Asia-Pacific
Economic Cooperation

2025/SOM3/EGILAT/DIA/012
Agenda Item: 6

Development of Artificial Intelligence (AI)-Powered Automation of Microscopic Feature Detection in Wood Identification

Submitted by: Korea

APEC 2025
KOREA

Dialogues and Mini-Exhibition on Enhancing Enforcement and Legal Timber Trade through Stakeholder Collaboration and Innovation
Incheon, Korea
28 July 2025

Development of AI-Powered Automation of Microscopic Feature Detection in Wood Identification

Ohkyung Kwon, Ph.D.
NICEM, Seoul National University

Traditional Wood Anatomy : Barriers and Bottlenecks

Traditional wood anatomy is **the gold standard**, but it's slow, requires rare expertise, and often fails to distinguish between closely related species—a critical flaw in regulatory enforcement.

Slow & Destructive

The manual process of preparing thin sections is a time-consuming craft, limiting throughput and requiring destruction of part of the sample.

Expert Dependent

Identification relies on a small and diminishing pool of highly trained anatomists, creating a significant bottleneck for large-scale analysis.

Genus-Level Barrier

Anatomical similarity between species within the same genus makes definitive species-level ID unreliable, hindering CITES enforcement.

The Search for a Better Way

Computer Vision (Classification)
Uses AI to recognize the overall pattern of a wood image. It's fast and accessible but suffers from the "black box" problem—its reasoning is opaque and not based on scientific anatomical features, making it hard to verify.

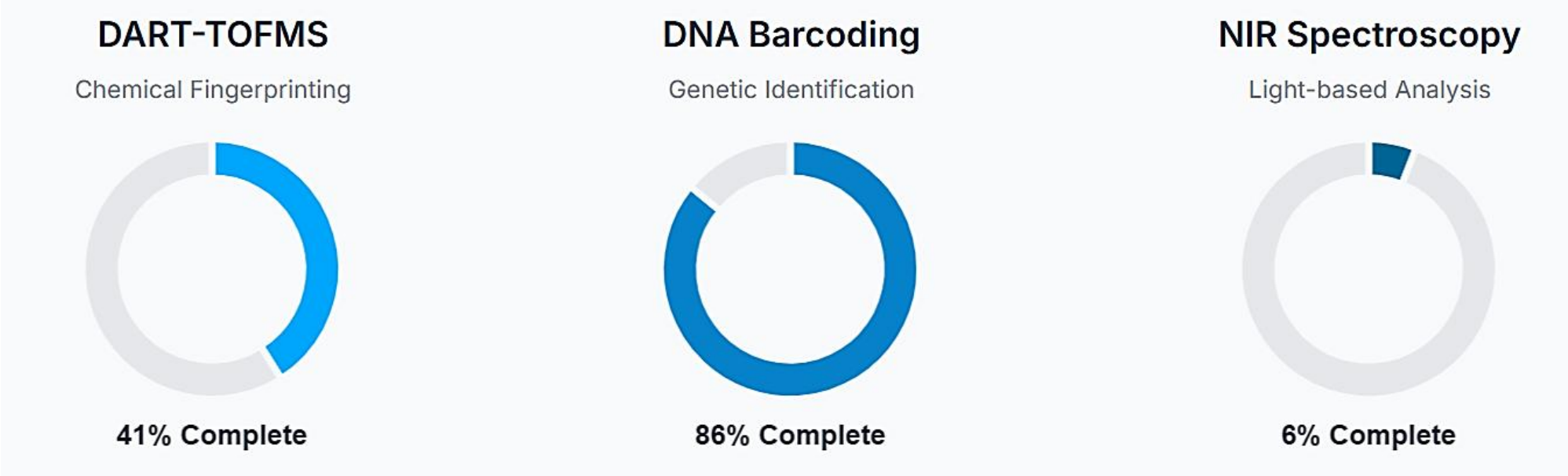
DART-TOFMS
Creates a unique chemical fingerprint of a wood sample. It's fast and powerful for certain applications but is lab-bound, expensive, and its accuracy depends heavily on the statistical models used.

NIR Spectrometry
A rapid, non-destructive method analyzing how wood interacts with near-infrared light. Its accuracy can be modest and is affected by factors like moisture content. Requires sophisticated statistical models to interpret results.

DNA Barcoding
Offers the highest potential for species-level accuracy by reading the genetic code. However, extracting usable DNA from processed wood is extremely difficult, costly, and often fails, making it impractical for large-scale use.

The Database Bottleneck

The Common Achilles' Heel
Every single modern method, regardless of its technology, is fundamentally dependent on **a large, comprehensive, and high-quality reference database.** Building these databases is **the true bottleneck** for the entire field.



Tracing the world's timber: the status of scientific verification technologies for species and origin identification, IAWA Journal 44(1):63-84, 2022

Overcome the Bottlenecks and Barrier

[1] Slow & Destructive

Very difficult to overcome, but not impossible

Remove the necessity to make microscope slides by utilizing sanded wood blocks and surface observation microscopy

[2] Expert Dependent

Automated investigation system for microscopic features of wood

Use trained object detection models for investigation with an automated imaging system

[3] Genus-Level Barrier

Large-scale investigation for anatomical features of wood

Construct large-scale microscopic image database and examination at various magnification and modality

Overcome the Bottlenecks and Barrier

We propose an automated system that uses AI to objectively quantify standardized anatomical features from microscopic images.

① **Standardize**

Adopt the IAWA List of Microscopic Features as a universal "alphabet" to describe wood anatomy, turning **qualitative observations into structured data**.

→

② **Automate**

Develop an automated, high-throughput microscopy system to generate the **massive, high-resolution image database** required for training deep learning models.

→

③ **Analyze**

Use AI object detection to **identify**, **localize**, and **quantify** IAWA features, creating a **verifiable**, "glass box" analysis instead of an opaque classification.

A New Approach: Object Detection AI on Microscopic Features of Wood

APEC 2025 KOREA

1. Automated Imaging
High-throughput scanner captures thousands of images.

→

2. Large-Scale Database
A massive, carefully annotated image library is built.

→

3. Object Detection AI
AI finds & measures IAWA features, not just guesses the species.

→

4. Verified ID
Feature list is matched to knowns for a verifiable result.

OLD WAY: The Black Box

Standard AI classifies images but can't explain its reasoning. It's a "trust me" system that lacks scientific verifiability.

```
Image → [ ??? ] → "Oak"
```

NEW WAY: The Glass Box

Our object detection AI shows its work. The output is a verifiable list of anatomical features, just like a human expert.

```
Image → [ Feature List ] → "Oak"
```

Overcome the Bottlenecks [1]: Wood Anatomy from Wood Surfaces

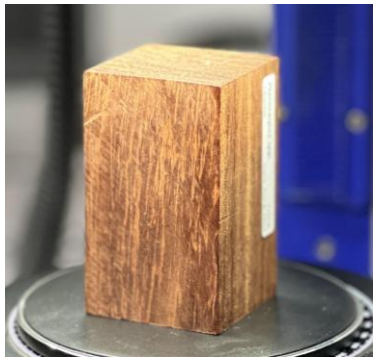
APEC 2025 KOREA

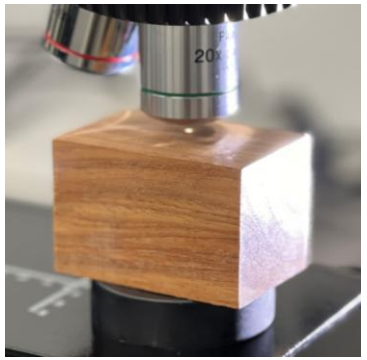
Epi-illumination Light Microscopy

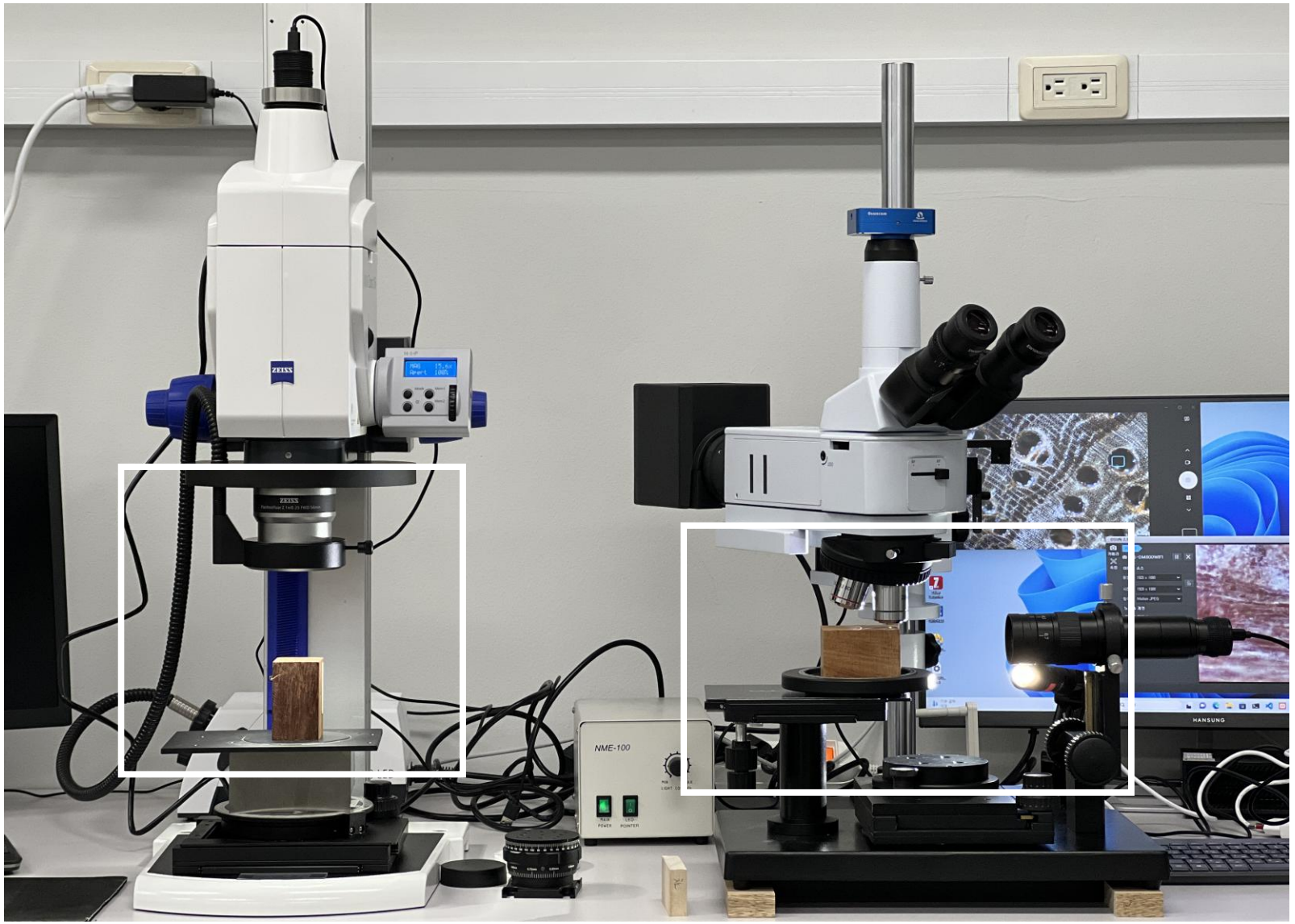
Stereomicroscope

Reflected light microscopy

Fluorescence microscopy





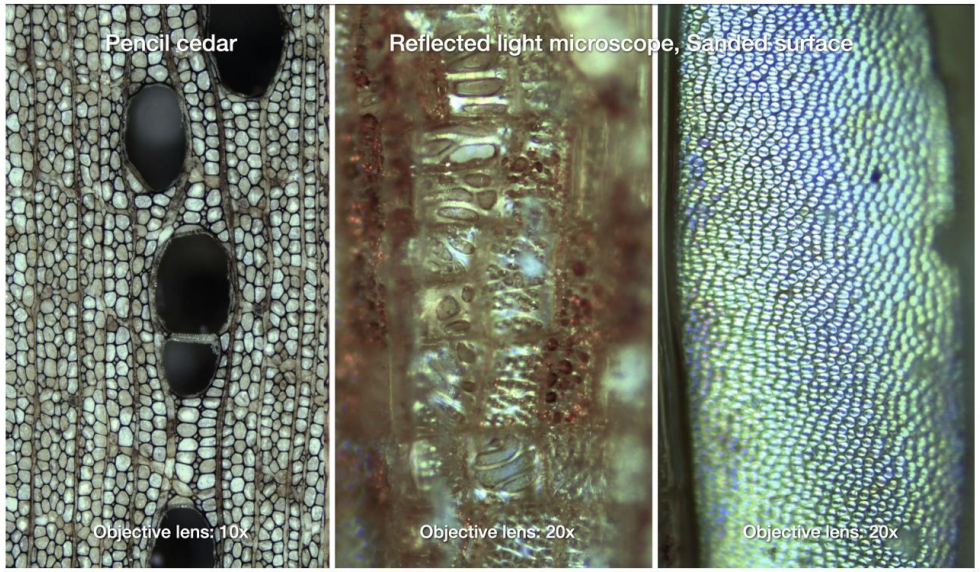


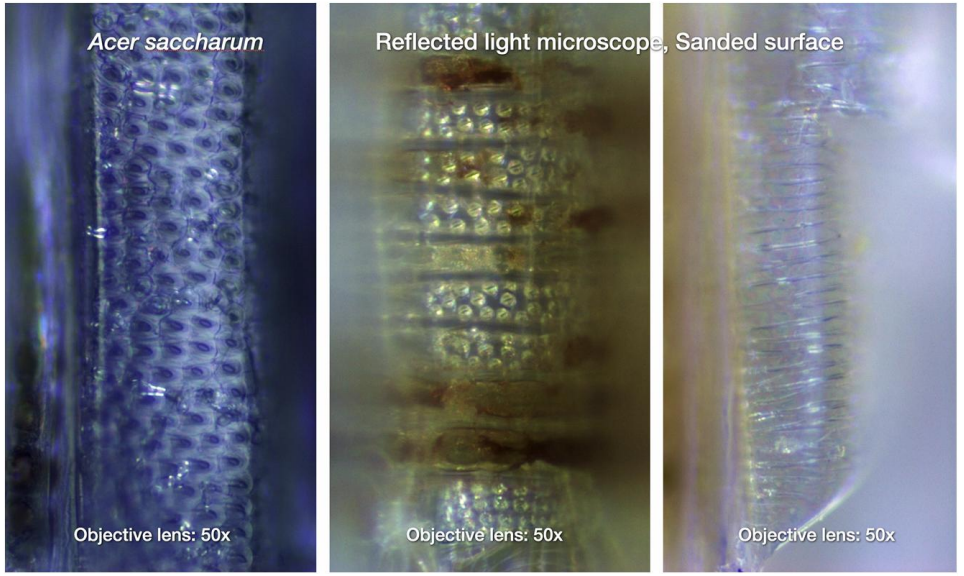
[1] Wood Anatomy from Wood Surfaces: Stereomicroscope

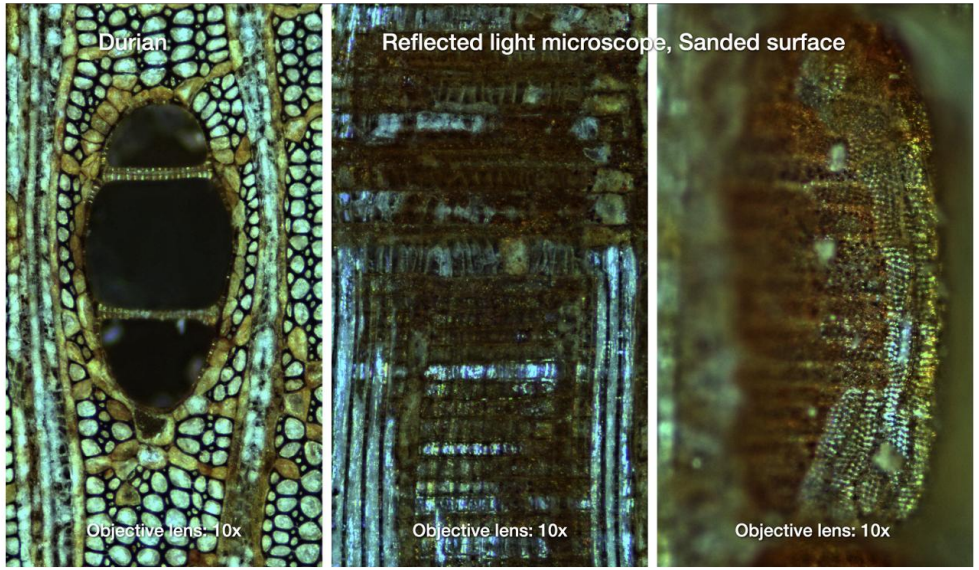
APEC 2025 KOREA

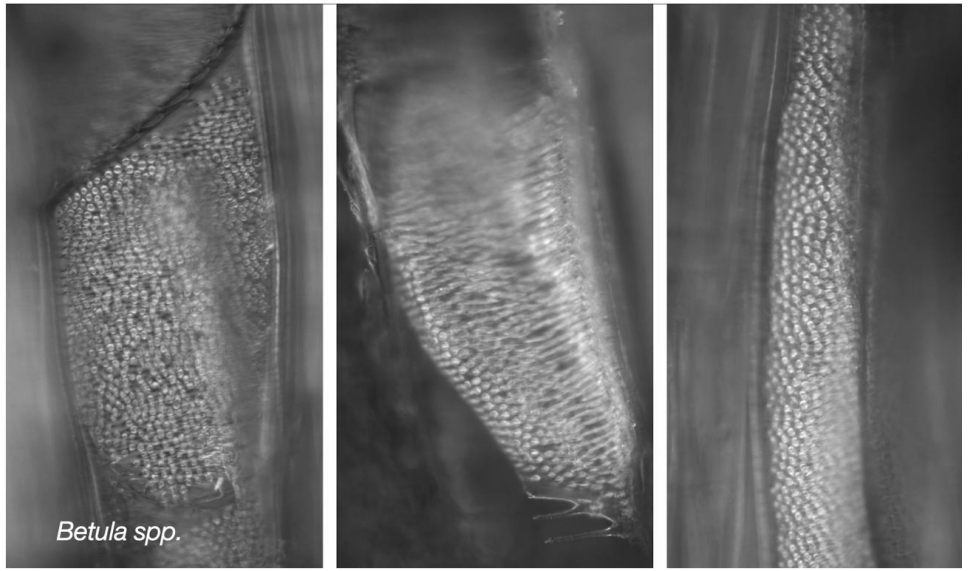
[1] Wood Anatomy from Wood Surfaces: Reflected Light Microscope

APEC 2025 KOREA

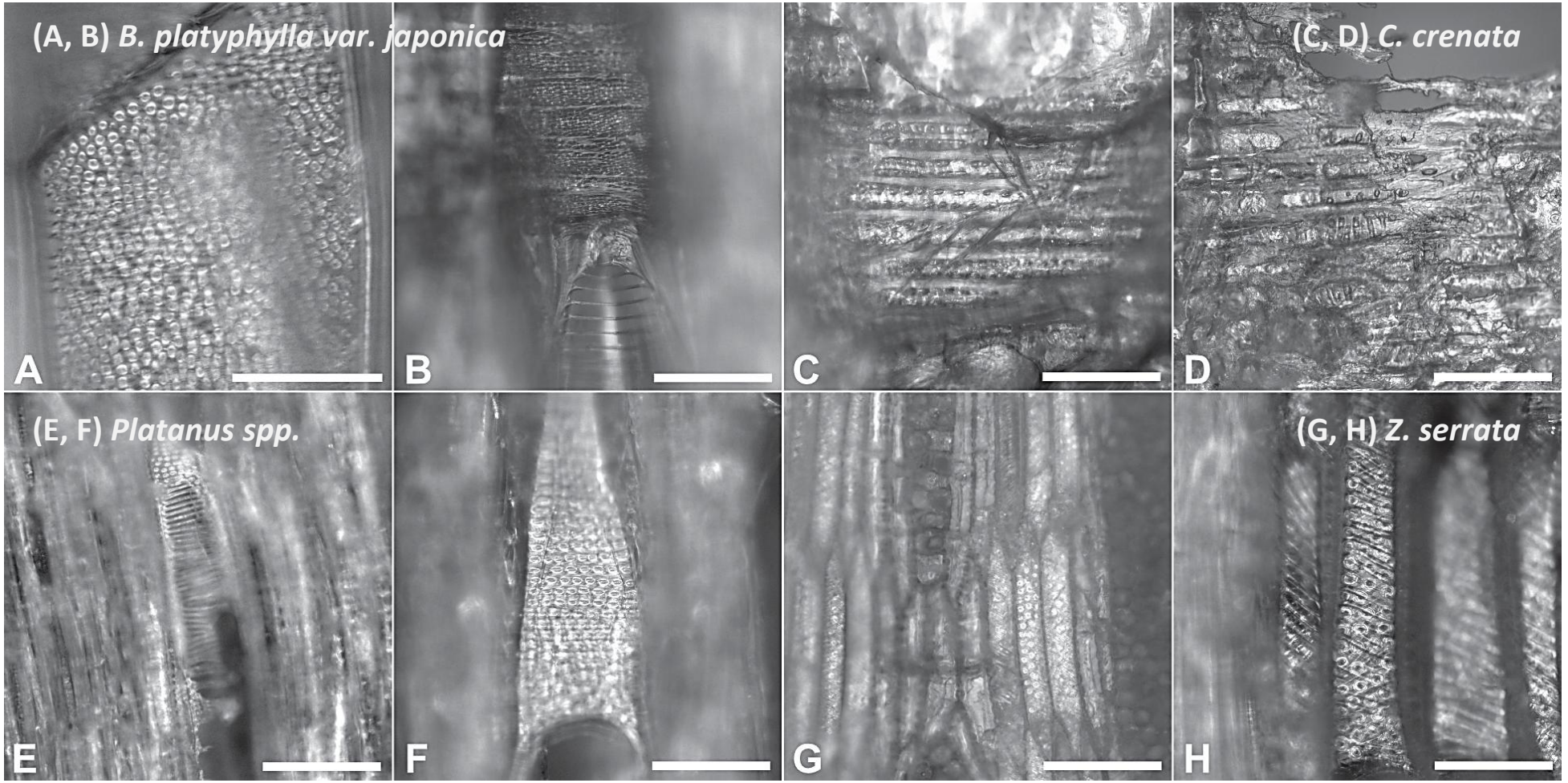








[1] Wood Anatomy from Wood Surfaces: Reflected Light Microscope



Scale bars:
(A) 50 μm
(B–H) 100 μm

(A) intervessel pits, (B) vessel-ray pits and scalariform perforation plates, (C, D) vessel-ray pits, (E) scalariform perforation plates, (F) intervessel pits, (G) ray and axial parenchyma cells, (H) intervessel pits and helical thickenings

Overcome the Bottleneck [2][3]: Automated Imaging for Large-Scale Image Collection

APEC 2025 KOREA

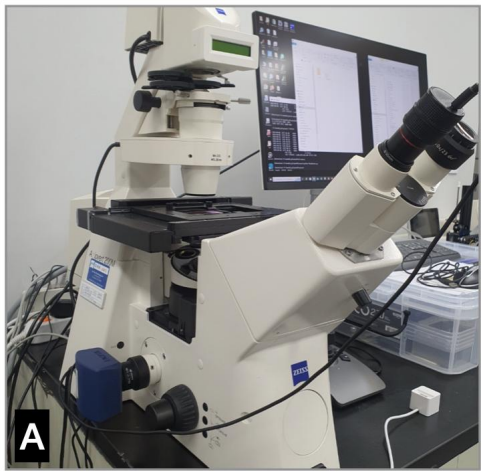
Commercial Products

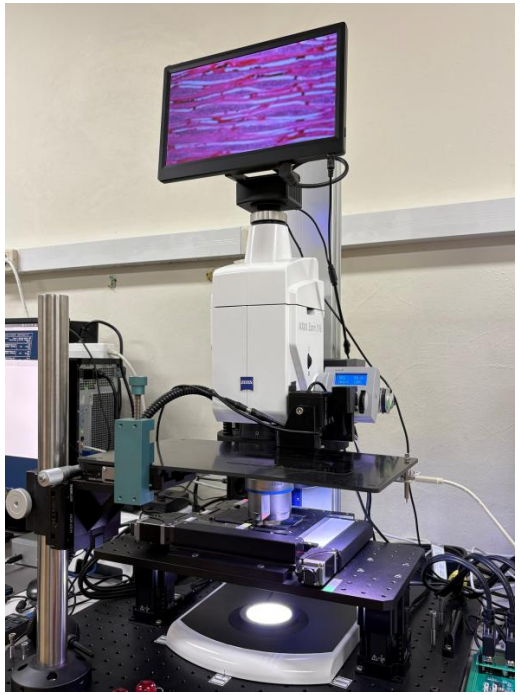
Slide scanners
Motorized light microscopes

No customized focus control
Single plane image

In-House Motorized Microscope

Smart focus control
Multi-slice images
Varying magnification for desired anatomical features

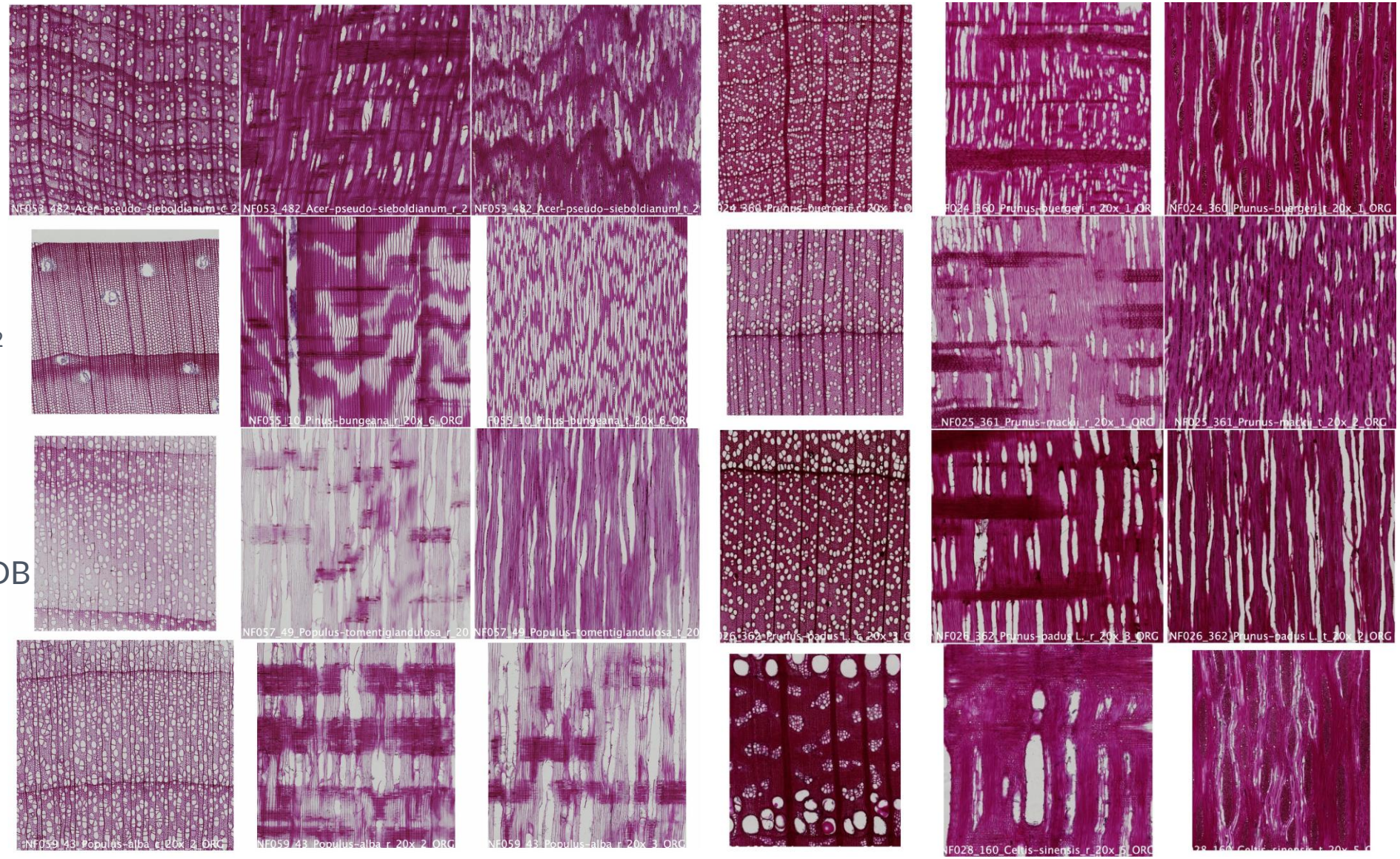




[2][3] Building Large-Scale Microscopic Image DB

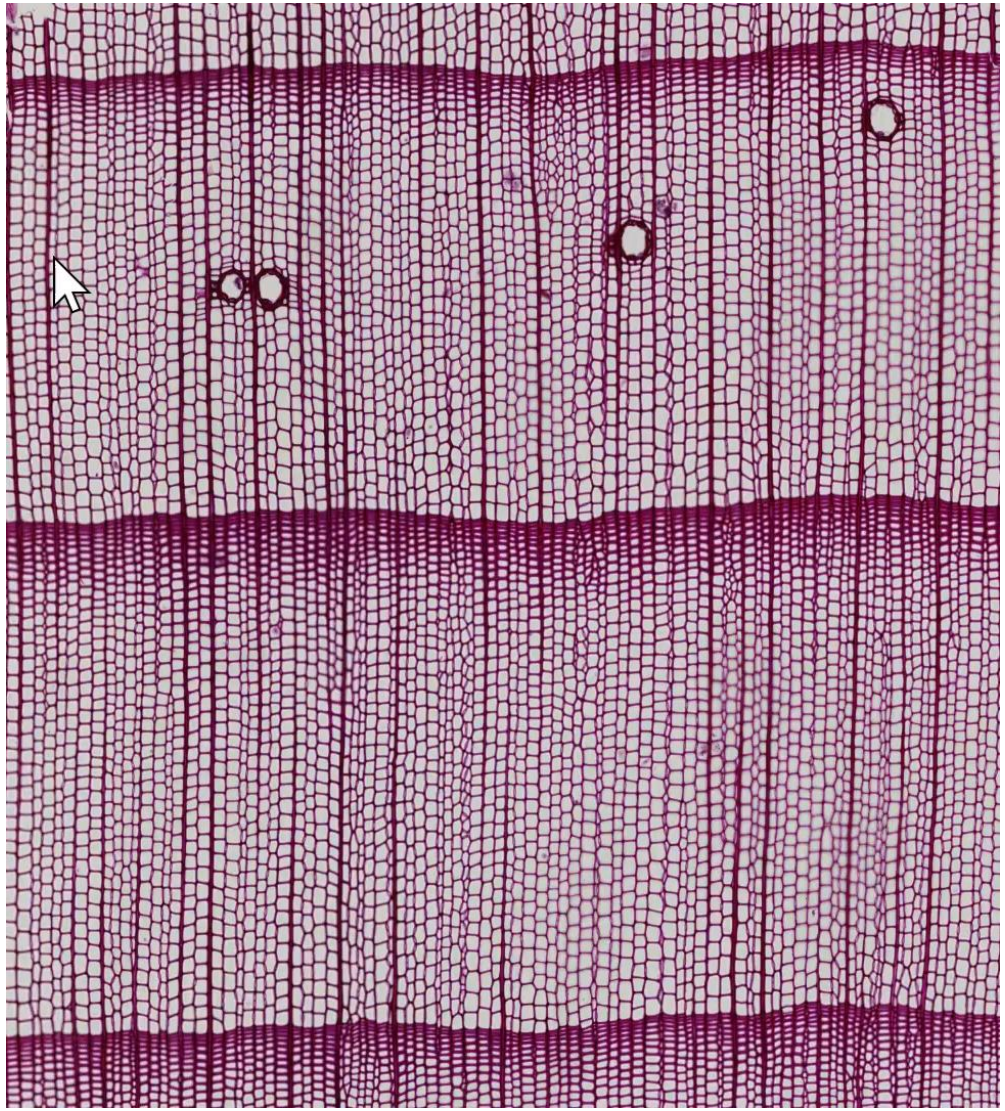
APEC 2025 KOREA

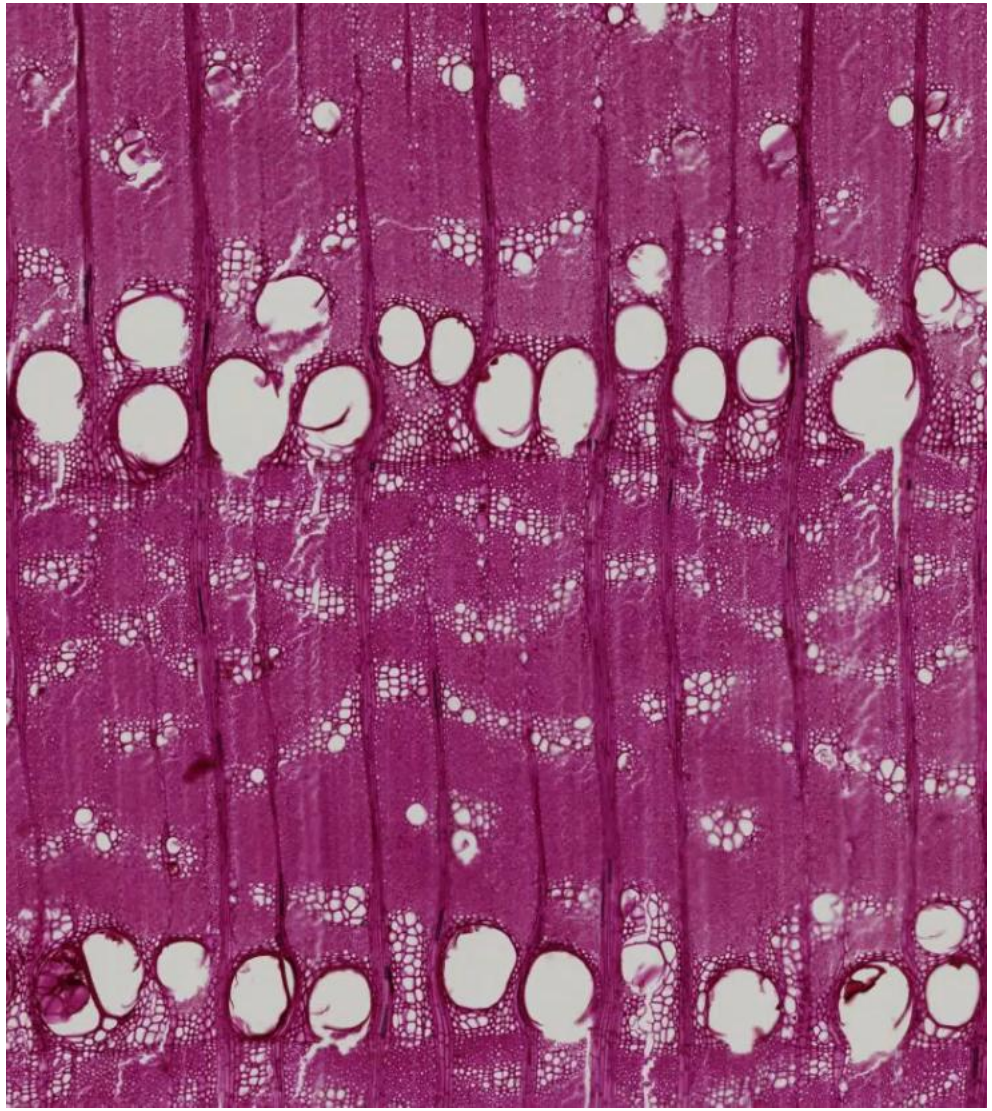
1. Objective lens: 20x/0.8
2. Imaging area: < ~15 x 15 mm^2
3. Stitched image dimension:
   > 20,000 x 20,000 pixels
4. > 3,000 microscope slides
5. > 9,000 images in the image DB



Exploring the Anatomical Features of Wood, Virtually!

APEC 2025 KOREA



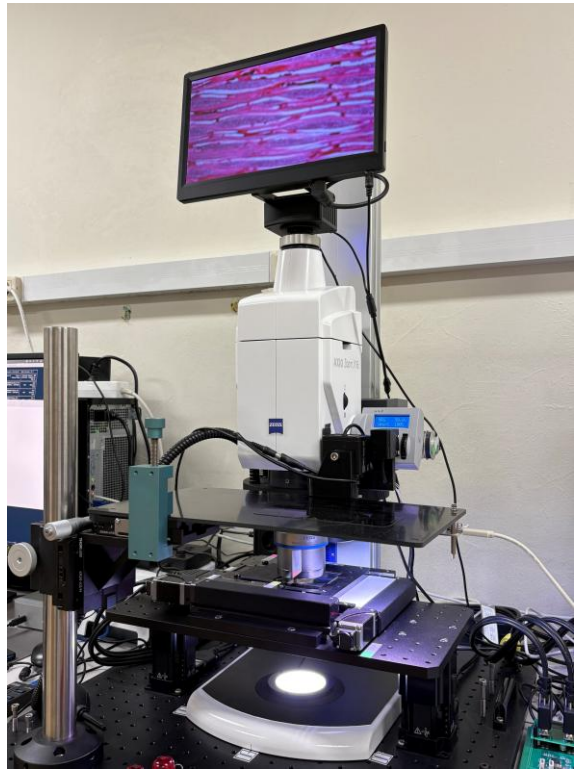


[2][3] Automated Imaging by an Intelligent Microscope

APEC 2025 KOREA

Automated Imaging

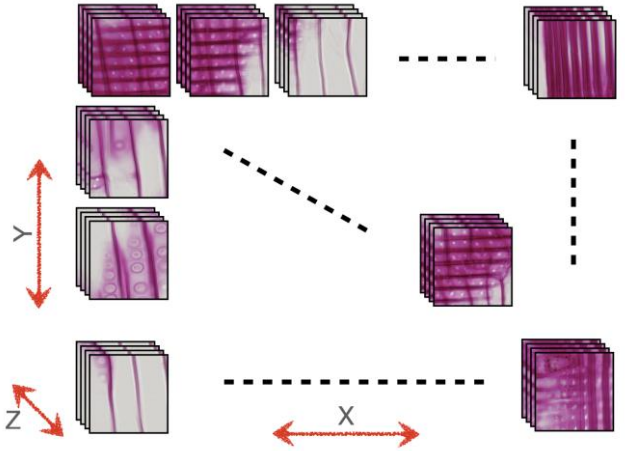
A robotic microscope captures thousands of high-resolution, standardized images of wood anatomy.



In-House Motorized Microscope

Smart focus control and multi-slice images
Varying magnification for desired anatomical features

1. ~2 sec/image ➔ ~1 hour/slide, 3 section/slide
2. Imaging at various focus positions
3. Feature-optimal magnification (in progress)
4. Feature-optimal focus control (in progress)
5. Stitched images can be generated from the tile images.

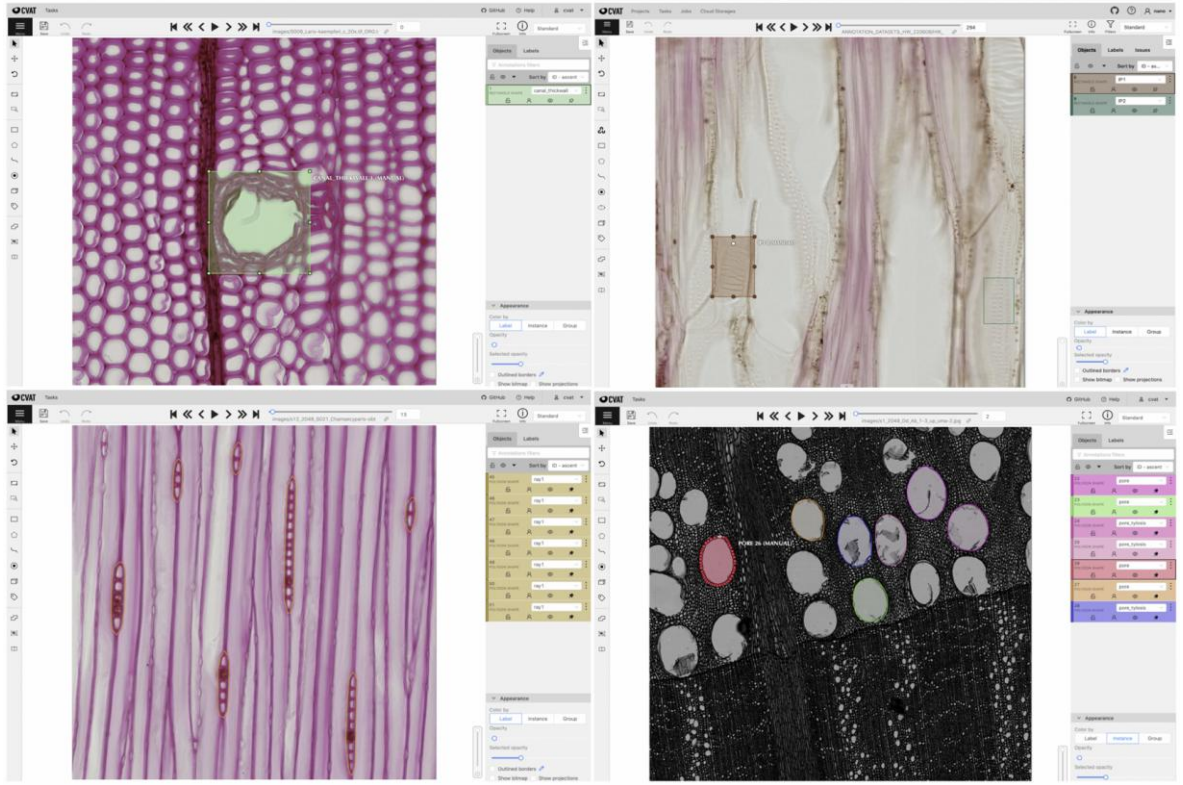


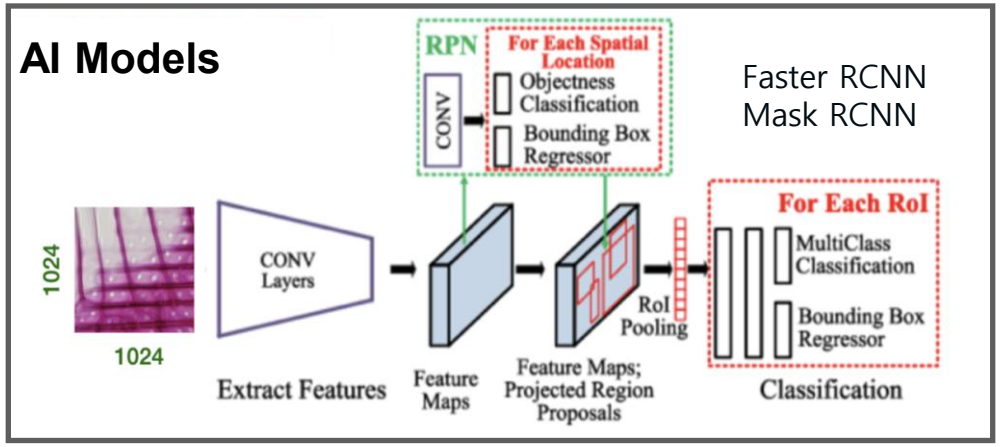
[2] Object Detection Model Training for Microscopic Features of Wood

APEC 2025 KOREA

Preparation of train datasets from the microscopic image database

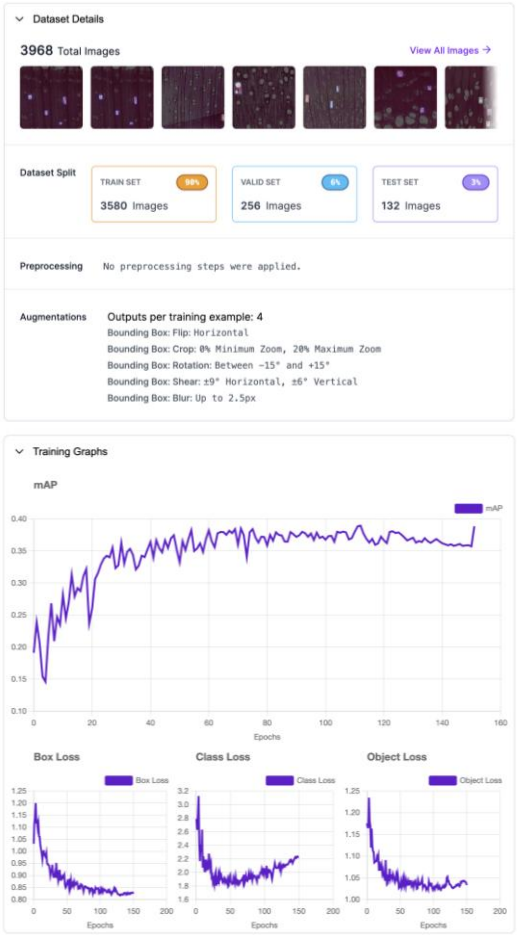
Annotation for anatomical features of wood according to IAWA codes

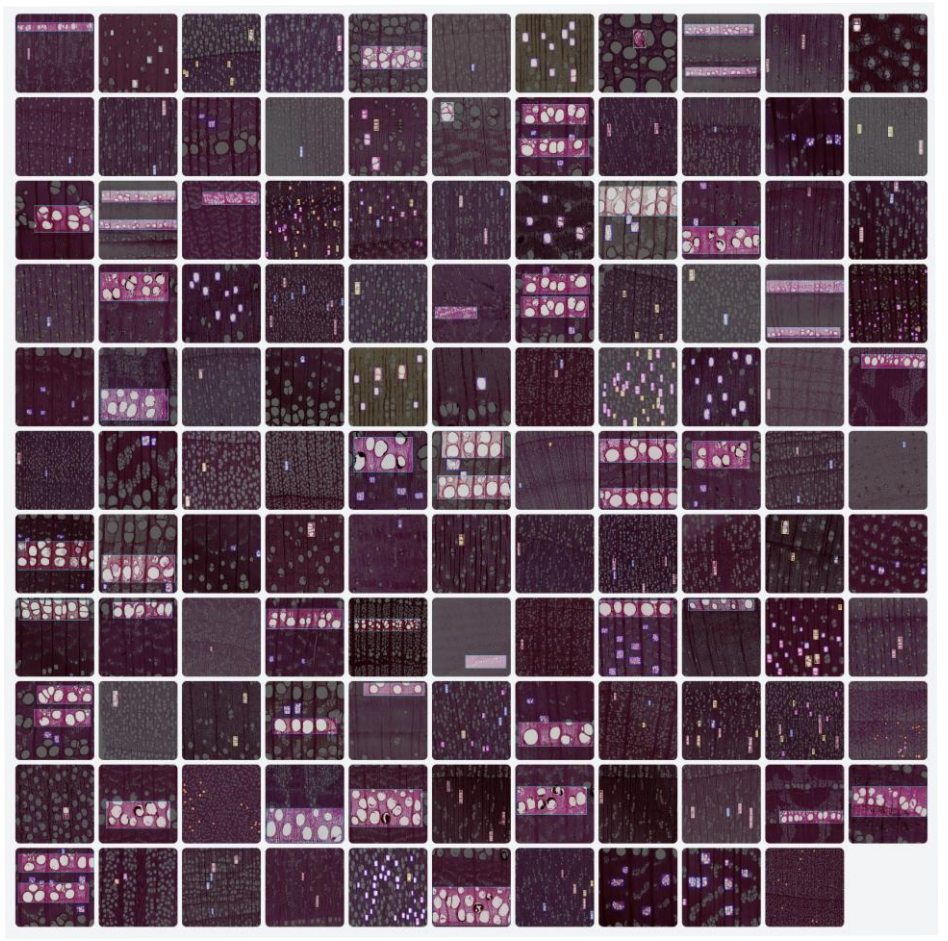


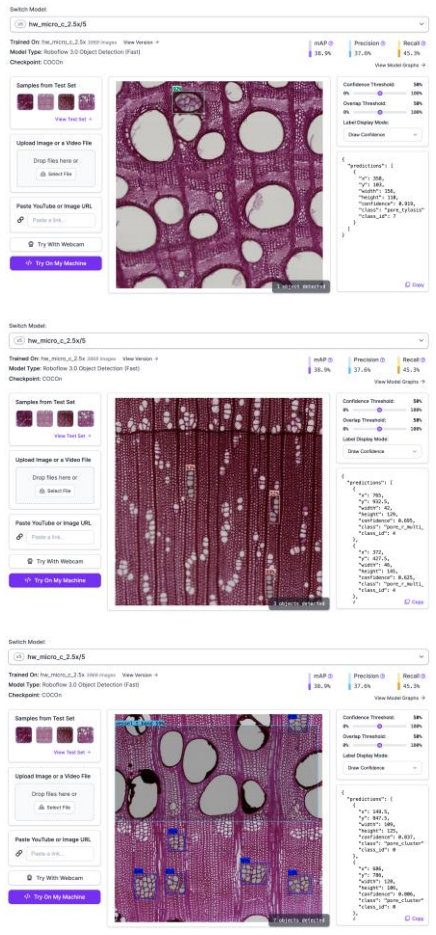


[2] Object Detection Model Training for Microscopic Features of Wood

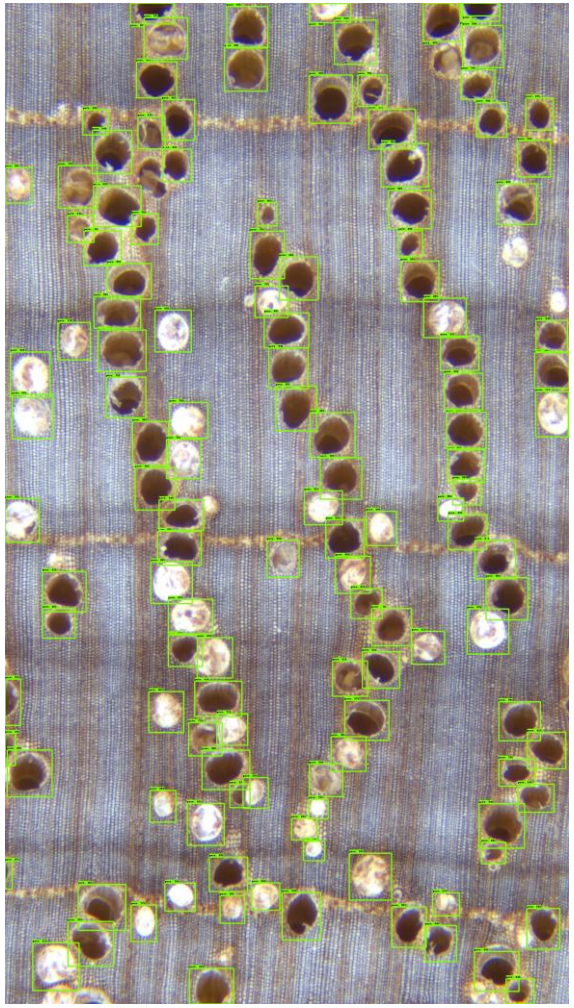
APEC 2025 KOREA

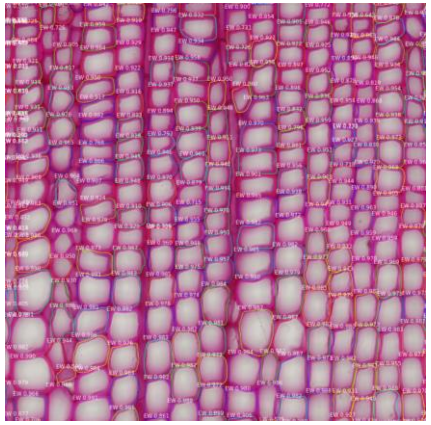


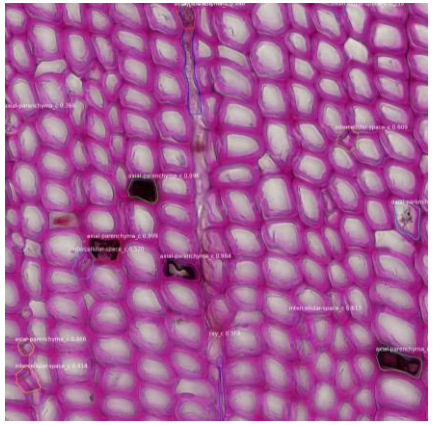


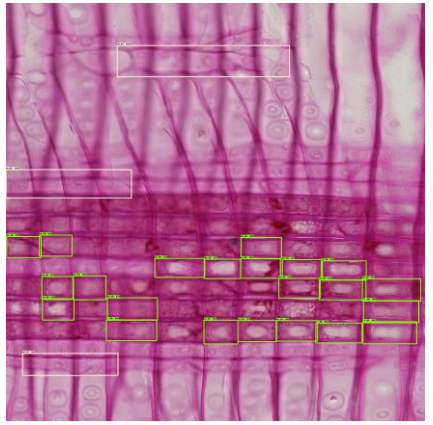


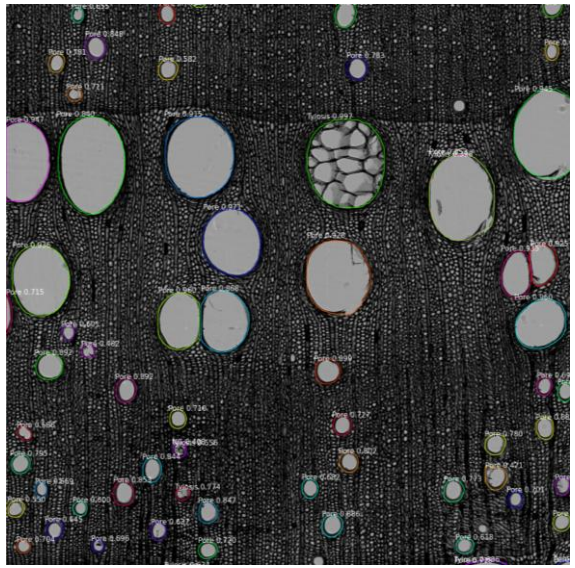
[2][3] Automatic Detection and Segmentation of Microscopic Features of Wood

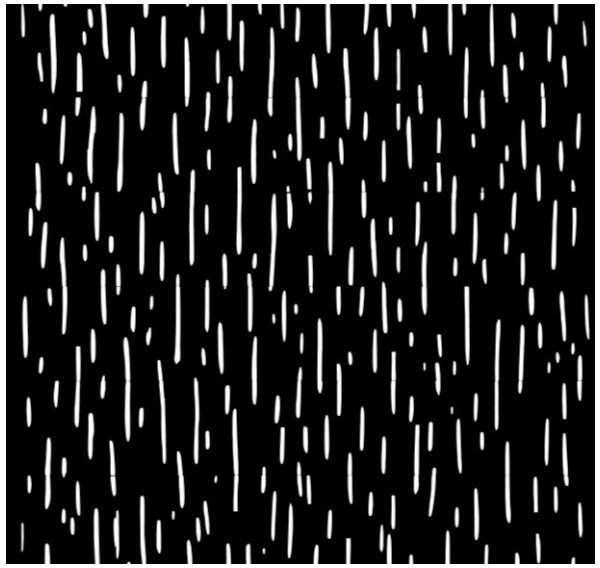




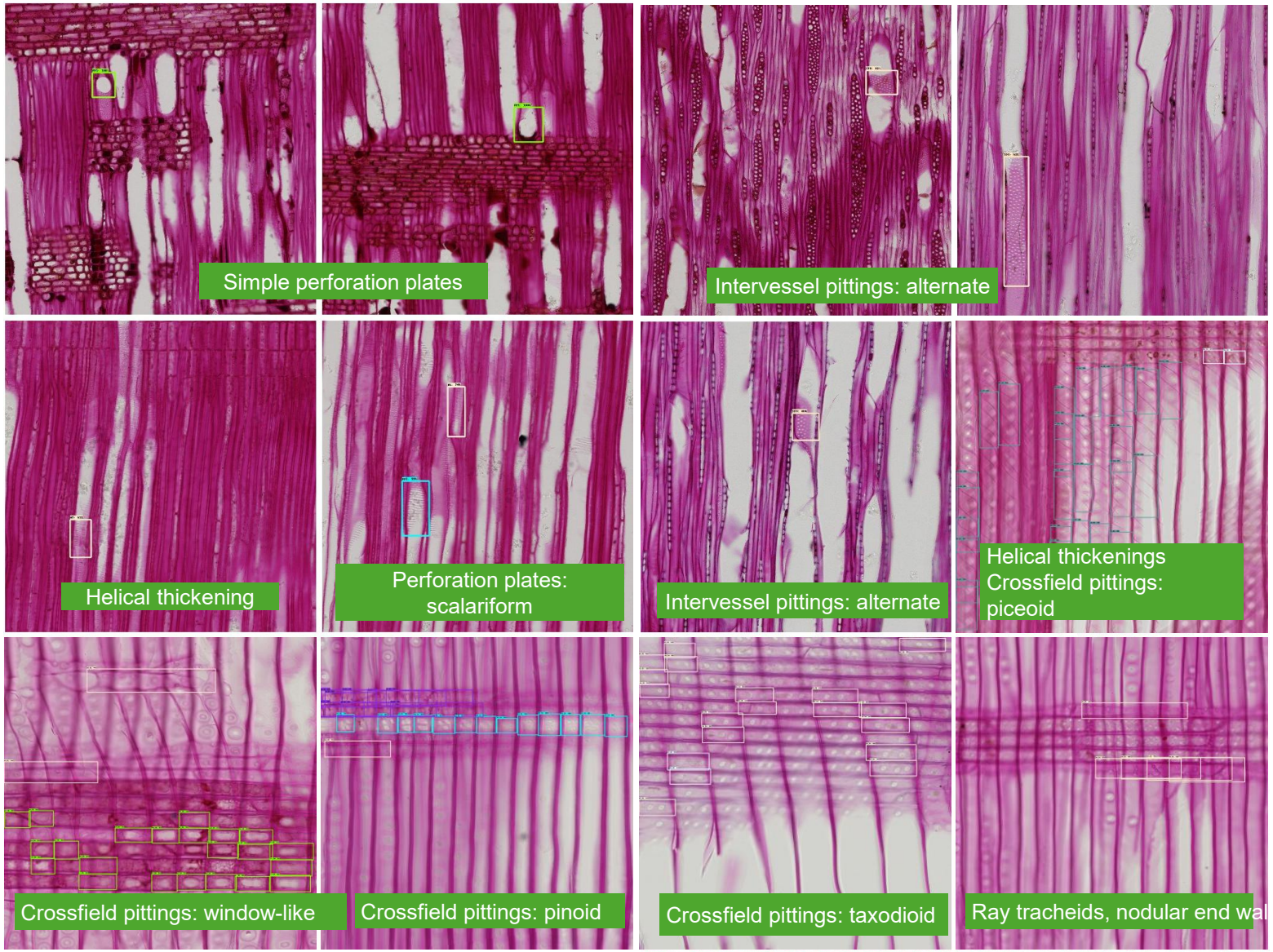




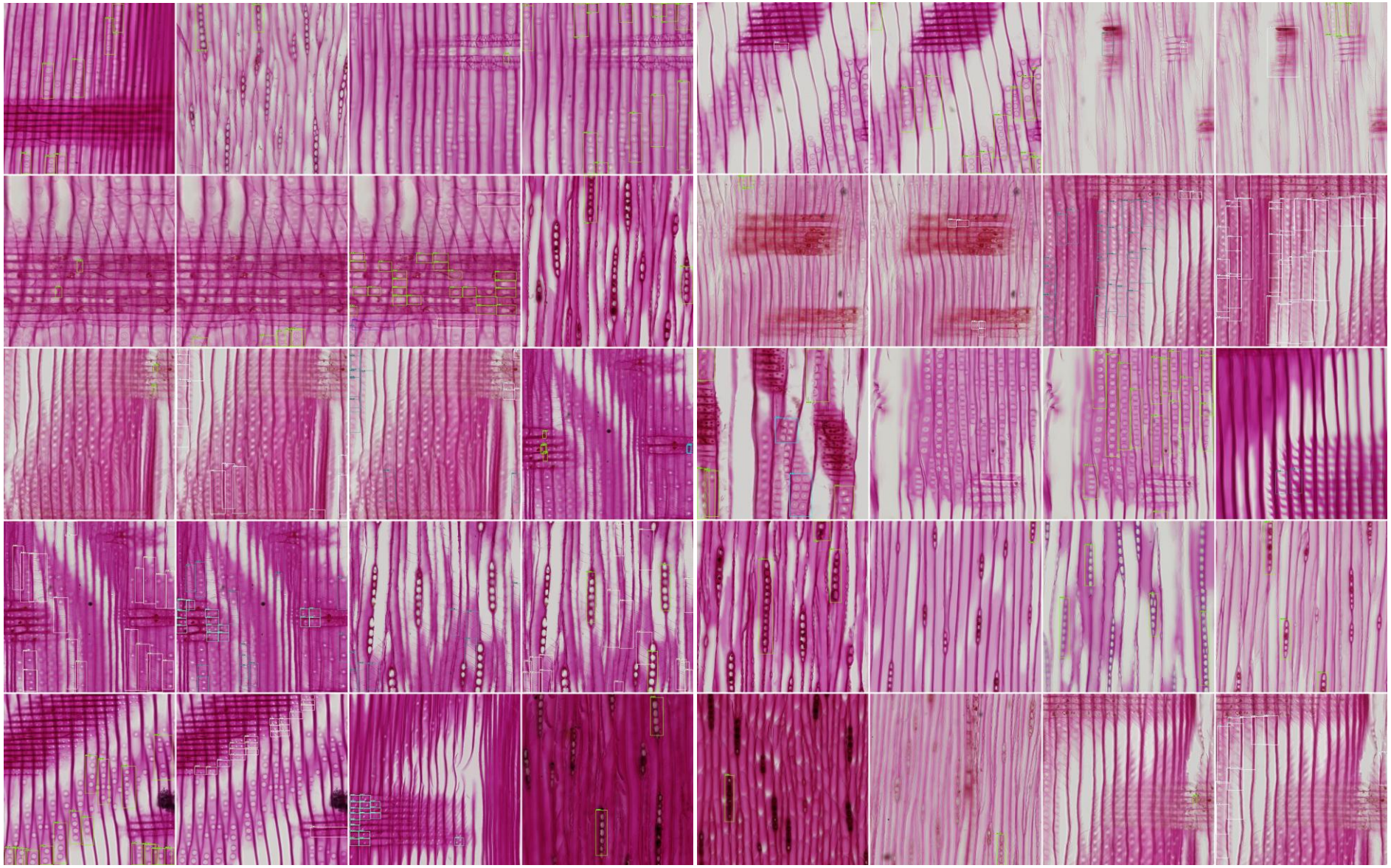




[2] Automatic Detection of Microscopic Features of Wood

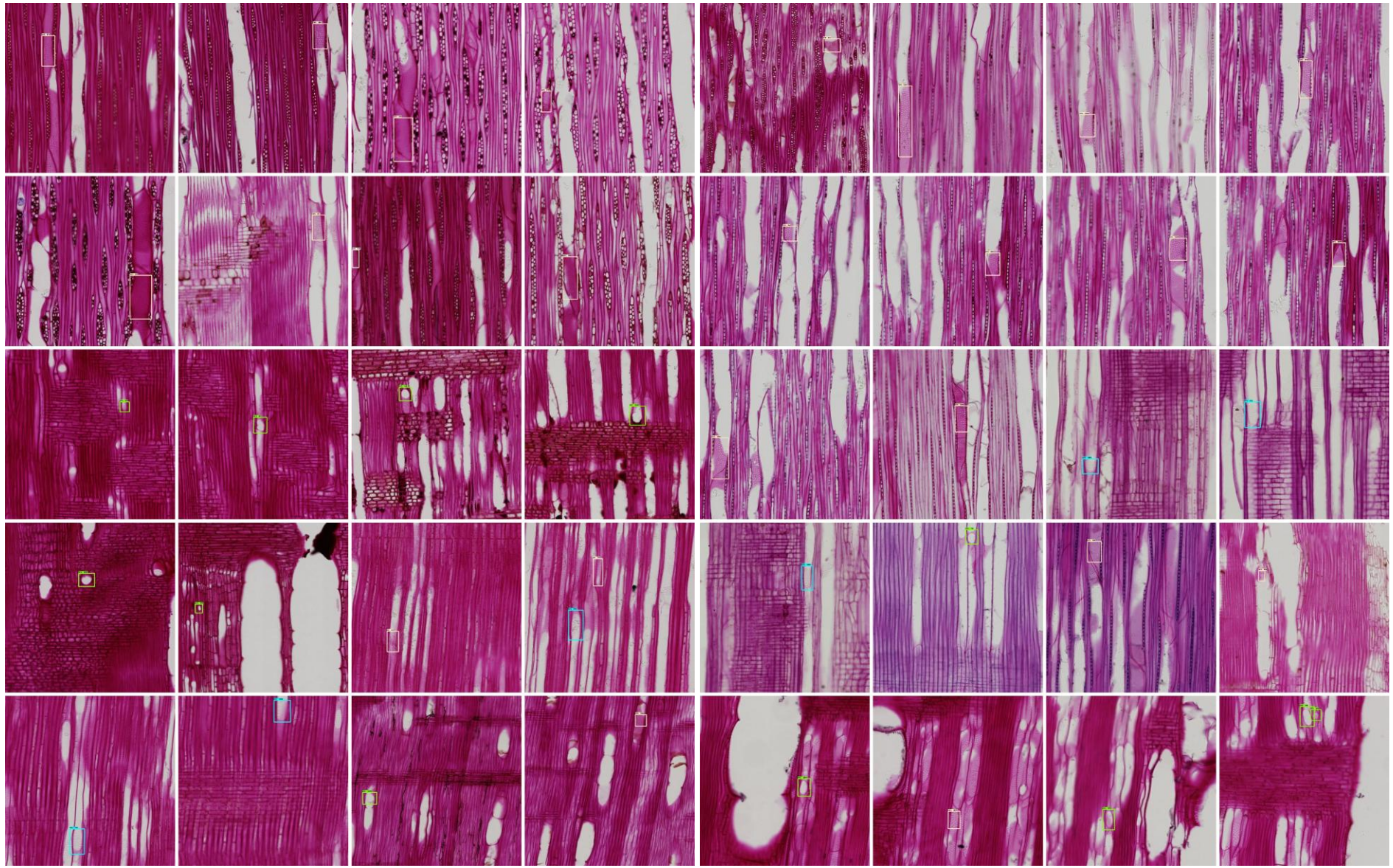


[2] Automatic Detection of Microscopic Features of Softwood

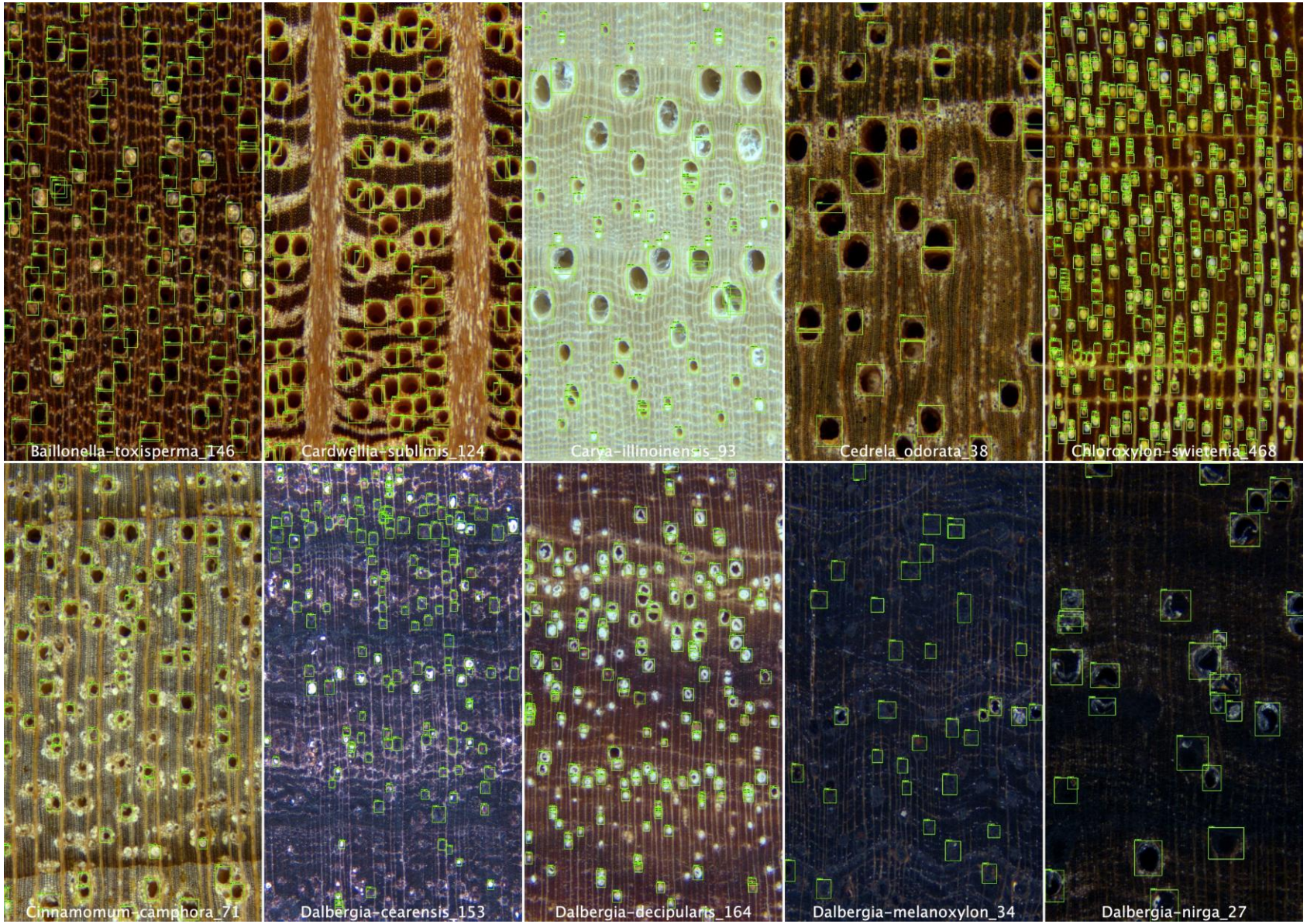


[2] Automatic Detection of Microscopic Features of Hardwood

APEC 2025 KOREA



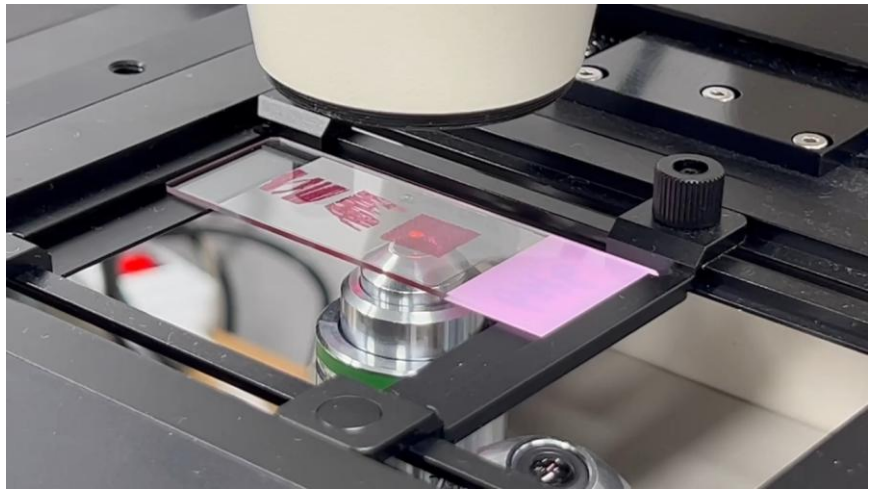
[2] Automatic Detection of Pores on Hardwood Surface



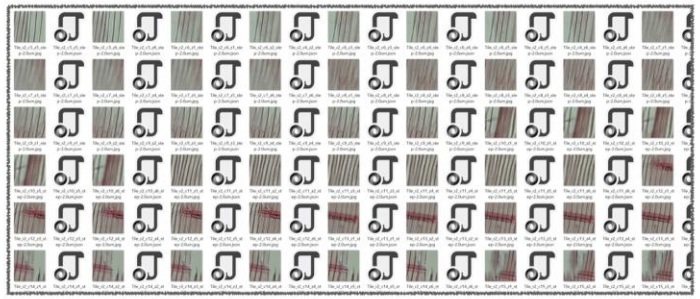
[2] Automated Microscopic Imaging, Extracting IAWA Codes, and Wood Identification

APEC 2025 KOREA

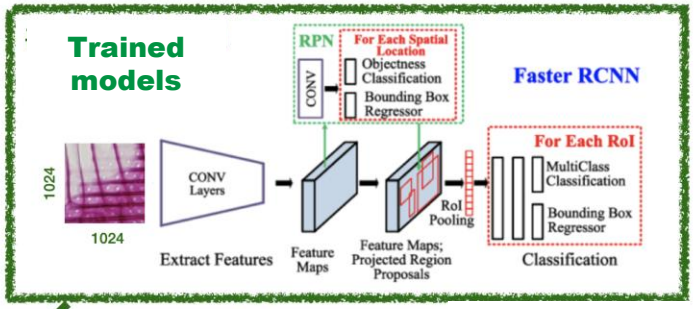
Motorized microscope: automatically collecting large number of microscopic images of wood

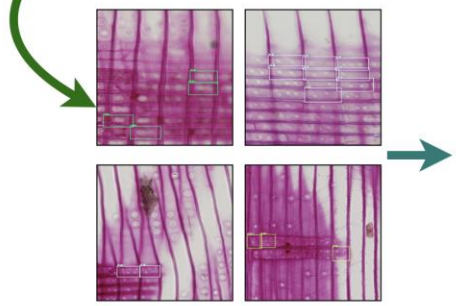


Detection model: automatic detection of anatomical features of wood



Collected images





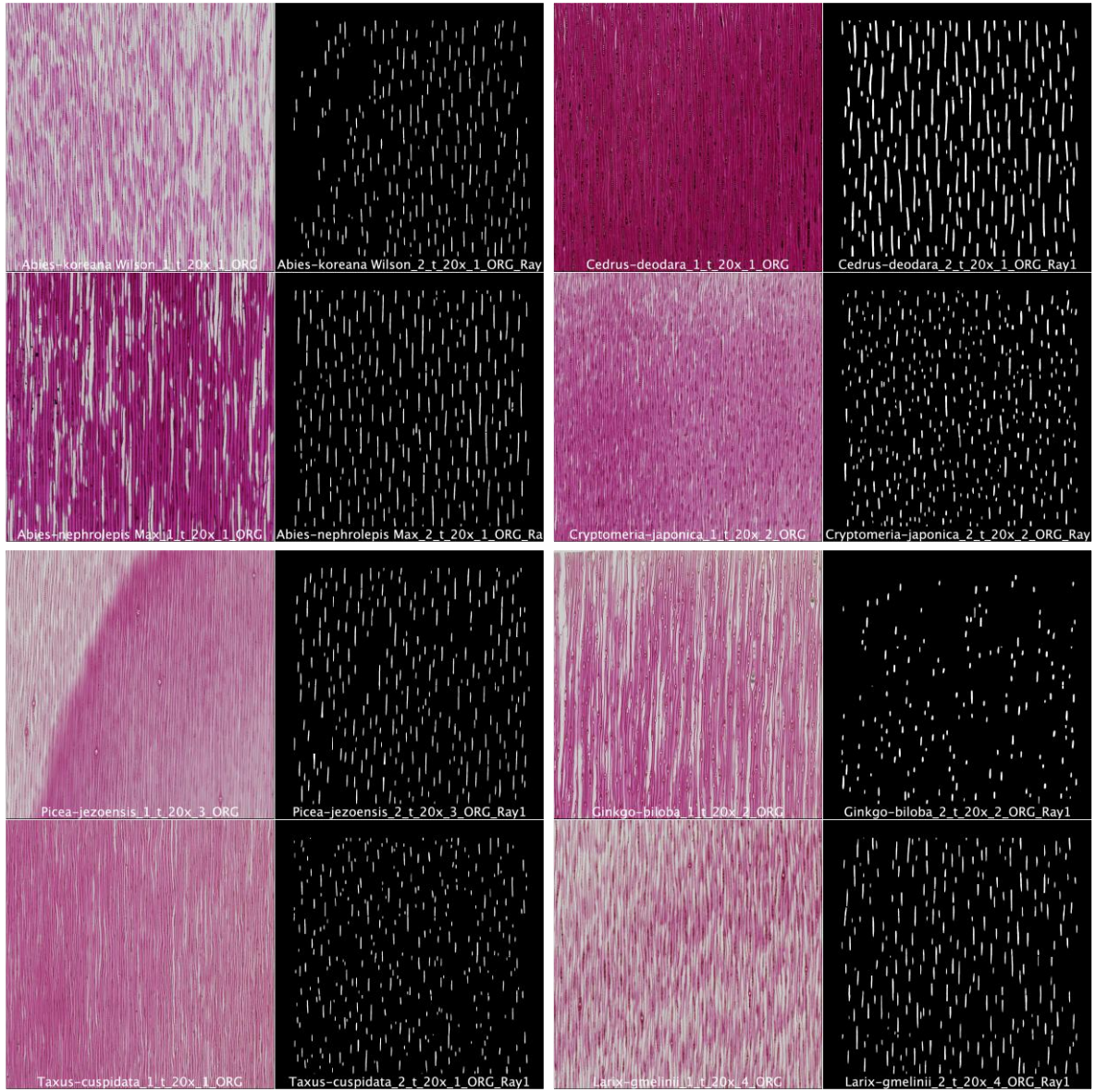
Detecting anatomical features

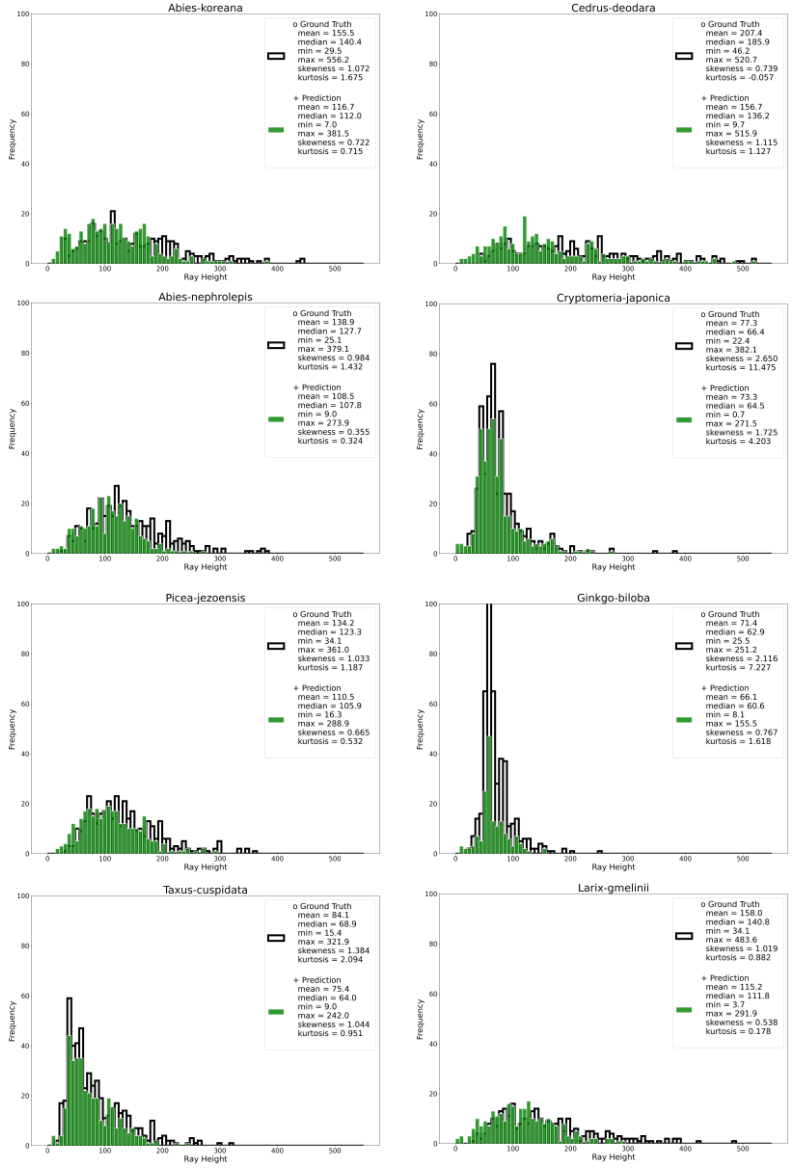
List of feature codes

Automatic selection of candidate species

	species	matching codes
0	Pinus albicaulis	[90, 0, 117]
1	Pinus armandi	[90, 91, 117]
2	Pinus brutia	[0, 91, 117]
3	Pinus bungeana	[0, 91, 117]
4	Pinus canariensis	[0, 91, 117]
5	Pinus caribaea	[0, 91, 117]
6	Pinus cembra	[90, 0, 117]
7	Pinus densata	[90, 0, 117]
8	Pinus densiflora	[90, 0, 117]
9	Pinus echinata	[0, 91, 117]
10	Pinus fenzeliana	[90, 0, 117]
11	Pinus halepensis	[0, 91, 117]
12	Pinus heldreichii	[0, 91, 117]
13	Pinus jeffreyi	[0, 91, 117]
14	Pinus kesiya	[90, 91, 117]
15	Pinus koraiensis	[90, 91, 117]
16	Pinus krempfii	[0, 91, 117]
17	Pinus lambertiana	[90, 0, 117]
18	Pinus latteri	[0, 91, 117]
19	Pinus luchuensis	[90, 0, 117]
20	Pinus massoniana	[90, 0, 117]
21	Pinus monticola	[90, 0, 117]
22	Pinus morrisonicola	[0, 91, 117]
23	Pinus mugo	[90, 0, 117]
24	Pinus nigra	[90, 0, 117]
25	Pinus palustris	[0, 91, 117]
26	Pinus parviflora	[90, 0, 117]
27	Pinus patula	[0, 91, 117]
28	Pinus peuce	[90, 0, 117]
29	Pinus pinaster	[0, 91, 117]
30	Pinus pinea	[0, 91, 117]
31	Pinus ponderosa	[0, 91, 117]
32	Pinus pumila	[90, 0, 117]
33	Pinus pungens	[0, 91, 117]
34	Pinus taeda	[0, 91, 117]

[3] Quantitative Analysis for Microscopic Features of Wood: Ray Height Distribution of Softwoods





J. Korean Wood Sci. Technol. 2022, 50(6): 490-498

Conclusion and Perspective

A Necessary Revolution in Wood Identification

Automated Wood ID that utilizes the microscopic features of wood is NECESSARY.

1. **The "Glass Box" AI:** By shifting from simple classification to **object detection**, our AI identifies the specific, verifiable IAWA anatomical features that form the basis of wood science. This provides transparent, trustworthy, and legally defensible results.
2. **The Engine of Progress:** This AI is powered by a **large-scale microscopic image database**. The creation of this database, which has been the primary obstacle for all other methods, is now possible.

A Collaborative, Data-Driven Future

- **Automated microscopic image collection is required** to overcome the bottlenecks of the traditional wood anatomy.
- **International collaboration is required.** Our automated system makes this collaboration **more feasible than ever before**, allowing partners worldwide to contribute to a single, unified, open-access resource.
- The ultimate vision is to transition wood identification from **a specialized, manual art** into **a scalable, objective, and globally accessible data-driven science**.