A bench-top robotic workstation for handling preserved arthropods for imaging and molecular workflows

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Abstract*—Large mixed arthropod samples are still processed largely by hand when projects require both specimen-level images and downstream molecular traceability. Existing robotic systems show that parts of the workflow can be automated, but they either depend on manually fed specimens or currently operate over a narrow size range. The central laboratory problem therefore remains unresolved: preserved bees, flies, ants, bugs, thrips, ticks and fragments are not equivalent mechanical objects. I propose a bench-top proof-of-concept device that images surface-wet preserved arthropods, classifies them first by handling class rather than taxonomy, and routes suitable specimens to fixed destinations such as 96-well plates with a complete audit trail. The first prototype combines an overview camera, a Cartesian motion platform, wet-transfer suction, a simple compliant gripper, pressure-based pick verification, and specimen-level logging. The goal is not a universal sorter in one step, but a robust research prototype that can validate handling, electronics integration, software control, and test methods on representative DETAIL project material.

I. Introduction / Background

DETAIL is generating mixed preserved arthropod material that needs to be classified, imaged, assembled into mock communities, and ultimately linked to PCR and sequencing workflows. At present, the slowest and least reproducible part of that pipeline is manual specimen handling. The problem is not only one of computer vision. Ethanol-preserved arthropods vary greatly in size, stiffness, fragility, hairiness, appendage splay, and tendency to clump with debris. A system that can recognize a specimen may still fail to pick, transfer, and release it without damage or loss. This short paper outlines a first device concept aimed at that bottleneck. The prototype is intentionally modest: it should establish a reliable bench-top workflow for imaging and routing preserved arthropods rather than attempt full taxonomic automation from the outset. In practical terms, success means repeated single-object pick, transfer, release, and logging on representative project material, with human oversight retained for awkward cases.

II. Related work

Recent work shows both the promise and the current limits of automated invertebrate handling. BIODISCOVER demonstrated image-based identification of ethanol-preserved specimens, but specimens are manually fed into the system one at a time and returned to a common container after imaging [1]. DiversityScanner moved the workflow closer to the needs of molecular ecology by imaging individual insects, classifying them into coarse taxa, and transferring suitable small specimens into a 96-well plate [2]. However, its published configuration is presently restricted to specimens under about 3 mm, which is a useful but narrow fraction of the material encountered in real mixed samples [2]. That limitation matters because projects such as DETAIL need specimen-level traceability, not only bulk composition. Metabarcoding is powerful, but it loses the direct association between a particular image, a particular specimen, and a particular downstream well unless that handling step is made explicit [3]. A recent 2025 review likewise describes benchtop insect-AI systems as promising but still effectively proof-of-concept rather than mature, broadly deployed instruments [4].

III. Proposed prototype

A. Handling-first architecture

The proposed Phase 1 device is an enclosed Cartesian bench platform with a fixed overview camera, a detail/QC imaging station, a shallow specimen tray, and a fixed plate nest. The preferred first pickup modes are a wet-transfer suction head for very small or suction-friendly material and a simple compliant gripper for medium, more robust specimens. In the initial workflow, specimens are taken from ethanol storage, briefly blotted to a repeatable surface-wet state, and laid out on the tray rather than handled fully submerged. This reduces optical reflections and simplifies pickup while still keeping the chemistry close to the real laboratory workflow. The key control decision is mechanical rather than taxonomic. Before asking “what insect is this?”, the device should ask “is this object processable, isolated, and which handling mode should be used?” The target output of the first classifier is therefore a handling label, confidence score, and QC state, followed by a unique specimen identifier, images, pick parameters, and destination well.

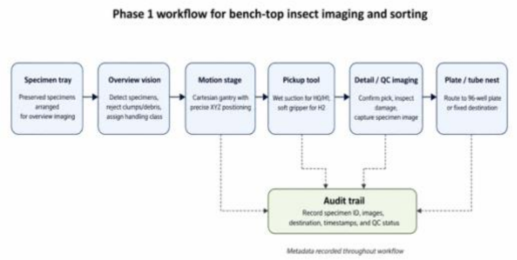

Fig. 1. Proposed Phase 1 device workflow: overview imaging, handling-class decision, tool-specific pickup, QC imaging, and plate or tube routing with full specimen-level logging.

B. Handling classes and success criteria

Four initial handling classes are sufficient for a defensible proof-of-concept. H0 covers microfragile specimens below about 1 mm such as thrips, minute parasitoids, or tiny aphids. H1 covers 1–3 mm suction-friendly material, which is the main target class for early automation. H2 covers approximately 3–8 mm medium or robust forms such as many flies, some bugs, ladybirds, and medium ants. H3 covers awkward or nonstandard material including ticks, very hairy bees, clumps, partial bodies, and strongly damaged specimens; these remain manual rejects in the first prototype. This handling-first scheme is important because bees, flies, ants, ticks, ladybirds, bugs, and thrips are not equivalent physical objects even when they may look separable in image space. For the proof-of-concept, the primary metrics are not species accuracy but single-pick success, double-pick rate, release success, visible damage, contamination control, and audit integrity. A useful early target is repeated H1 handling at approximately 60 successful picks per hour with explicit logging of all failures.

C. Electronics and software

The electronics and software stack should be kept modular. Low-level motion, homing, and valve or pump control can be handled by a microcontroller-based motion controller, while higher-level orchestration runs on a separate computer. Classical computer vision should be used first for calibration, object detection, size filtering, nearest-neighbour distance, and reject cases such as debris or clumps. Once that loop is stable, a handling-class model can be trained from accumulated images. ROS 2 is a sensible medium-term integration layer, but the earliest bench rig should favour the shortest path to reliable mechanics over middleware completeness. This is precisely where the summer school would be most useful: the prototype would benefit from better judgement on component selection, PCB and I/O design, harnessing and enclosure strategy, design for manufacture and test, wetted-path consumables, and the construction of test jigs for repeatable wet specimen handling.

IV. Development questions for the summer school

At present, the concept is clear but several practical device questions remain open. The most important are when a custom control PCB should replace off-the-shelf control boards; how the suction path, sensors, and lighting should be packaged for a cleanable low-volume build; what should be standardized so that multiple copies of the prototype can be reproduced; and what test rig is most appropriate for measuring pickup, release, and damage rates before the system ever sees valuable specimens. Structured advice on these questions would materially accelerate the transition from research concept to buildable prototype.

V. Responsible innovation

The prototype is motivated by a real scientific bottleneck, but it should remain modest, transparent, and repairable. It should reduce repetitive manual labour without hiding uncertainty, and it should record failures rather than silently discard them. Environmental and laboratory safety also matter: ethanol compatibility, low-contamination consumables, minimal electronic waste, and maintainable parts are all design requirements rather than afterthoughts. Finally, the device should support expert judgement rather than replace it. Human taxonomic and laboratory expertise remains essential, especially for H3 material and for validating whether the automated workflow preserves downstream molecular utility.

VI. Author bio(s) / experiences

Paul Scholefield is a researcher at Lancaster University working on the DETAIL project. His current role includes specimen handling, imaging workflow development, data management, and integration of image-derived data with downstream molecular and analytical workflows. This prototype emerges from that practical laboratory bottleneck rather than from a purely engineering-first starting point.

VII. Acknowledgements

This concept has been shaped by ongoing discussions within the DETAIL project around specimen imaging, mock-community assembly, and downstream sequencing workflows.

VIII. References

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