

afspm Overview

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Outline

1 Justification

2 Introduction to afspm

3 Design Particulars

SPM Basics

In Scanning Probe Microscopy (SPM), an **atomically-sharp tip** is **scanned** above a **surface**, while **measuring** one or more **properties** gleaned from this tip.

This process allows **atomic-level imaging** of properties, spectroscopic analysis, and even manipulation of a sample (toward **atomic-scale manufacturing**).

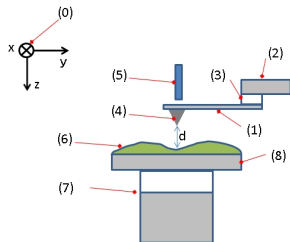


Figure: Typical AFM Configuration, Tom Toyosaki, Wikimedia Commons.

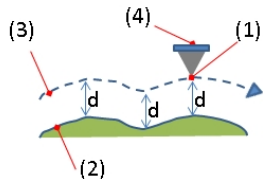
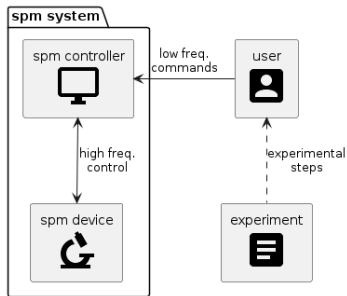


Figure: Schematics of AFM topographic image forming, Tom Toyosaki, Wikimedia Commons.

Standard Experiment



In a traditional SPM experiment, a researcher with domain knowledge will:

- 1 **Prepare the system:** including defining the SPM mode (e.g. FM-AFM).
- 2 **Run the experiment:** monitoring collected scans, deciding on next scans, and updating any aspects of the experiment.
- 3 **Finalize the experiment:** by undoing any experiment-specific setup needed to run.

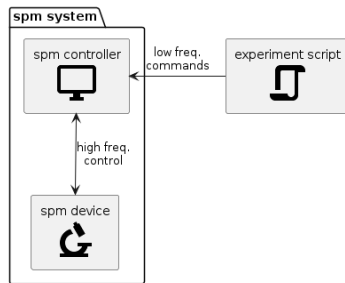
*Running the experiment is often **long**, and requires **constant** researcher **attention**.*

System Scripting and Code Reuse

Many SPM systems allow custom scripts to run an experiment.

However:

- Scripts written for a **specific** SPM system **cannot be re-used** for other SPM systems: different API/language constraints.
- While **decoupling** of SPM device and experiment logic **is possible**, it is **rarely** a **priority** for researchers.



*Code **reuse** is **rare**.*

Goals and Scope

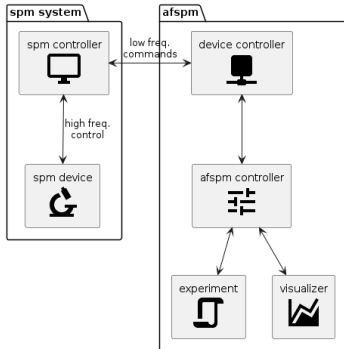
Goals

- **Clear Decoupling:** of SPM device specifics from the desired experiment; to allow reuse of a given experiment on multiple devices.
- **Multi-Language Support:** for integration with SPM devices; we should not be the limiting factor to integration.
- **Pausable Automation:** to allow a researcher to take over.
- **Separable on Multiple Devices:** composed of concise, separable components.

Scope

afspm will concern itself **only** with automation of high-level, low-frequency decisions a researcher would perform **during** an experiment.

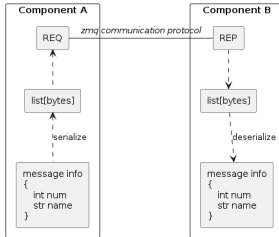
High-Level Design



afspm is designed around 'computation' components that correspond to nodes in a network. An experiment contains:

- **Device Controller:** abstract - specifies the required methods to communicate with an SPM device. Each SPM device will have its own DeviceController implementation.
- **Afspm Controller:** mediates control of the SPM device (only 1 component in control at a time).
- **Afspm Components:** the one or more components the user requires to run their experiment.

Communication Protocol



afspm uses ZeroMQ as its communications/concurrency framework and protobufs as its serialization layer. Both are cross-platform and cross-language.

What is ZeroMQ?

Library that abstracts away protocols used, allowing easy switching of how 'nodes' communicate in a system.

What are protobufs?

Library for serializing structured data (translating a data structure into a format that can be stored/communicated).

I/O Paths

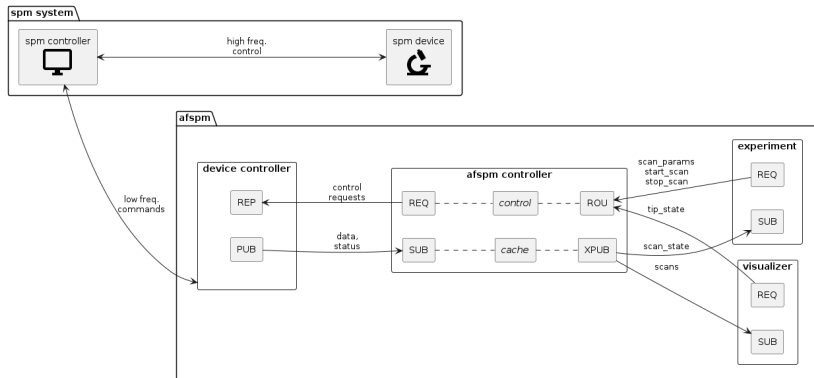
Publisher-Subscriber Path

- The DeviceController **publishes** ScanState, ScanParameters, and Scan changes.
- These are passed on by the AfspmController. Data is **stored** in a **cache** and resent to new/crashed components.
- Each component choose what aspects to **subscribe** to, and receives data from these.

Control Path

- Each component can send **control requests** over its client.
- The AfspmController determines which **client** is **in-control**, and **forwards** these to the DeviceController.
- The DeviceController **receives** control requests from one client and **responds**.

afspm: Detailed View



afspm Controller

Cache Logic

Data is **stored** into the **cache** according to a **user-defined configuration**.

These map a **protobuf message** to a **cache key** (envelope), and vice-versa.

Experiment Problems

Any component can **report** experiment **problems**, indicating issues that should cause the experiment to **pause** until **resolved**, and can **remove** these problems.

This allows, e.g., detecting a tip crash and attempting to correct it.

Control Modes

The AfspmController defines the **control mode**, which can be:

- **Automated**: default, automation runs.
- **Manual**: pause automation.
- **Problem**: experiment problems are logged, pause automation.

The Config File

afspm uses a **single TOML configuration file** per experiment.

Within this file, a user defines:

- The communication protocols used between components.
- Common variables passed between components (e.g. how big the scan size will be).
- The components to spawn.

Top-level definitions can function as **variables**: any **references** deeper in the config are **replaced** by them. This should minimize repeating oneself.

```
# --- General variables --- #
pub_url = "tcp://127.0.0.1:8000"
pbc_url = "tcp://127.0.0.1:8002"
server_url = "tcp://127.0.0.1:8004"
router_url = "tcp://127.0.0.1:8007"

# --- Timing logic --- #
wait_ms = 3000
poll_timeout_ms = 1000 # was 1000 # was 250
loop_sleep_s = 0.1 # 0.1 # was 0
nb_period = 1

# --- Experiment Scan Aspects --- #
# --- Physical Stuff --- #
physical_units = "m"
full_scan_origin = [0, 0]
full_scan_size = [200, 200]
sub_res_per_dim = 5
small_scan_origin = [0, 0]
small_scan_size = [40, 40] # 200 / 5

# --- Data Stuff --- #
data_units = "m"
full_scan_res = [200, 200]
small_scan_res = [512, 512]

# --- PubSub Params --- #
topics_experiment = [""] # TODO: test instantiating proper topics
sub_extract_proto = "afspm.io.cache.pbc_logic.extract_proto"
std_envelope_for_proto = "afspm.io.cache.pbc_logic.CacheLogic.get_envelope_for_proto"
pbc_envelope_for_proto = "afspm.io.cache.pbc_logic.PBCNITROLogic.get_envelope_for_proto"
update_cache = "afspm.io.cache.pbc_logic.update_cache"

# --- Cache Aspects --- #
[proto_hist_list]
class = "afspm.io.cache.pbc_logic.create_roi_proto_hist_list"
size_with_hist_list = [{"full_scan_size", 1}, {"small_scan_size", 0}]

[pbc_with_roi_logic]
class = "afspm.io.cache.pbc_logic.PBCNITROLogic"
proto_with_history_list = "proto_hist_list"

[cache_manager]
cache_logic = "afspm.io.cache.pbc_logic.ProtobasedCacheLogic()"

[roi_cache_manager]
cache_logic = "pbc_with_roi_logic"
```

Spawning the Experiment

Distributed Computing

Components can be **split up** among devices; on startup, the components to spawn can be specified.

Component Monitoring

All spawned components are **monitored**:

- Each sends **heartbeats** at a regular cadence.
- If one **stops** beating, it is **restarted**.

This should minimize a crash breaking experiments.