Scanning

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What is a scan?

A scan is a method of collecting experimental data that involves ‘moving’ one or more independent positioners to a series of positions, triggering one or more detectors, and collecting data from those detectors.

Step scans

A step scan moves the positioner to each defined position, waits for the move to complete, then triggers the detector, waits for the acquisition to complete, then gathers the detector data. This process repeats until data has been acquired at all positions.

Step scan

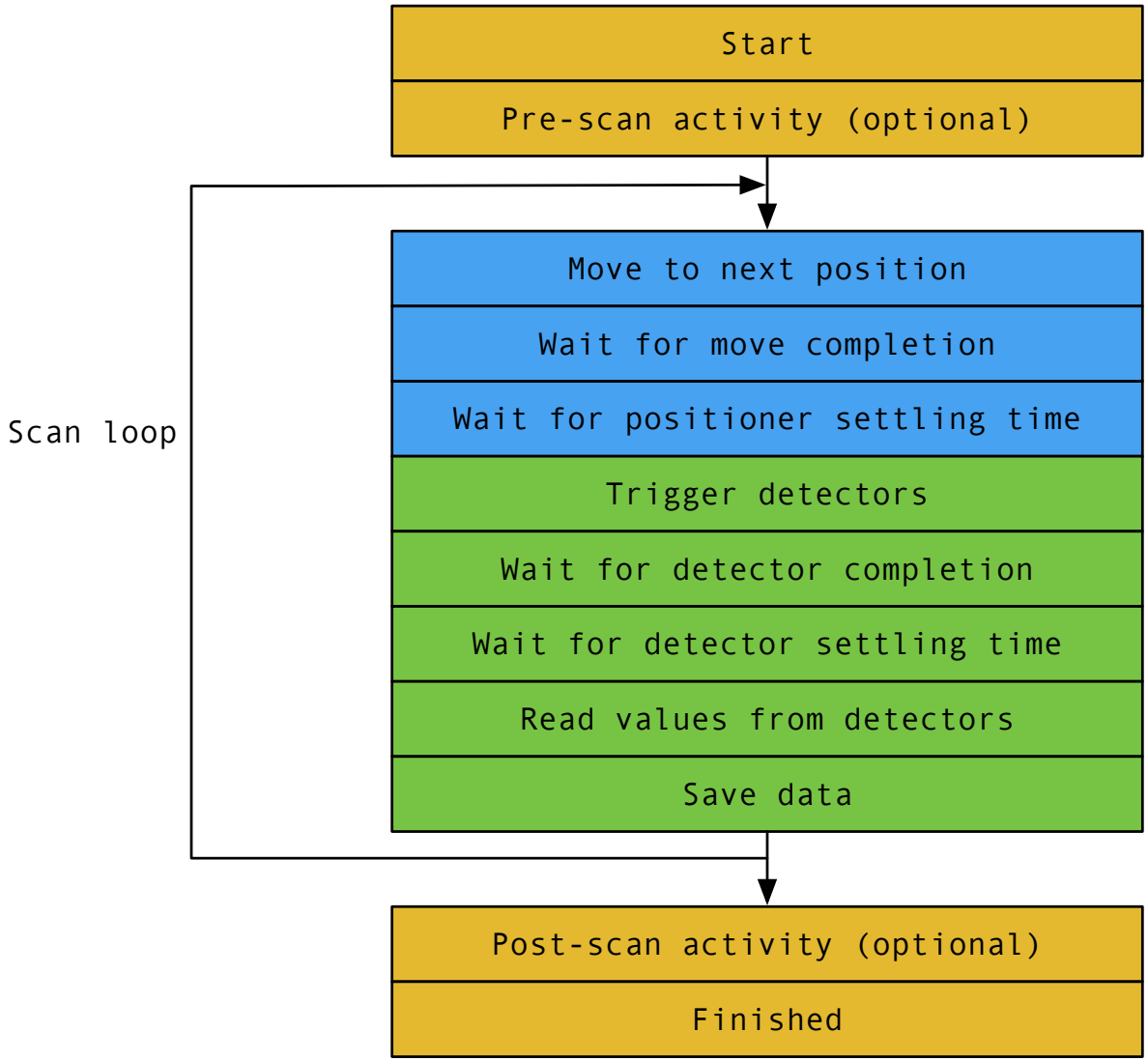

Figure 1: Step scan

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Fly scan

A fly scan does not require the positioner to stop at each position. It requires hardware support for trigger generation and data buffering. The master of the scan must generate triggers at pre-defined intervals, and each slave in the scan must buffer the required data when it receives each trigger.

Fly scan

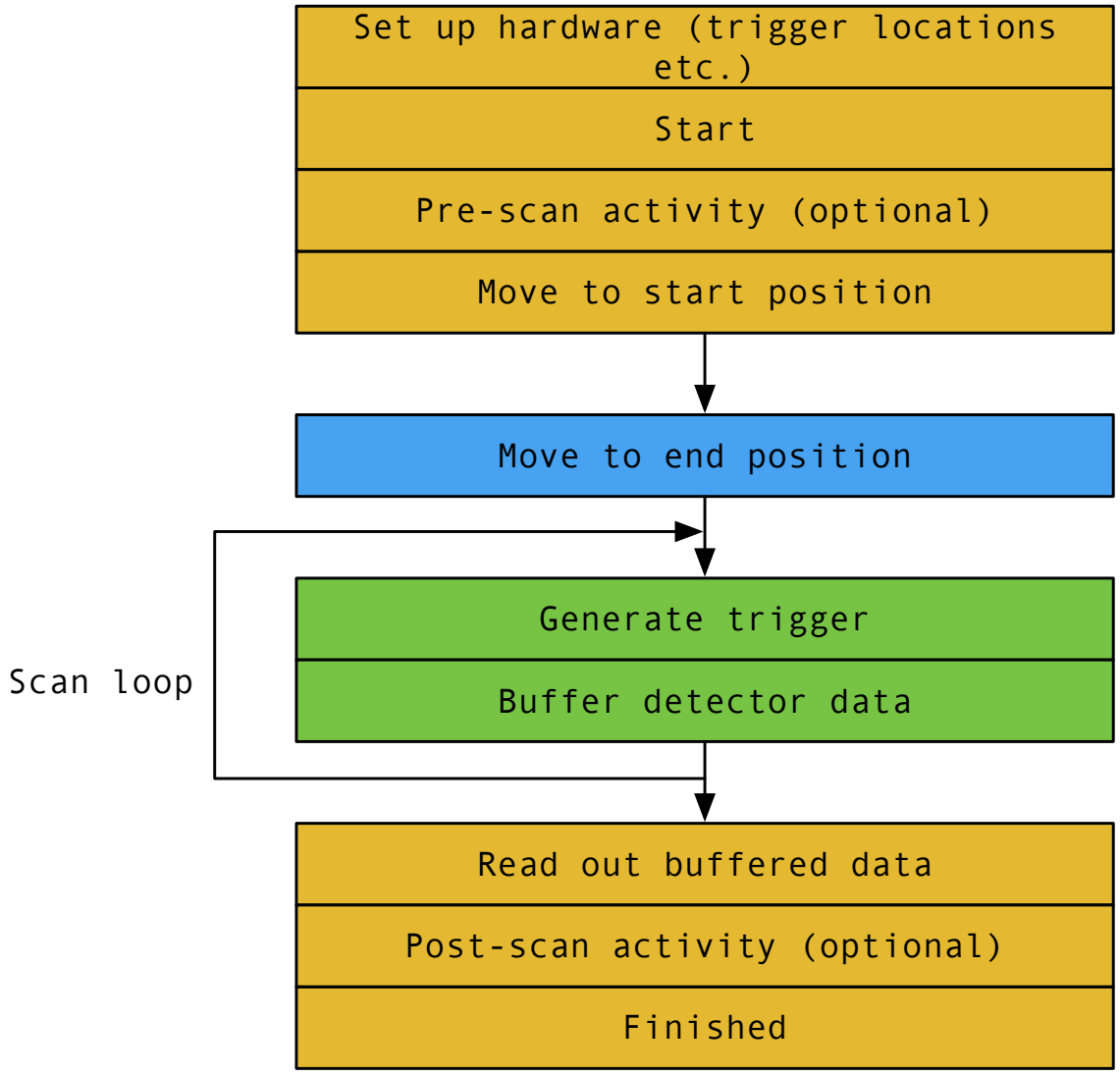

Figure 2: Fly scan

Positioners

A positioner is the independent variable in a scan.

A scan can move one or more independent variables simultaneously.

The number of steps for each positioner must be the same, but the step sizes, and start and end points, can be different.

Positioner steps - equal size

For a step scan, the locations for each step of the scan must be defined for each positioner. For equal size steps, this can be done by defining three of the following parameters:

- start position
- end position
- number of steps
- step size

Some scan engines also allow the scan midpoint to be defined. This could replace either the start or end position.

Positioner steps - arbitrary size

For some scans, it is desirable to have unequal step sizes. The `sscan` record provides `TABLE` mode to support this. In this mode, an array of positions is loaded to the scan record prior to execution. The `sscan` record then moves the positioner to each of these locations in turn.

An example of a scan that uses unequal step sizes is a XANES or EXAFS scan, where the energy steps are large at the beginning and end of the scan, but small around the areas of interest.

Common positioners

- Motor stages - physically moving the sample, or detector
- Energy - moving incoming photon energy for spectroscopy experiments - will typically involve motors
- Sample environment - temperature, pressure, flow rate
- Sample number - using automated sample changing system

Software triggers

For a step scan, the scan trigger is typically an EPICS PV that the scan engine activates to start the data acquisition process. The trigger command is sent after the positioner moves have completed.

Hardware triggers

For a fly scan, the master device must communicate that each position has been reached. The slave devices must capture their relevant information each time a trigger is received. This trigger is typically a TTL signal, and is hardwired between devices.

Hardware triggers must have minimal latency, hence they must typically be independent of EPICS.

Common triggers

Software triggers:

- Detector start
- Scan record start (for multi-dimensional scan)
- Sequence record start

Hardware triggers:

- Motor in position
- Detector acquisition starting
- Time interval elapsed

Detectors

Detectors are the instruments that capture the experimental data. They are sensitive, in some way, to the x-rays or other light going to or coming from the sample. Different experimental techniques require different detectors.

Common detectors

- Ion chambers - measure intensity
- Fluorescence detectors - measure emitted spectra
- Area detectors - measure diffracted or scattered x-rays in two dimensions. Can also be used to capture absorption images for tomography or other imaging techniques.
- Strip detectors - measure diffracted x-rays in one dimension

Metadata

Not all experimental data is directly associated with the x-rays. A number of parameters may be used to characterize the conditions under which the experiment is performed. This data forms the experimental metadata.

- Ring current
- Beamline configuration - energy, mono crystal, filters
- Measured temperature, pressure, vacuum
- Sample number

Completion of action

An important feature of EPICS is the ‘put callback’ feature. This allows an application such as a scan record to block while the commanded device completes the requested task. The device is responsible for knowing when the task is complete, and signals this via a ‘put callback’.

A benefit of this is that the scan does not need to know anything about how the device works, or what conditions must be met for the task to be complete.

Examples of action completion

- Motor has moved to the target position and is within the configured 'in position' band
- Detector has completed the acquisition of a frame or other data and is ready to acquire another
- Sample environment has finished moving to the next commanded state and is stable
- Sample mounting system has removed prior sample and loaded the next sample

Settling time

Allows for a fixed time to elapse after the action has been completed before moving on to the next step.

Positioner settling time can be used to allow for mechanical settling after a move has completed, or to allow the sample to equilibrate to a sample environment change.

Detector settling time can be used to allow the detector to finish writing to disk, or for it to reset after an acquisition.

Multi-dimensional scans

Scans can be nested to create multi-dimensional scans. This is often done by linking the 'trigger' output of the outer-level scan to the 'start' command of the inner-level scan. The inner scan will be executed, in full, once for each position of the outer scan.

The only limit to the number of dimensions is the number of available scan records or scan engines.

Multi-dimensional scans

Examples of multi-dimensional scans:

- XY scanning for imaging or fluorescence
- Energy–XY scanning for spectroscopy mapping - energy scan at each pixel
- Temperature–two-theta detector scan

EPICS sscan record

Included in synApps distribution

https://epics.anl.gov/bcda/synApps/sscan/sscan.html

https://github.com/epics-modules/sscan

saveData

saveData is an application for writing sscan record data to disk in a compressed binary format. It is included as part of the synApps package. Data is written in MDA files, which uses the XDR cross-platform data format.

Bluesky

`Bluesky` is a software project from NSLS-II that implements a range of experimental control and data acquisition functions in a modern framework.

http://nsls-ii.github.io/

spec

spec is a command line application that provides scanning capability.

https://certif.com/spec.html

Scan demonstration requirements

- Motion IOC
- Scan IOC
- Area detector IOC
- CSS

Scan demonstration

- Open CSS display for scan record
- Open CSS display for motor record
- Open CSS display for area detector
- Check positioner PV assignment
- Check area detector trigger assignment
- Set desired start/end position and number of steps
- Run scan

Scan exercises

- Adjust number of steps - observe change in step size
- Adjust step size - observe change in number of steps
- Add second positioner - second motor, exposure time
- Add positioner and detector settling times and observe change in overhead
- Build multi-dimensional scan

Scan exercises - multi-dimensional scan

- Requires second scan record
- Trigger field of outer scan is ‘Start’ button of inner scan
- Use two motors to create XY scan