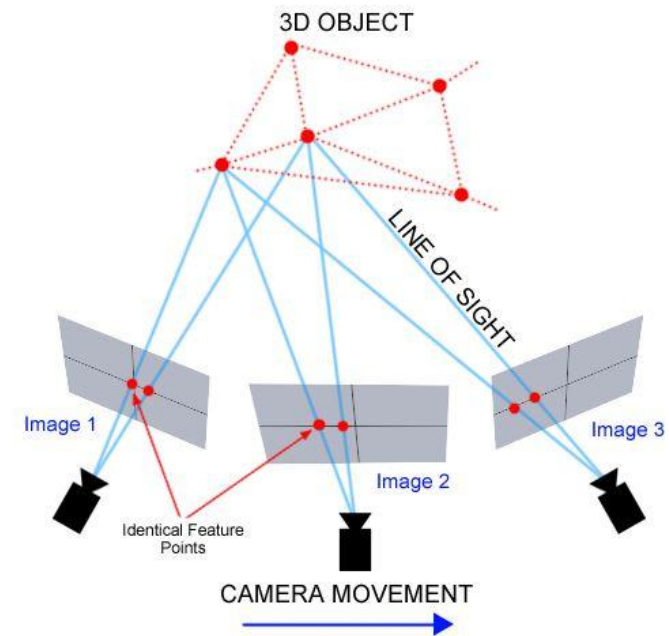
17

Humans can perceive depth by combining information from our two eyes



© Encyclopædia Britannica, Inc.

We can replicate this by using multiple cameras, or multiple photographs from different positions



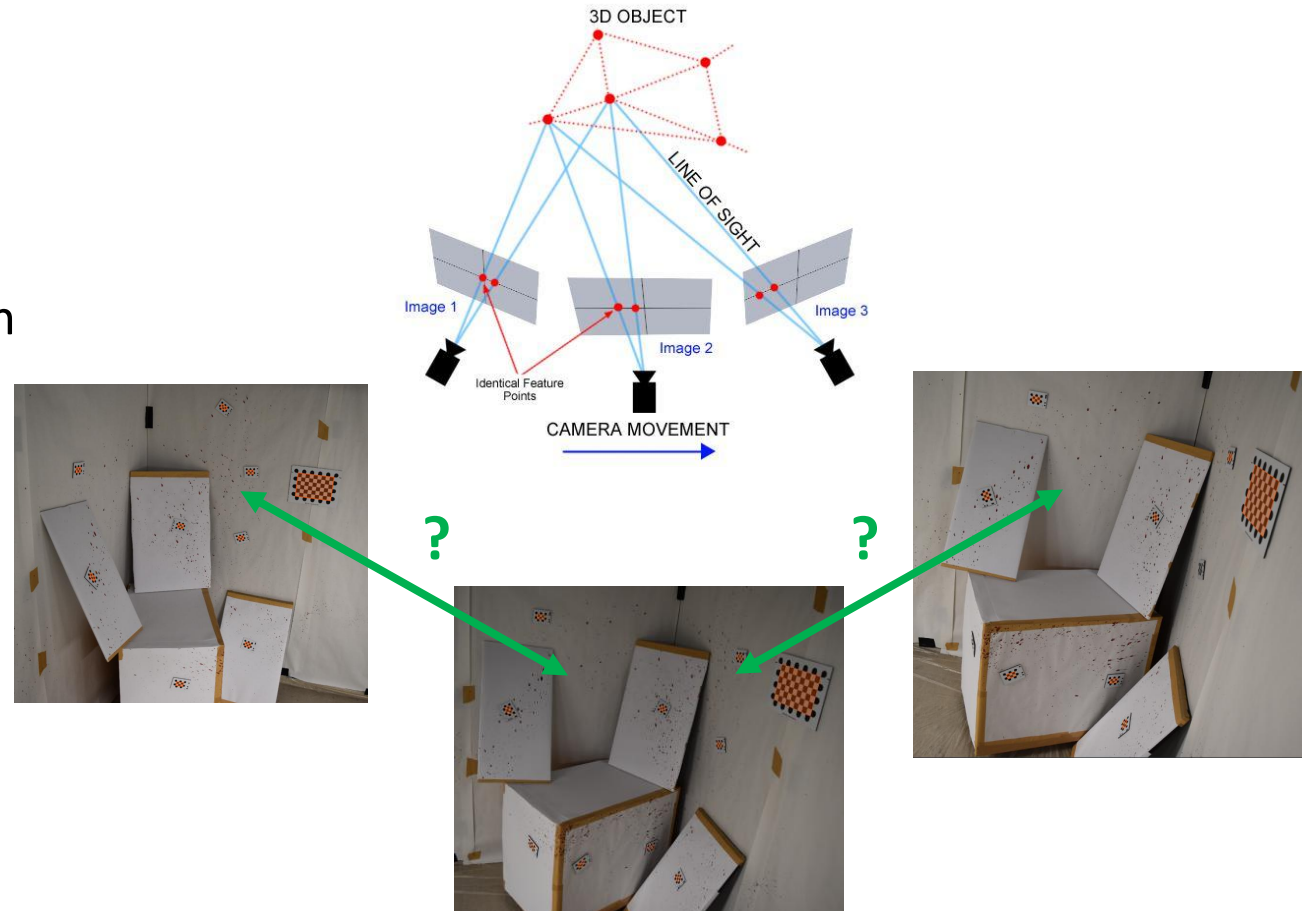
Scene Reconstruction

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“Structure from motion”: combination of computer vision and mathematics.

We need to find corresponding points between images to triangulate.

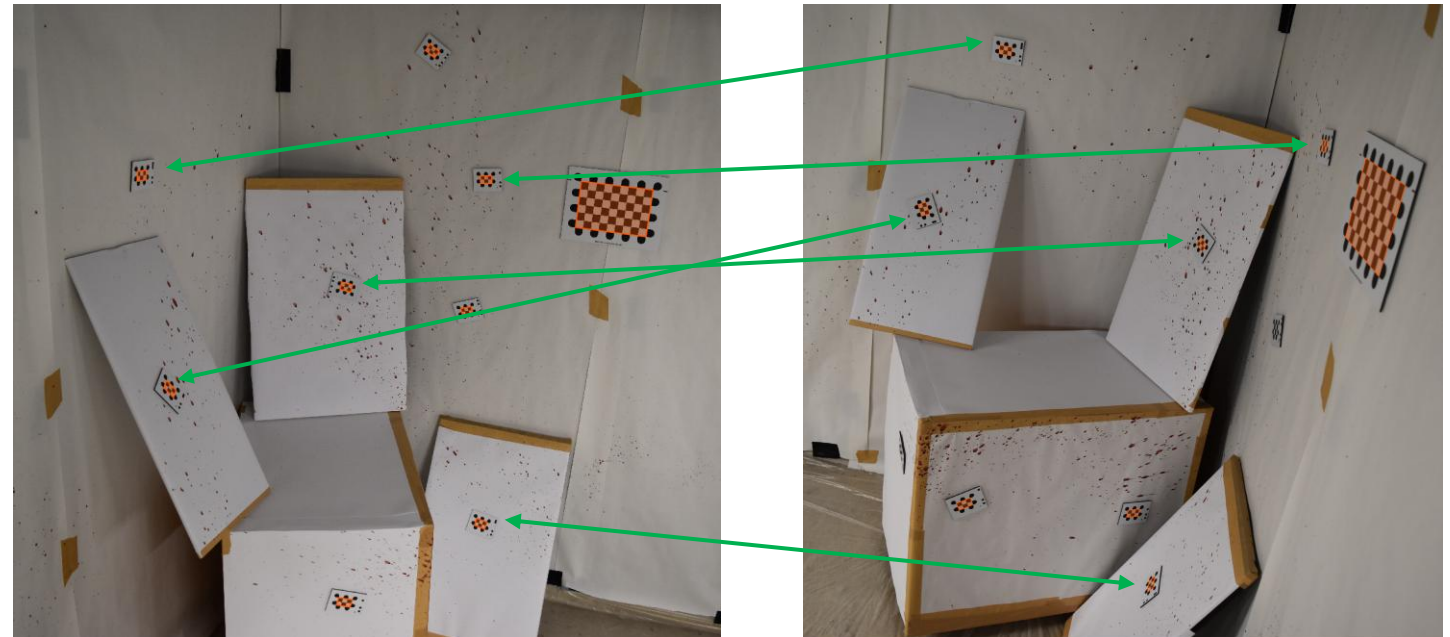
- Difficult in low-texture environments
- Needs to be robust for a forensic setting



Scene Reconstruction

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- We place markers on the scene
- We use computer vision to:
 - Detect markers
 - Identify markers
- We can then easily match points across images



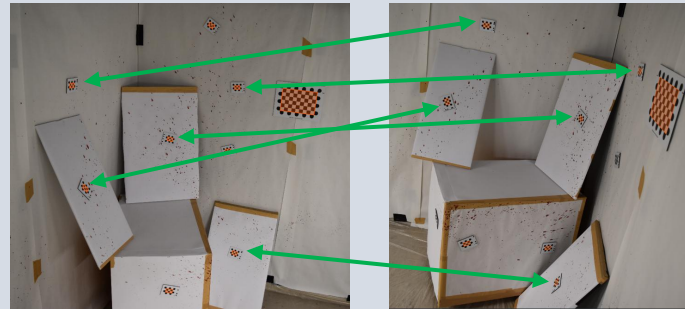
Scene Reconstruction

20

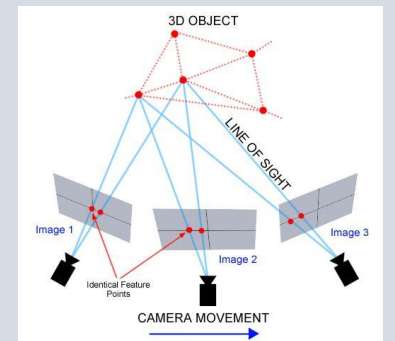
1. Marker & feature point detection



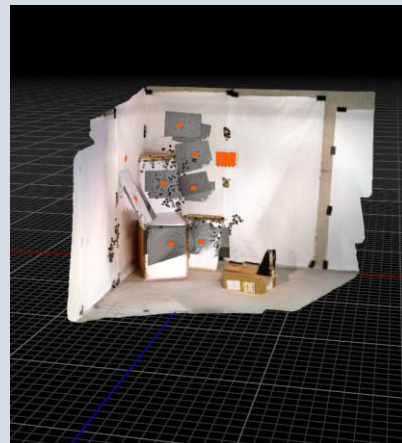
2. Marker & feature point matching



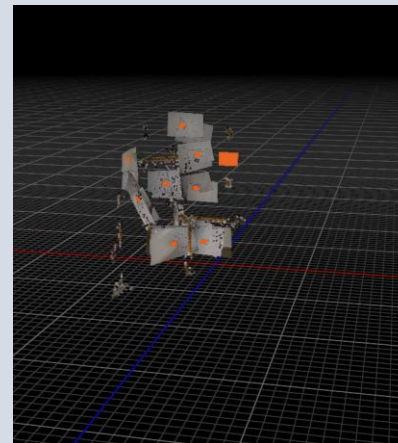
3. Triangulation



4. Add point cloud



4. Add images



RECONSTRUCTION PIPELINE

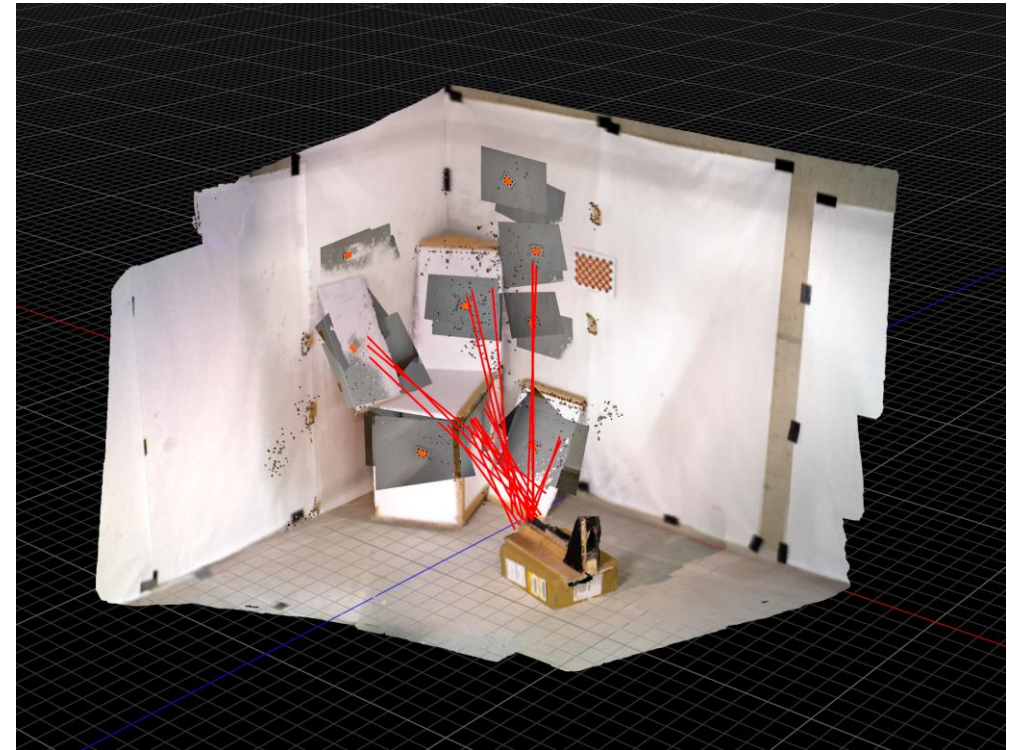
Translational median error < 3mm
Rotational median error < 0.2°

Step 2: Trajectory Calculation

Trajectory Calculation

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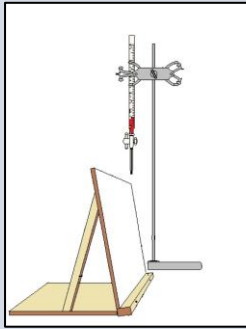
- **Problem**: we want to reconstruct the trajectories of our bloodstains.
 - We do not want to measure or calculate manually
 - We do not want to assume shape (we want to **learn** it)
- **AI - Machine learning**: algorithms that enable computers to learn patterns from data and improve their performance on tasks without being explicitly programmed for every rule.



Trajectory Calculation

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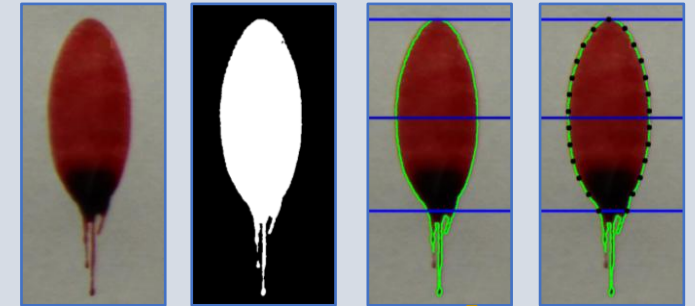
1. Stain creation



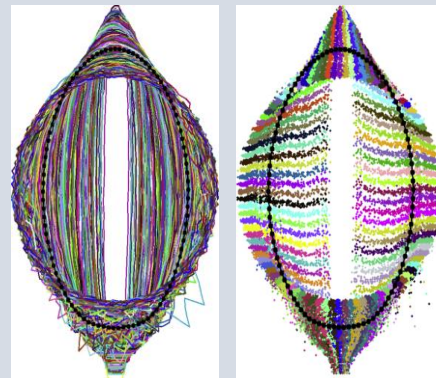
2. Extract stains



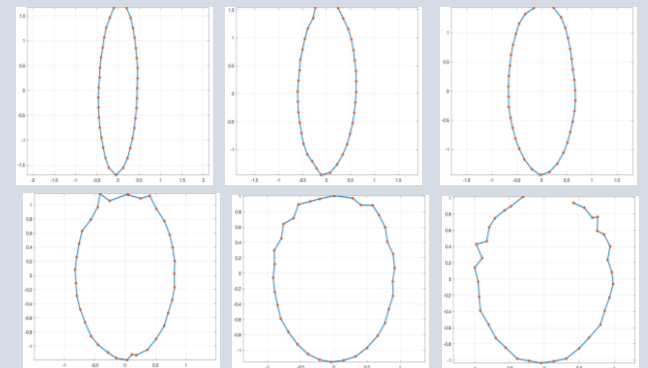
3. Contour subsampling



4. Contour alignment



3. Contour subsampling



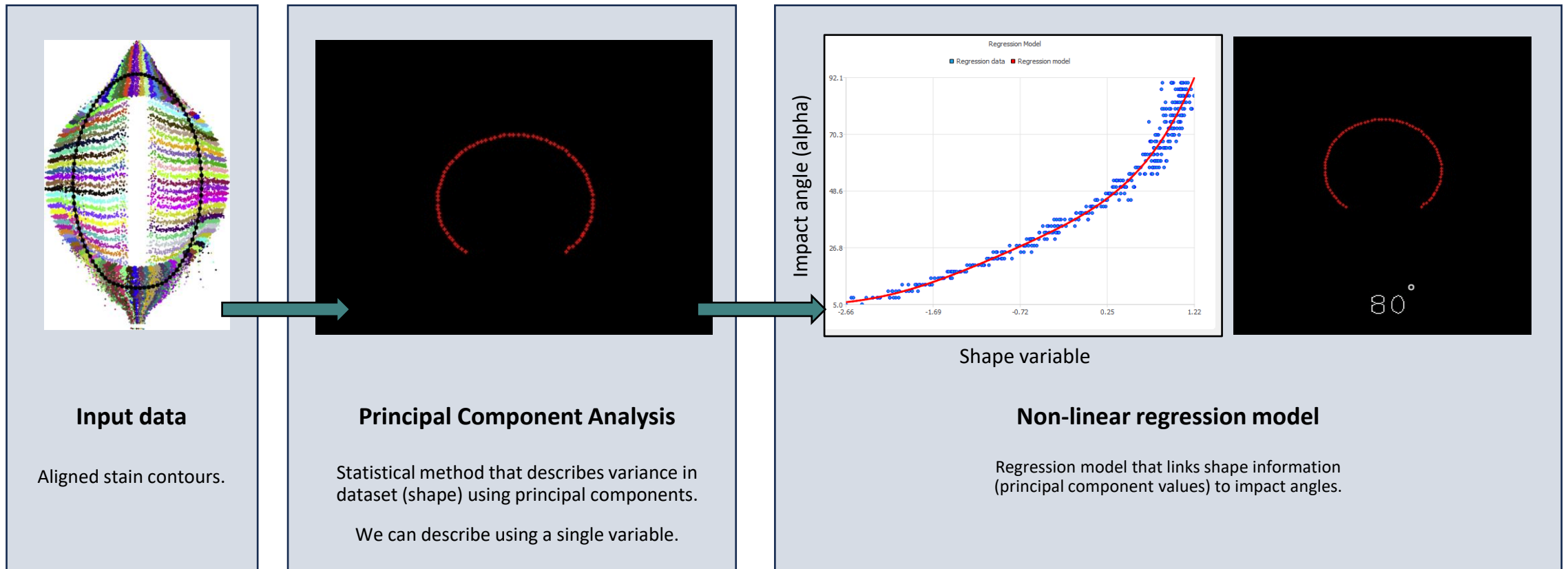
STEP 1: DATA COLLECTION

We need a representative dataset of stains with known impact angles.

Trajectory Calculation

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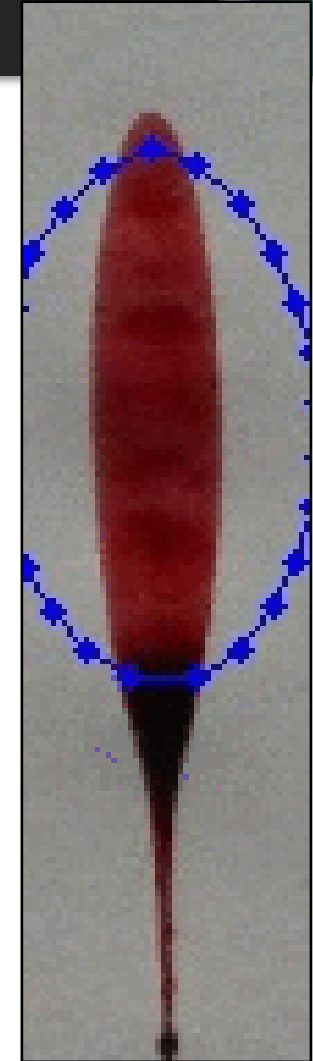
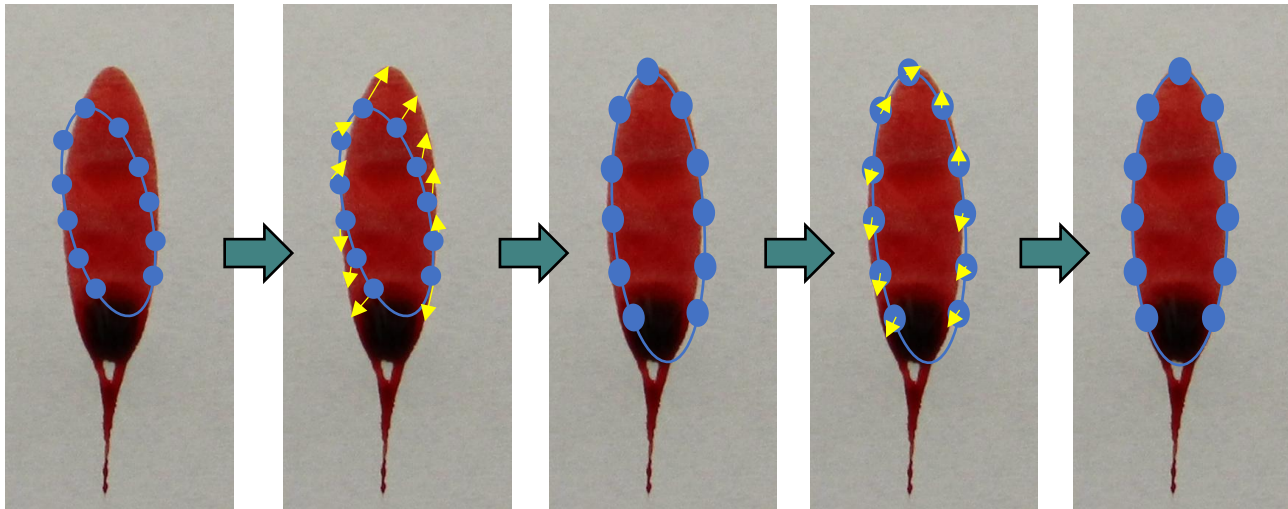
STEP 2: LEARNING STAGE



Trajectory Calculation

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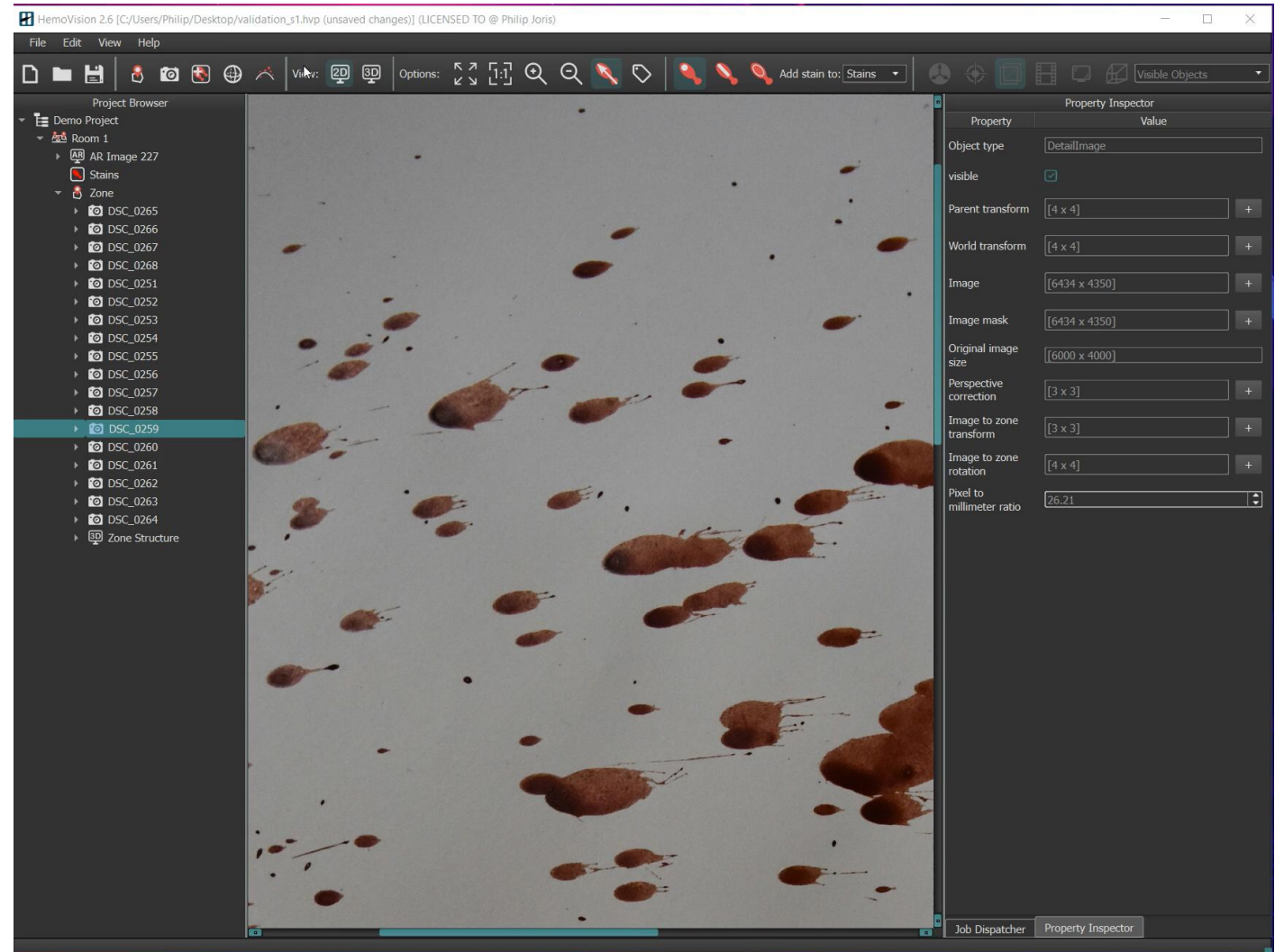
- We can now apply this model to new (unseen) stains
 - Alternatively change model shape and align to stain



Trajectory Calculation

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- Stain analysis in HemoVision
- Simply click on any stain

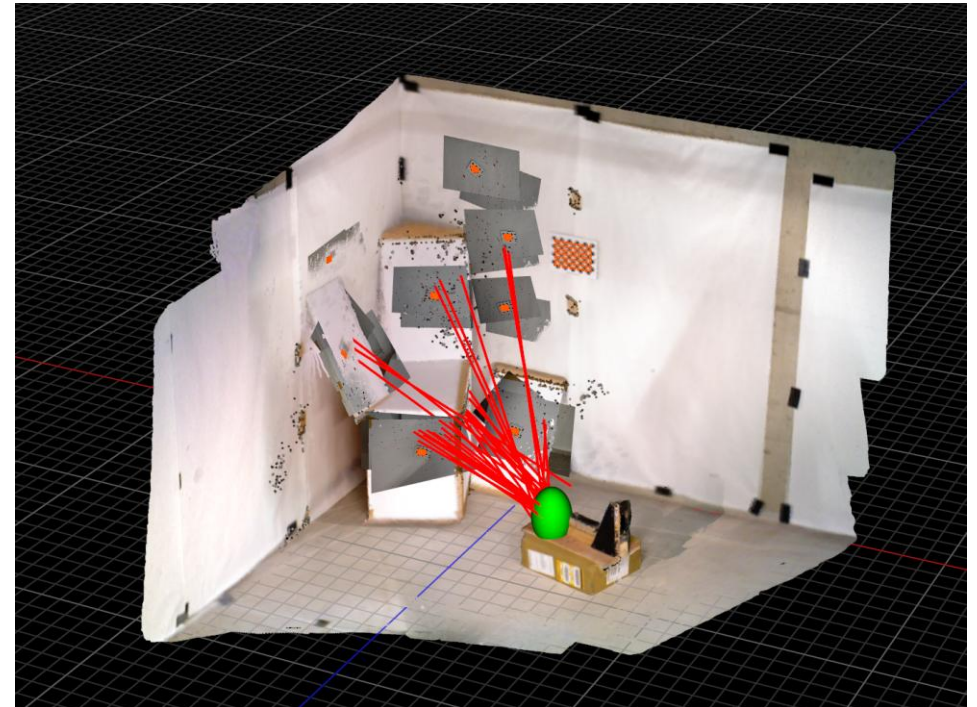


Step 3: Convergence Analysis

Convergence Analysis

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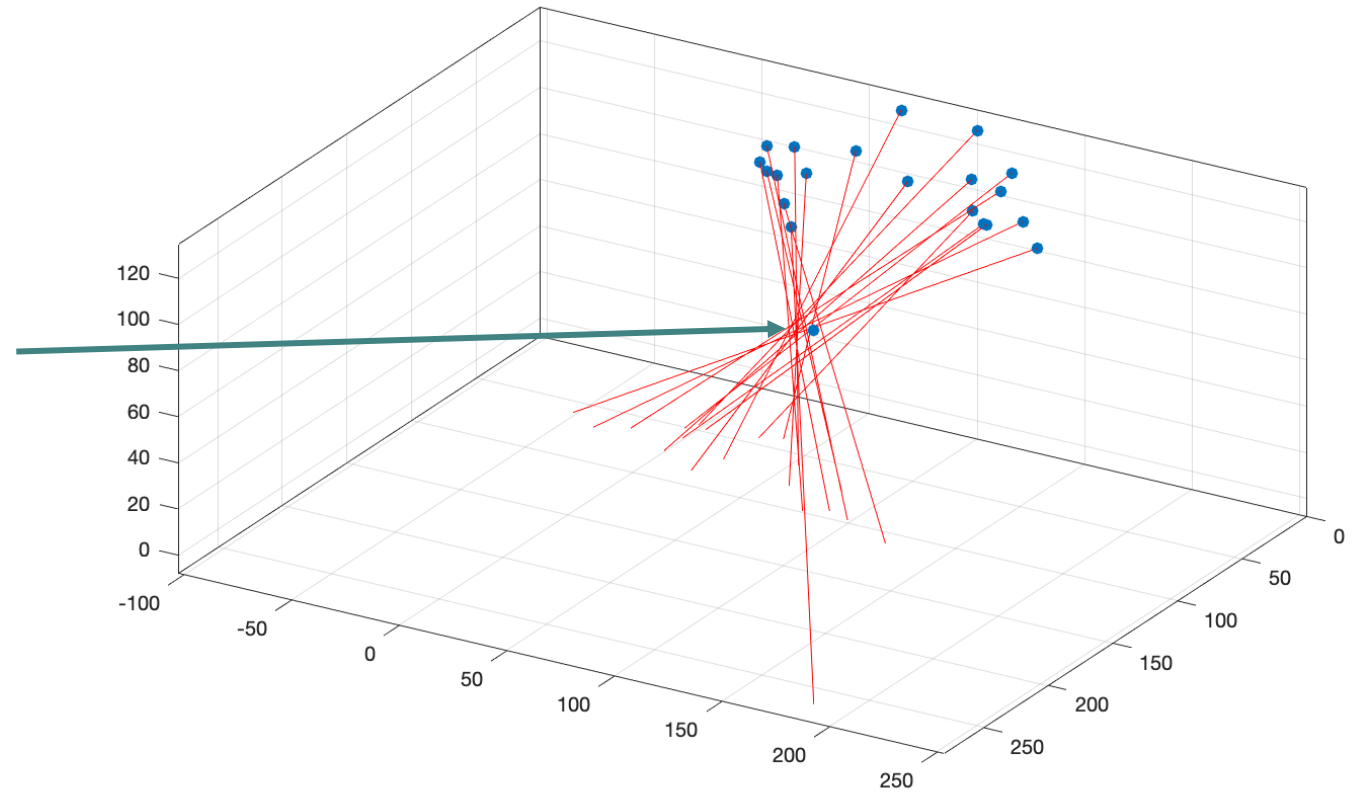
- **Problem**: we want to analyze convergence of trajectories to estimate the area of origin (AO)
 - We do not want to calculate manually
 - We want the most likely solution
- **AI - Optimization methods**: computational techniques used to identify the best solution or decision from a set of possible alternatives based on defined objectives and constraints.



Convergence Analysis

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- We are given a set of linear trajectories
 - Find the point where 'convergence is the highest'
 - How to do this?

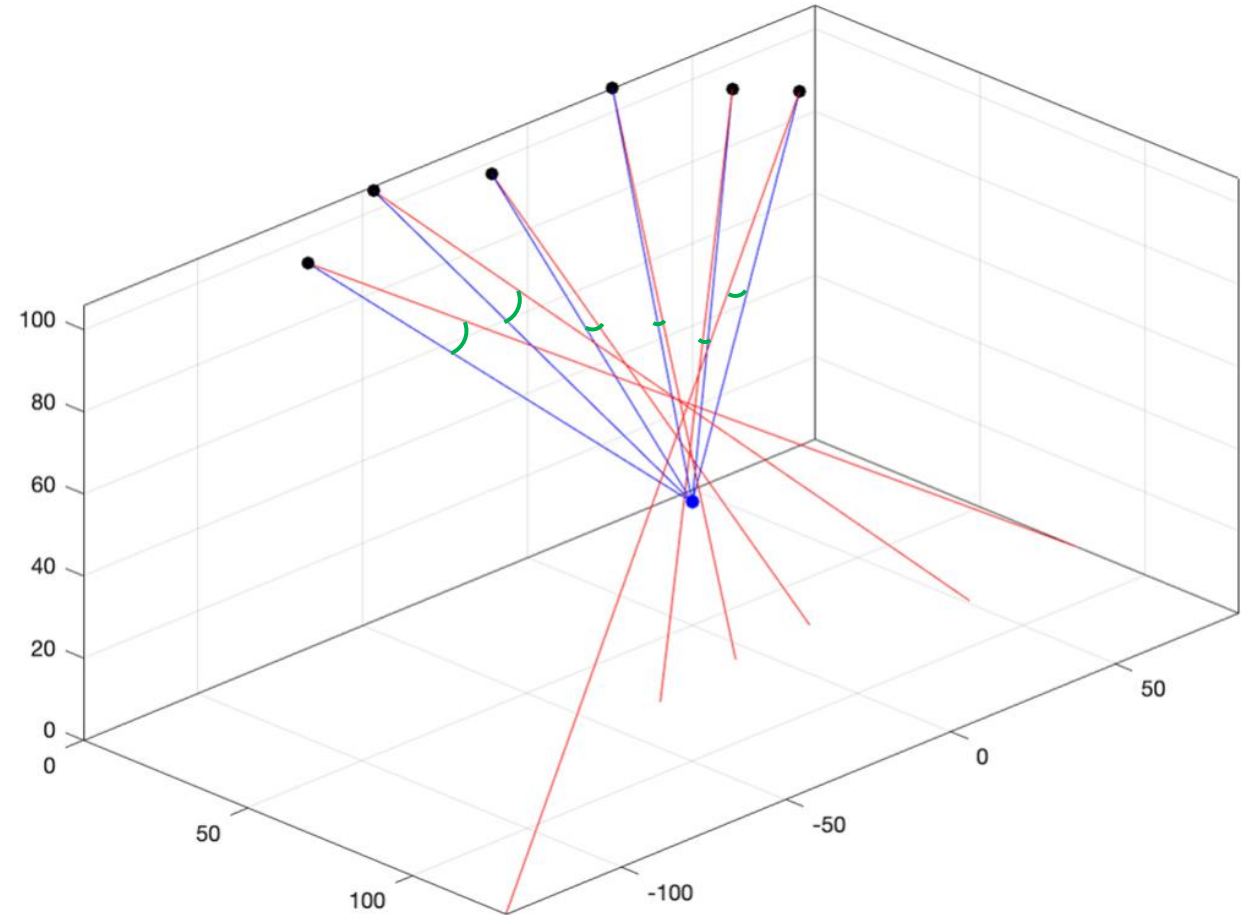


Convergence Analysis

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- We want the computer to find the ‘best’ AO location
 - We need a way to **express how good (or bad) a location is.**
- Procedure:
 1. Calculate stain trajectories (red)
 2. Choose a random location for the AO (blue)
 3. Connect random point with stains (blue)
 4. Calculate the angles between blue and red lines (green)
 5. Smaller angles = more convergence
- Express mathematically

$$\operatorname{argmin}_{\mathbf{AO}} \sum_{i=1}^n \left[\cos^{-1} \left(\frac{(\mathbf{AO} - \mathbf{c}_i) \cdot \mathbf{d}_i}{\|\mathbf{AO} - \mathbf{c}_i\| \cdot \|\mathbf{d}_i\|} \right) \right]^2$$



Convergence Analysis

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- We can calculate this cost function for each point in 3D space.
 - This is slow.
- **Mathematical optimization**: we ask computer to find the optimal point.
 - This is fast.

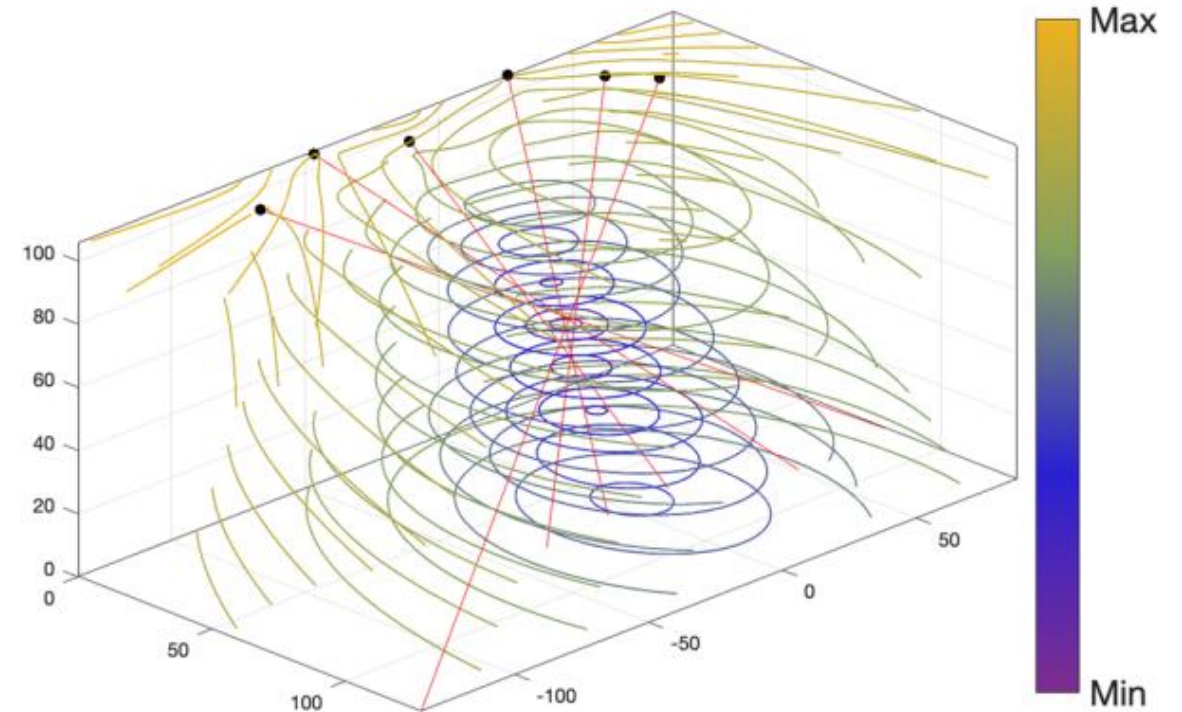


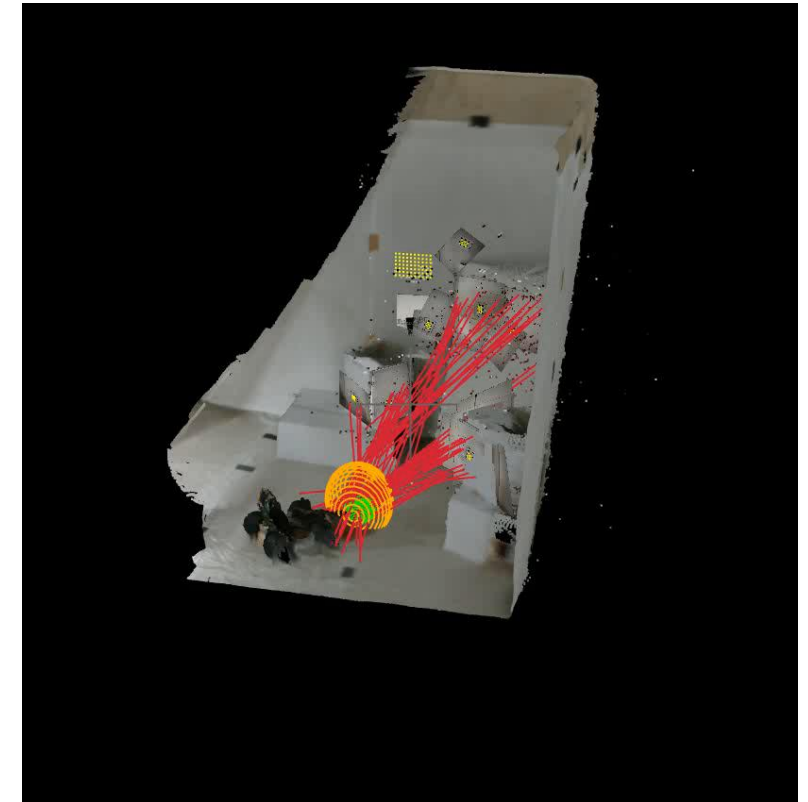
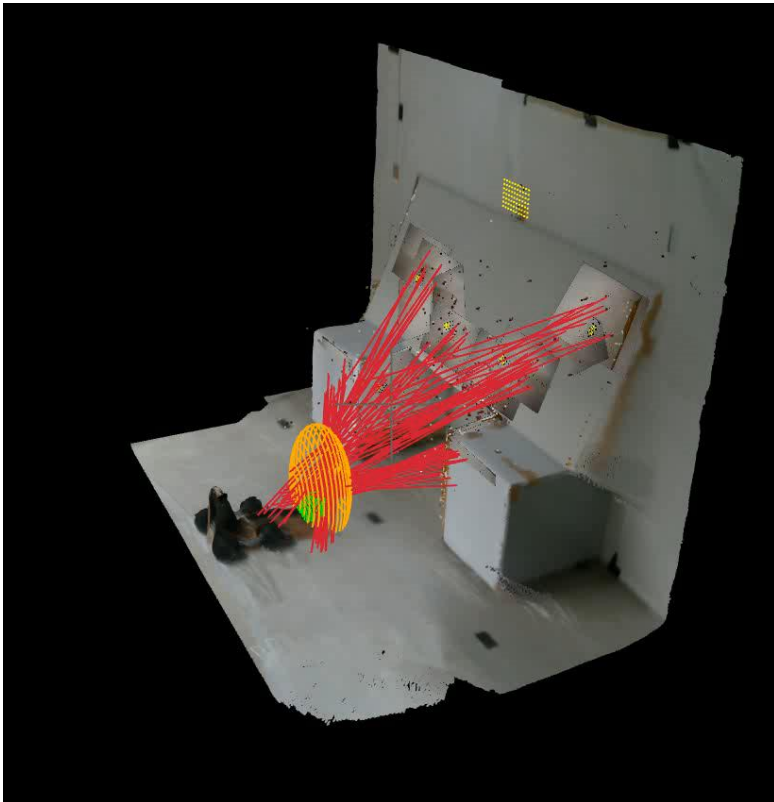
Fig. 7. A contour plot of the cost function from Eq. (17) around a set of linear trajectories.

Validation Studies

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- Document true Area of Origin
 - Compare to the estimated Area of Origin

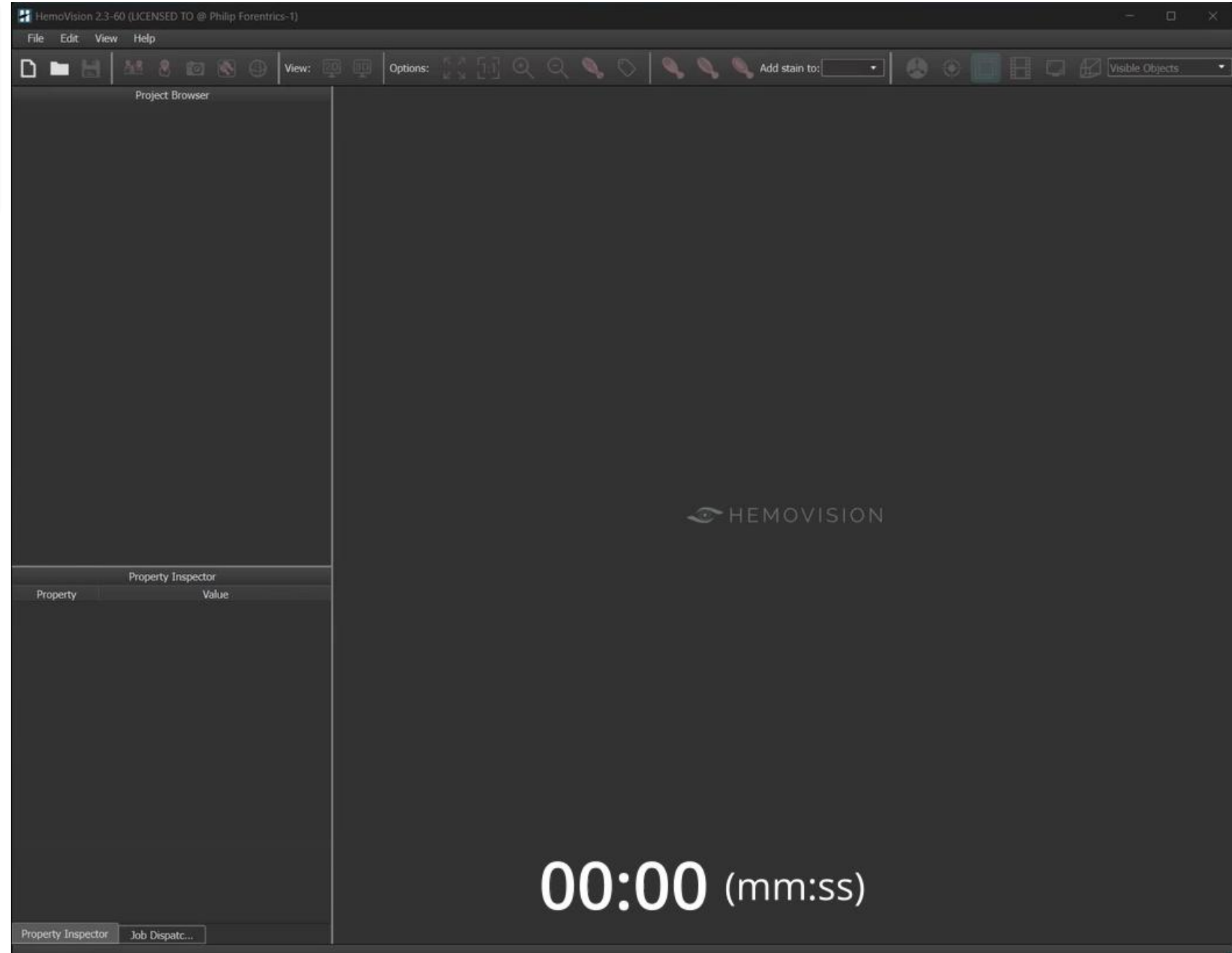
Average X-Error	2.2cm
Average Y-Error (height)	6.9cm
Average Z-Error	2.5cm
Average Total Error	8.1cm



Step 3: Some Examples

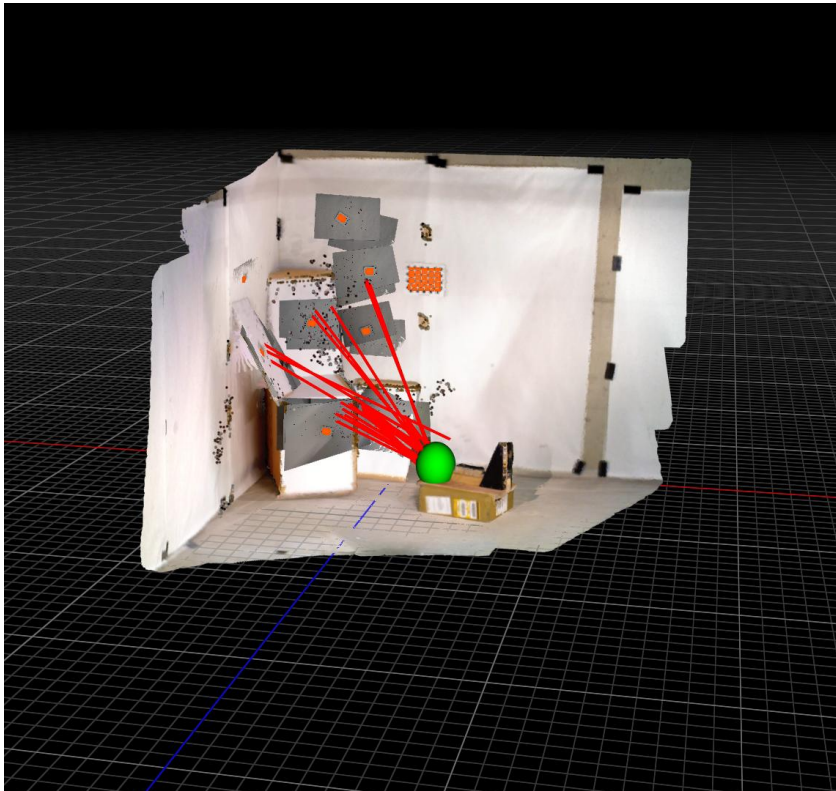
Quick & Easy

- Impact pattern with 60+ stains
- Usually takes hours to process, only with a few stains
- Few minutes with HemoVision + visualization

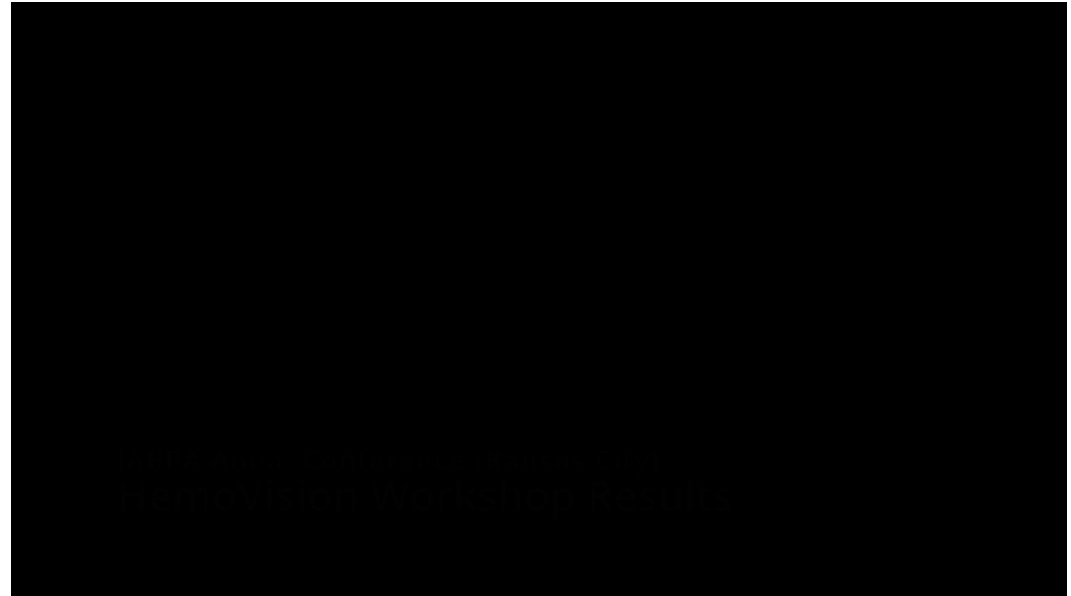


Analyze Various types of patterns

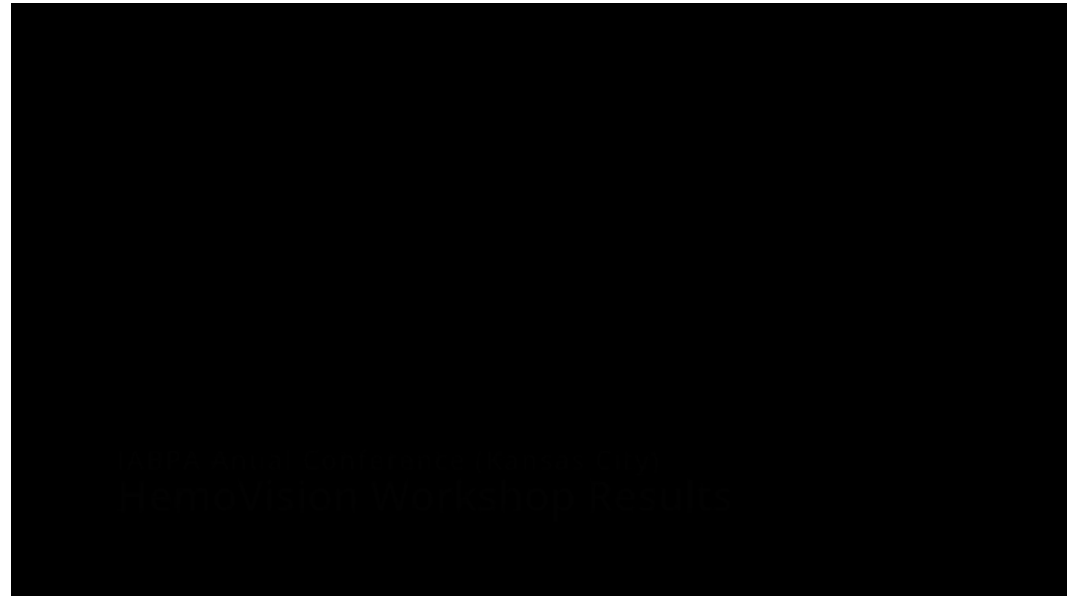
Impact Pattern



Cast-off Pattern

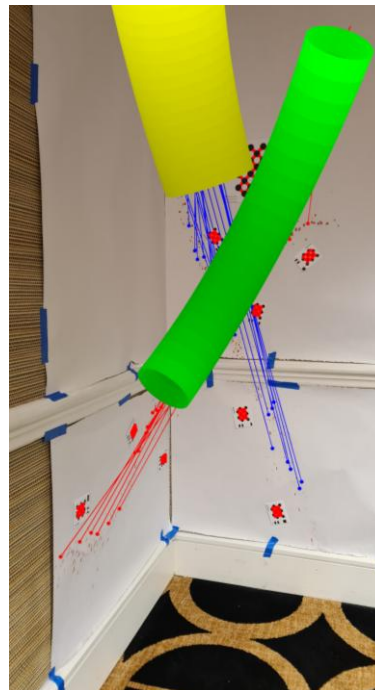
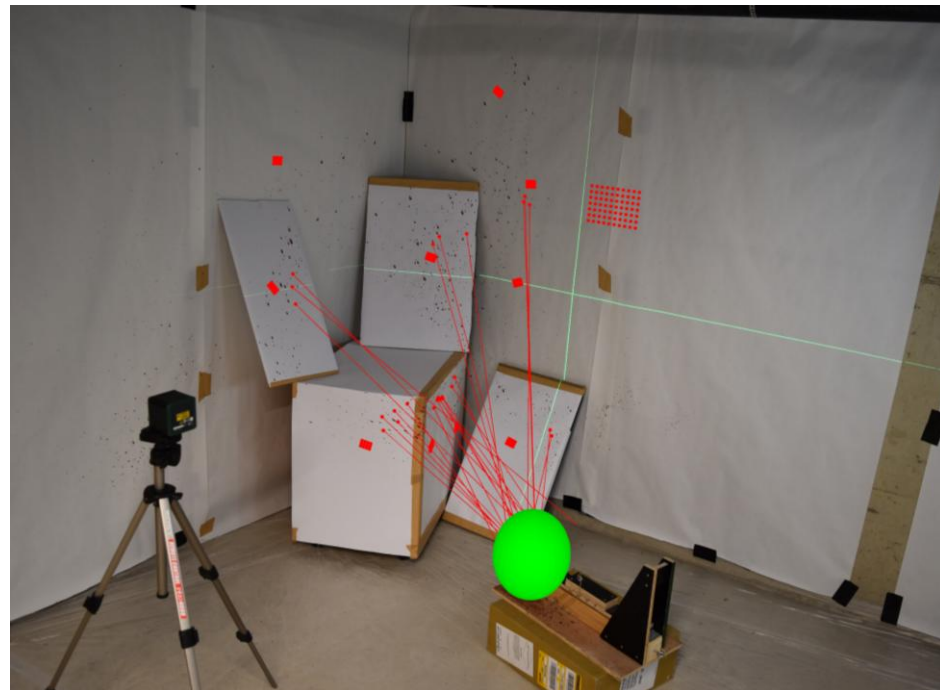
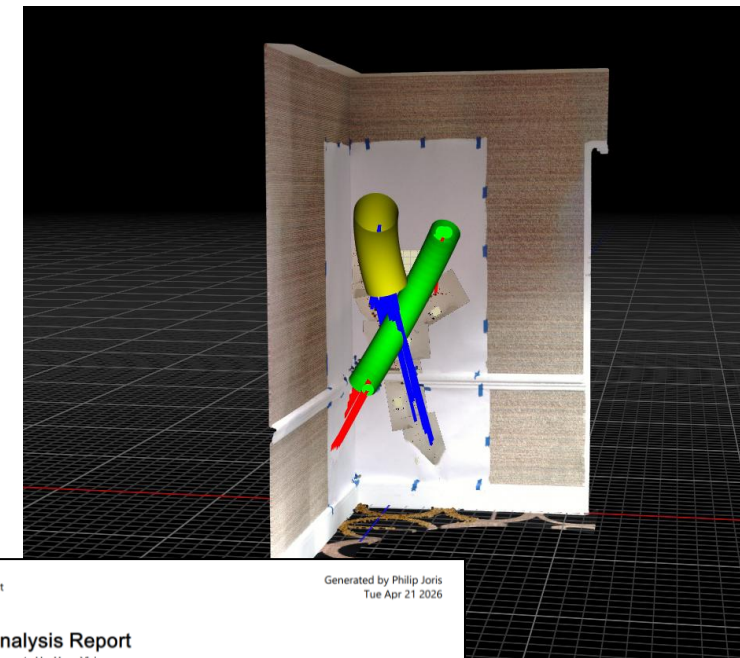
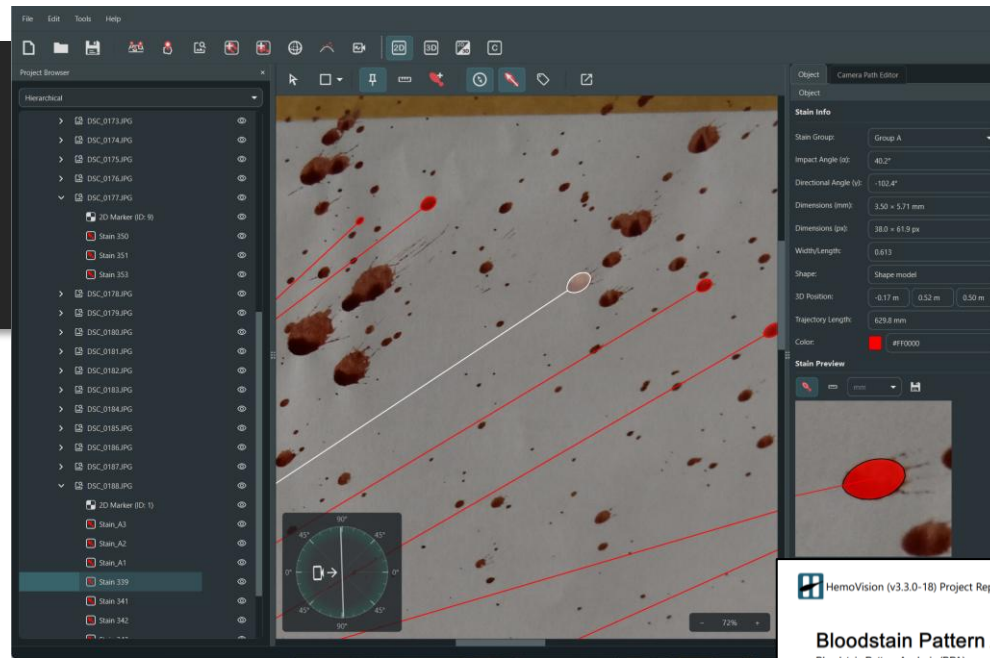


Expired Pattern



Compelling Visualizations

2D view, 3D view, Augmented Reality, automatic reports, videos, ...



HemoVision (v3.3.0-18) Project Report Generated by Philip Joris
Tue Apr 21 2026

Bloodstain Pattern Analysis Report

Bloodstain Pattern Analysis (BPA) report generated by HemoVision.

General Information

This section contains general information about the scene and the analysis.

HemoVision Licensee: Philip Joris
 Project name: Scene5
 Project date: 2026-03-16
 Project description:
 Coordinate system: Y-up (right-handed)
 Report generated on: 2026-04-21

Results Section

This section contains all numerical data associated calculated areas of origin.

Area of Origin (AOO)	
Scene:	Scene 1
AOO method:	Least-Squares Angles
AOO center:	0.35m 0.24m 0.72m
AOO sigma (1x):	0.04m 0.04m 0.04m
AOO sigma (3x):	0.11m 0.13m 0.11m
AOO diameter:	0.22m 0.26m 0.22m
Stain groups:	Group A (24 stains)

Detailed Stain Information

This sections gives an overview of all stains that are included in the project, along with the stains' properties.

Stain name: Stain 331	
Image coordinate (px):	3187.60px 1110.62px 0.00px
World coordinate:	-0.18m 0.49m 0.70m
World direction:	0.89 -0.46 0.04
Alpha:	24.61°
Gamma:	105.85°
Group:	Group A
Trajectory length:	0.59m
Color (R,G,B):	255 0 0

Stain name: Stain 332	
Image coordinate (px):	2835.01px 1538.28px 0.00px
World coordinate:	-0.22m 0.46m 0.72m

- AI is an umbrella term, covering a wide array of techniques.
- HemoVision integrates various forms of AI into a complete and easy-to-use software tool.
- AI offers significant advantages over traditional methods



Efficient Workflow

Removes manual work and gets results up to 10 times faster compared to other methods.



Accurate Results

Internal and independent validation studies have proven HemoVision to be reliable and accurate.



Advanced Reporting

Rich visualization features allow you to report and present your findings in the most compelling way.

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www.hemovision.com

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Any questions?

Have an idea? Want to collaborate, or discuss ideas? Reach out!

