LightPick: Projection assistance for manual actions in laboratories

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Date of first publication: January 28th 2026.

This technical white paper describes the "LightPick", a visual aid for manual actions taken in laboratories, like pipetting and placing/retrieving tubes. This device can support existing workflows and enable new ones, while reducing the risk of errors, reducing cognitive load and exhaustion, and improving traceability.

Introduction

Despite the growing reliance on automated systems in laboratories, a significant amount of time is still spent performing these manual actions, usually related to tube and liquid handling. This may be because automation has not yet been realized, but more often because certain actions are not economical to fully automate. This can be because the frequency of the action is too low, or because some samples require different handling, for example if the tube is of a different type than is supported by the automated systems.

Manual pipetting or tube picking have disadvantages though. The technician needs to be very focused, leading to exhaustion. It is also easy to make mistakes, even in well-structured workflows.

The LightPick system is designed to significantly reduce errors during manual liquid or tube handling tasks.

The LightPick system

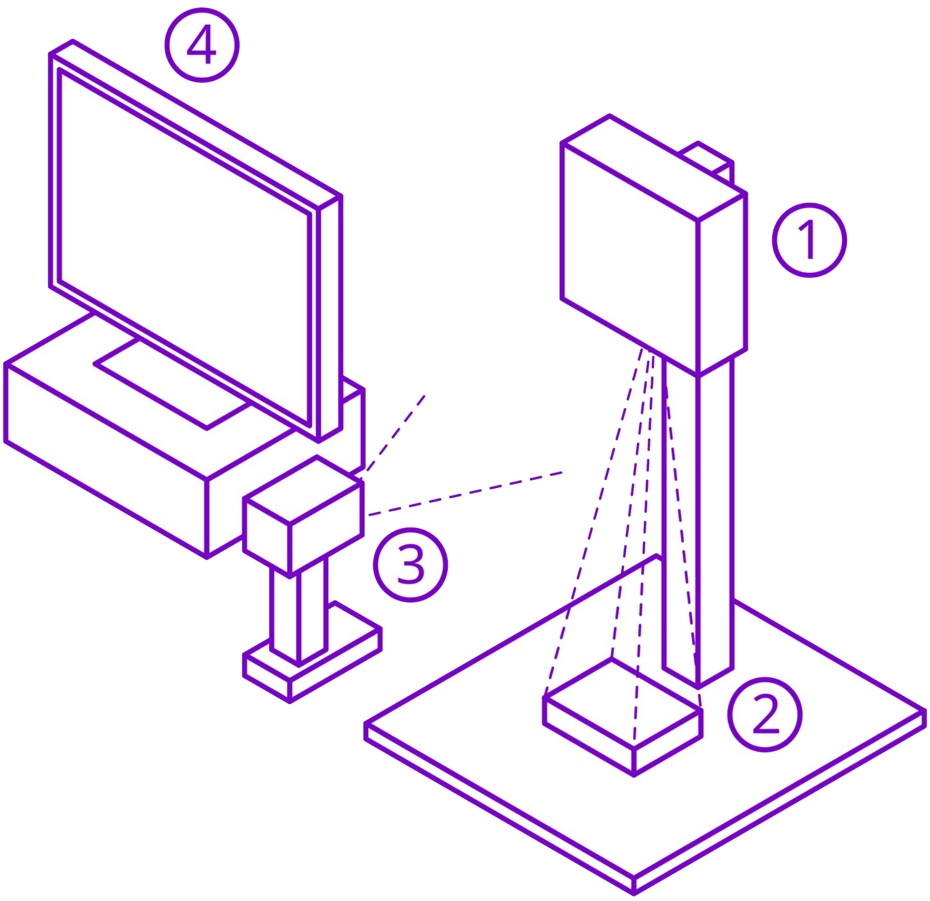

Figure 1: The LightPick System

The LightPick system consists of these parts (see Figure 1):

1. A projection device, which projects onto an object being worked on, usually downwards.
2. One or more fixtures to hold a tube rack, plate, or other objects which are to be indicated on.
3. A (barcode) scanner to identify racks, plates, tubes or other items.
4. A computer running software that performs the following actions:
   a. Receiving or requesting instructions from a different system (or by direct user input) on what actions the user needs to take.
   b. Controlling the projection based on the scanned or manually indicated items. This also includes previous actions and other state.
   c. Logging and reporting of scanned barcodes and/or performed actions

At its core, the system links digital workflow steps to physical laboratory coordinates by projecting task-specific information directly onto the working surface.

In general, the system operates by maintaining an internal representation of workflow state, physical object identity, and spatial calibration. Visual guidance is generated dynamically based on the combination of:

1. the identified physical object(s)
2. the current workflow state
3. allowed (next) actions defined by external or internal rules.

The projected guidance updates immediately upon changes in any of these elements. An example of the visually projected guidance can be seen in Figure 2.

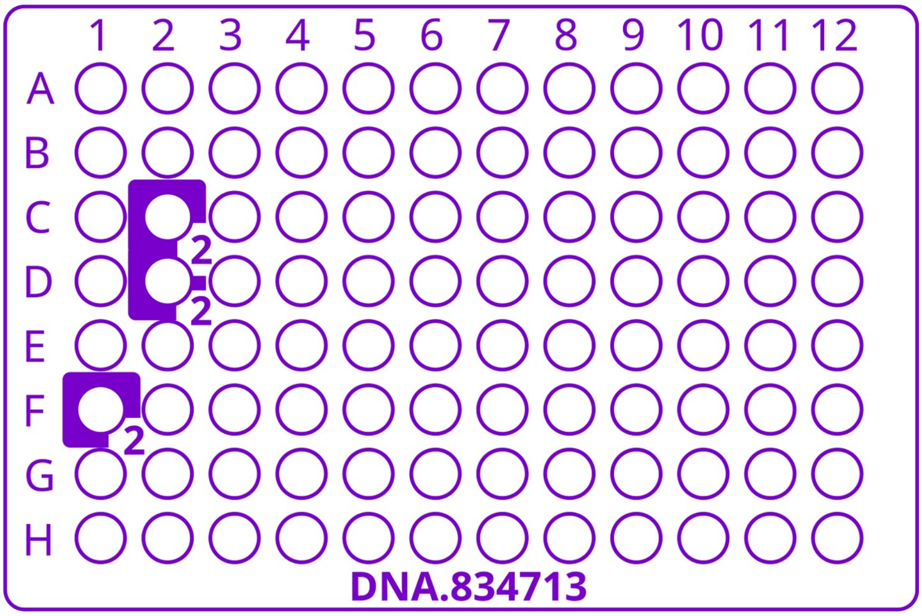

Figure 2: Example of projection-based visual guidance onto a laboratory plate. The specific layout, symbols, identifiers, volumes, and visual appearance shown are illustrative and non-limiting. In this example, the system indicates 3 wells that should all receive 2 µl of the just scanned DNA sample identified by "DNA.834713".

Example Use-Cases

The following non-exhaustive examples illustrate supported workflows.

Use-case: guided pipetting from multiple source tubes into a single plate

In this use-case, the LightPick assists with preparing plates with DNA/primer for PCR.

1. The technician prints a worklist from the LIMS (Laboratory Information Management System).
2. Required DNA and primer tubes are gathered. In some cases, the technician is allowed to select alternate dilutions of the same DNA or primer stock.
3. A 96-well plate with a barcode is prepared and registered in the LIMS.
4. The plate barcode is scanned on the LightPick system.
5. The LightPick retrieves pipetting instructions from the LIMS via an API.
6. A preview of the required pipetting actions is projected onto the plate.
7. A source tube is selected and its barcode is scanned.
8. If the barcode matches the expected source, the target wells and required volumes are projected.
9. If the barcode is for an alternate dilution, a confirmation or selection is presented on the PC screen.
10. All indicated actions are logged to the LIMS via the API.
11. When all actions are completed, the projection changes to indicate completion.
12. The plate is scanned to confirm the process is finished.

Use-case: guided correction of low DNA concentration prior to sequencing

In this use-case, extra DNA is added to wells that do not contain enough DNA for sequencing.

1. DNA concentration of the plate is measured.
2. Wells with insufficient concentration are identified.
3. The technician gathers the required DNA samples.
4. The plate barcode is scanned on the LightPick system.
5. The LightPick requests the actions from the LIMS.
6. A DNA tube is scanned.
7. The LightPick projects the target well(s) where the DNA needs to be pipetted.

Use-case: guided retrieval of specific tubes from storage racks

In this use-case, specific tubes are retrieved from storage freezers. The tubes are stored in 96 tube racks, and can only be identified by their barcode.

1. The technician looks up rack locations in the LIMS.
2. The relevant racks are retrieved from storage.
3. All racks are sequentially placed on the LightPick system.
4. The rack barcode is scanned.
5. The LightPick projects which tubes need to be retrieved.
6. The indicated tubes are placed into a new rack.
7. The new rack is scanned using a rack scanner.
8. Tube locations are verified and updated in the LIMS.

Technical Implementation

There are multiple ways to implement the LightPick system. The system consists of hardware and software.

The described system is intended as a non-limiting example. Variations in geometry, projection technology, sensing modalities, calibration methods, and software architecture are considered within the scope of this publication.

Hardware

The most important design element is the selection of a suitable projector. The following aspects are important:

1. Minimum focus distance: A larger minimum focus distance will both increase the height of the setup and will spread the projection over a larger distance, resulting in reduced brightness. This needs to be as low as possible.
2. Projection offset: Projectors usually don't project straight out, but are designed to produce an image 'shifted' from the center axis of the projector. This is so the projector can be placed on a table and project an image on the wall at a comfortable height. This needs to be considered in combination with the stand part of the device.

3. Weight: A lightweight projector will increase the mechanical stability of the system, preventing wobbling and tipping over.
4. Features: It is advantageous if the projector has a ‘ceiling mount’ setting so the image can be rotated 180 degrees. A feature where the projector can be powered on/off from the PC is also useful. An alternative is a setting where the projector can turn on when the power is connected. This way it’s easy to use an external switch to turn it on and off, which makes the system easier to use and reduces the risks of alignment being thrown off.

The next component is a suitable stand. This consists of a base-plate and a vertical arm. For prototyping the base-plate can be made of 38mm thick MDF. Generally 40x40cm is a good size for projecting on a standard plate or rack. For production systems we recommend powder-coated steel or thick plastic. On this base-plate a vertical arm is mounted. A 40x40mm aluminium extrusion is very suitable for this. Systems exist that have a lot of compatible connectors. When selecting materials it’s important to take resistance to (cleaning) chemicals into account.

It’s best to design the stand and the attachment of the projector so it projects fully straight down. It might be tempting to project on an angle, but this will result in certain parts of the projection not being fully in focus.

The last part of the hardware design is the fixture. This can be made by simply attaching 4 straight metal strips to the base-plate, or alternatively 4 corner pieces. These need to support a small amount of adjustment (0.2 mm) so they can be adjusted for easy insertion while still providing a secure fixture for the plate or rack.

Software

While the hardware components are relatively generic, the effectiveness of the system strongly depends on the software logic governing calibration, task sequencing, state-dependent validation of actions, and traceability.

The software component of the LightPick system runs on a separate PC. It provides the following functions:
1. Interfacing with the projector and attached (barcode) scanners.
2. Loading the required pipetting/picking steps the technician needs to take, from a LIMS or from a provided file.
3. Identifying the plate and tubes by the scanned barcodes.
4. Determining what needs to be indicated based on the scanned barcodes. This is based on whether the scanned barcode matches the current workflow steps. Usually the indication is for one or more spots on the plate or rack, which the user needs to pipet into, or interact with in some other way.
5. Providing a calibrated projection image to the projector that aligns with the currently placed plate or rack. Calibration is performed periodically by the user, fully through software, using a plate/rack or other reference.
6. Sending data back to the LIMS or saving it as a report, based on scanned barcodes and input from the technician.

Alternate Use Cases and Variations

There are many more cases the LightPick can assist with. For example, it could assist with:
1. Placing tubes at indicated positions.
2. Pipetting from an indicated position on one plate to an indicated position on one or more other plates.
3. Pipetting directly into a device.
4. Projecting where in a pipetting robot a rack should be placed.

Possible variations on the LightPick system may include but are not limited to:
1. The software running on other hardware, like a mini-PC which is part of the device itself, a microcontroller or a tablet.
2. The projector being mounted separately, for example on the ceiling.
3. Projecting directly into/onto a different device, for example a machine that is performing a reaction or temperature control.
4. Projection calibration being done partially or fully in hardware.
5. Integration with cameras or other sensors for:
   a. Determining rack/plate type or identity.
   b. Determining container locations.

   c. Determining if a certain action has been performed and if it has been performed correctly. For example, the system could detect if the user placed a pipette tip at the right location. The system could also scan the bottom of placed tubes.
6. A barcode scanner mounted directly to the LightPick to automatically scan placed plates or racks.
7. A screen mounted to the LightPick so the technician doesn't need to look at a separate screen. This could also be achieved by using the projector itself to project an interface or other information.
8. Integration with a heating or cooling plate on the LightPick base.

Availability

The LightPick system is available for purchase from Krol Inventions. For more information visit https://krolinventions.nl or contact us at info@krolinventions.nl.

Scope and intent of publication

This document is published to establish prior art for projection-based assistance systems for manual laboratory actions. It is not intended as a complete design specification, nor does it grant permission to use proprietary software or trademarks associated with the LightPick system.

The technical contribution lies in dynamically projecting task-specific visual guidance onto laboratory objects based on identified physical items and workflow state.