XrayFeed

Release 1.0

CAS

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ONE

XRAYFEED INTRODUCTION

The XrayFeed device is designed to provide a beam position feedback system for different components of the XFEL system. The feedback provides X-ray beam-position stability which is indispensable in cutting-edge experiments at XFEL. At the moment the feedback mechanism is made of a beam position monitor (defined as "Detector" in the device editor) and a device (defined as "actuator") to steer the beam (typically a motor to turn the mirror support).

Several devices can be selected according to the specific experimental area where the feedback is needed. Before initializing the device, the user must select the detector and actuator which he wants to use for the feedback, Fig. 1.1.

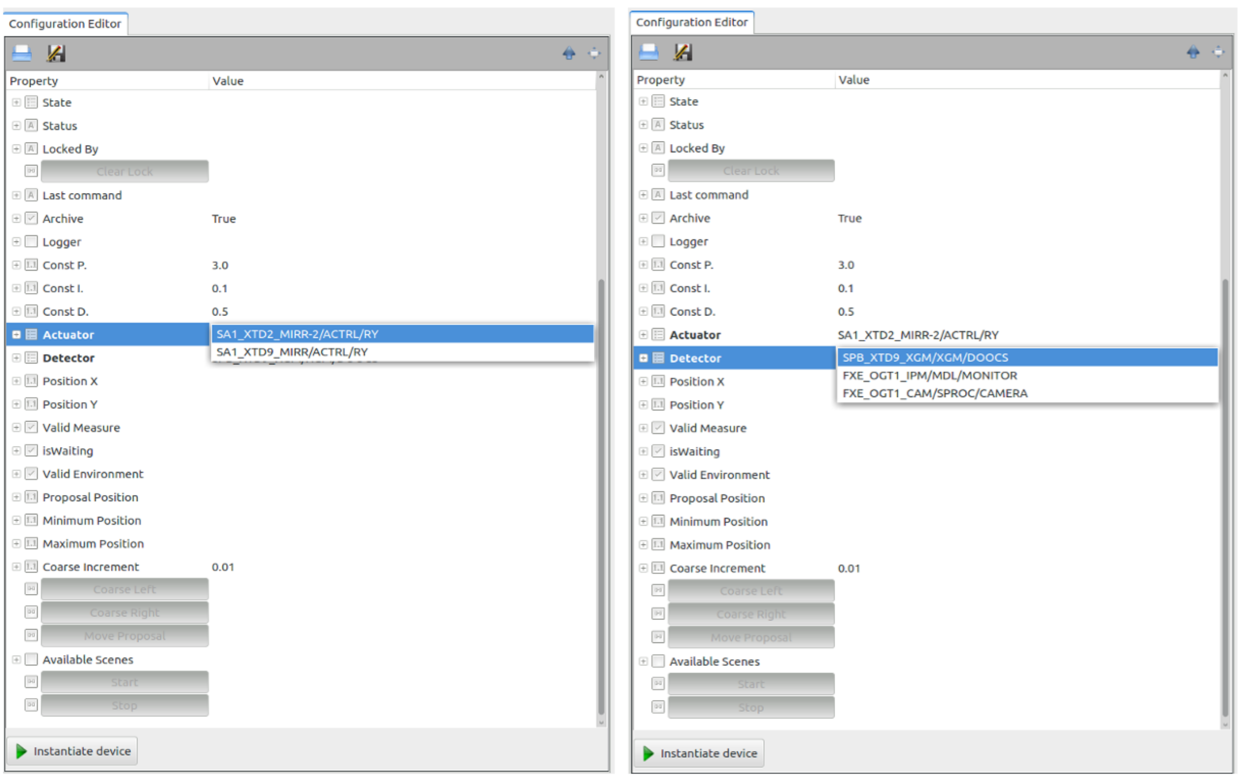

Fig. 1.1: Fig. 1.1 The selection of actuator and monitoring devices is done before instantiating the feedback device.

Up-to-now the beam position monitors (individually) used in the feedback are an x-ray gas monitor (XGM[1]) for the SPB instrument line while for FXE a camera and an intensity position monitor (IPM[2]) are implemented. The available detectors and actuators are shown in the following table:

[1] K. Tono et al., Single-shot beam-position monitor for x-ray free electron laser, Review of Scientific Instruments 82, 023108 (2011)
[2] K. Tiedtke et al., Gas detectors for x-ray lasers, Journal of Applied Physics 103, 094511 (2008)

Instrument Line	Detector	Actuator
SPB	SPB_XTD9_XGM/XGM/DOOCS	SA1_XTD2_MIRR-2/ACTRL/RY
FXE	FXE_OGT1_CAM/SPROC/CAMERA	SA1_XTD9_MIRR/ACTRL/RY
	FXE_OGT1_IPM/MDL/MONITOR	

As for many karabo devices the XrayFeed configuration can be performed either directly in the configuration editor or in a dedicated scene which provides graphically almost all functionalities of the editor, Fig. 1.2. To access the pre-designed scene the user can double-click the running device in the navigation panel. Alternatively, right-clicking the device from a project shows a pop-up menu, which provides the possibility to open the default scene.

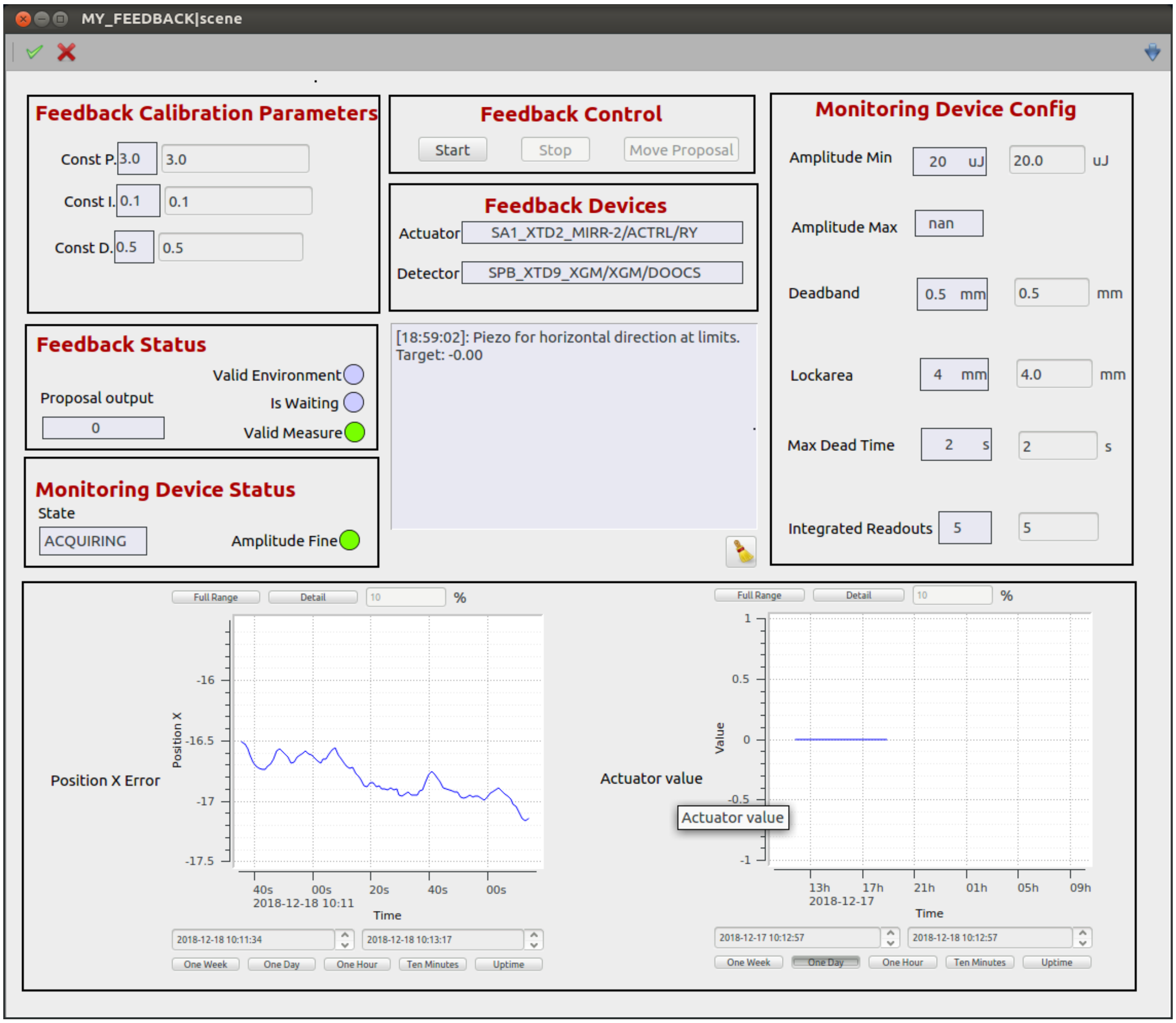

Fig. 1.2: Fig. 1.2 A scene allows to monitor and configure the XrayFeed device from a dedicated GUI.

CHAPTER

TWO

DEVICE INITIALIZATION

At initialization stage the feedback device connects to the selected devices and shows some of their parameters relevant to the feedback. In case a choice of incompatible devices is done, e.g. selecting a monitoring device for SPB and an actuator of FXE, the program will raise an error. In case one device is unreachable, e.g. because not instantiated yet, the program will remain in the state INIT and its status will report it, e.g., reporting "Connecting to beam actuator" in case of failing connection to the actuator, Fig. 2.1.

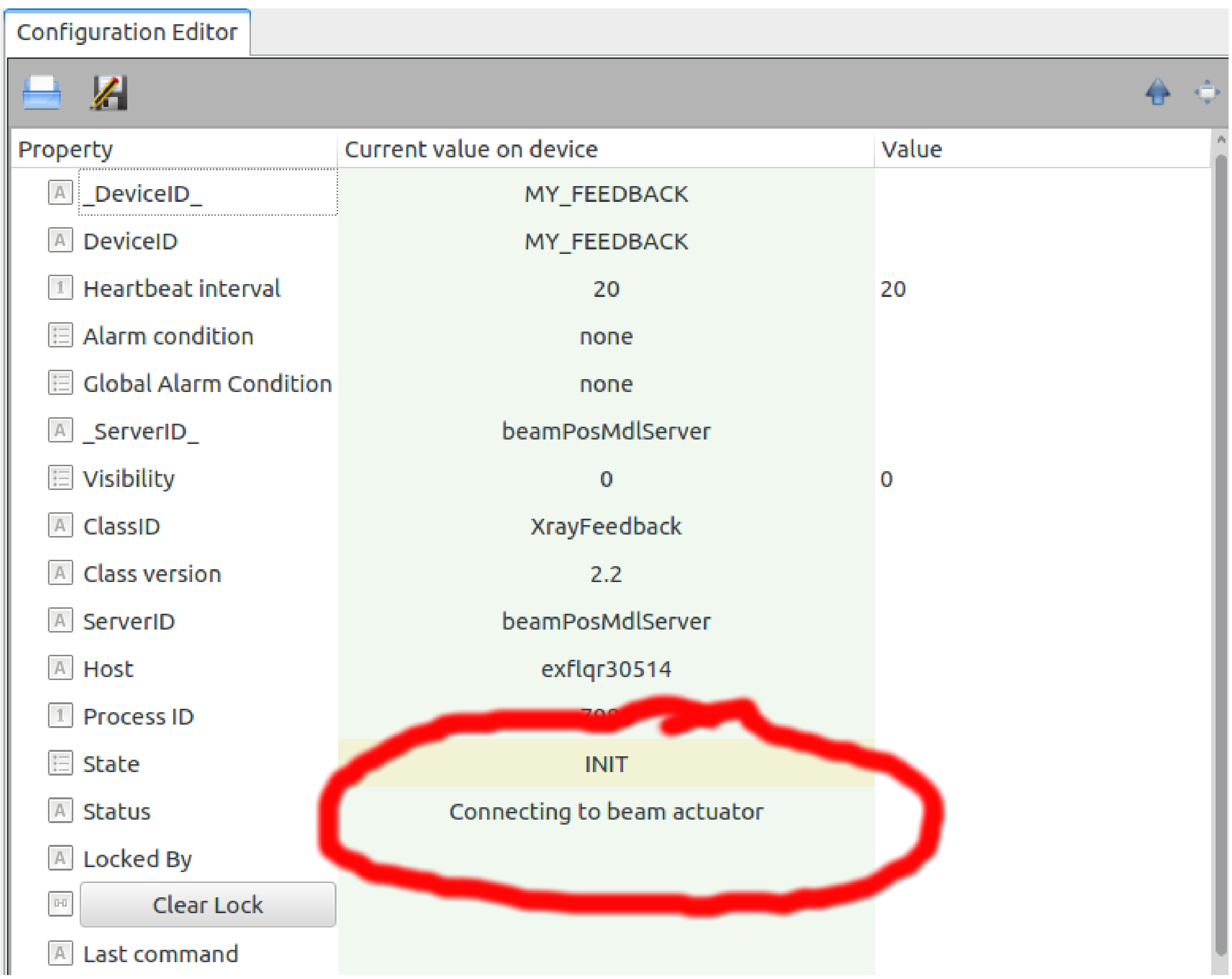

Fig. 2.1: Fig. 2.1: The device remains in the INIT state when trying to connect to an actuator which is not reachable.

Once the device is correctly initialized, relevant parameters of the monitoring device are accessible as a "node" in the configuration editor, Fig. 2.2, and are described in the following:

- **State**: The state of the detector device;
- **Amplitude Min**: The minimum signal seen by the detector to validate beam;
- **Amplitude Max**: The maximum signal seen by the detector to validate beam;
- **DeadBand**: The range of values for the beam position considered as accepted by the feedback control; no action will be taken by the device in this scenario;
- **Lockarea**: The range of values for the beam position which are rejected by the feedback control; the device will propose thus an action to be taken (a new value for the actuator) in order to bring the beam position within the allowed deadband. Note that in case of values outside the lockarea, although not good for the beam, the device will take no action to correct the beam position, and the FIFO buffer will be emptied.
- **Set Point X**: The reference point of x coordinate of the beam position on the detector used for feedback control;
- **Amplitude Fine**: A Boolean flag notifying whether the signal amplitude is within the allowed region;
- **Integrated Readouts**: Number of readouts to consider in the running average;
- **Max Dead Time**: Maximum accepted time interval between two consecutive readouts.

Some of these properties can be tuned by the user at run-time; as for every karabo device this can verified by clicking on the parameter "Value" field in the configuration editor. For some monitoring device (as for XGM) there is no need to set an upper threshold for the signal. The default values set to the properties are typically agreed with the corresponding detector experts.

The following three important booleans are accessible to the user to monitor the status of the device environment:

- **Valid Measure**: Should be "*True*" in case the current signal amplitude is within the allowed region, and the FIFO buffer for evaluating a running average is full. Note that the signal is also considered not fine in case the interval between two consecutive measurements is larger than the allowed dead-time;
- **isWaiting**: Should be "*True*" in case the current signal amplitude is within the allowed region, and the FIFO buffer for evaluating a running average is not yet full. This property is typically True soon after the initialization stage or after a wrong amplitude was found;
- **Valid Environment**: Should be "*True*" in case the safety check of the device environment was successful (to be implemented).

The FIFO (first-in first-out) buffer is described later in this documentation.

The position of the x-ray beam ("Position X" and "Position Y") on the selected monitor is shown in the editor relatively to the reference value, and is updates at the rate provided by the connected device, Fig. 2.3. The reference one, initially is set to null (virtually at the center of the monitoring device), can be changed at run-time by the user. The update will proceed also when the XrayFeed has not started its feedback activity yet.

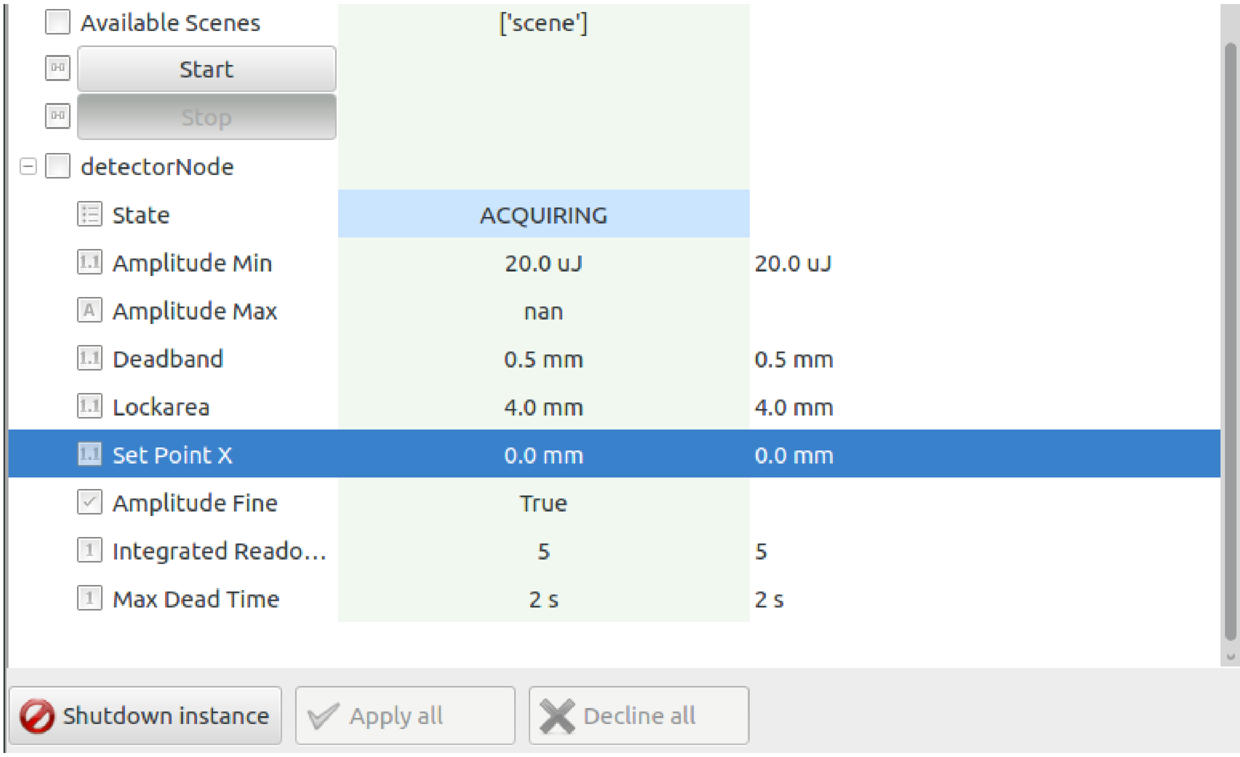

Fig. 2.2: Fig. 2.2: At initialization a node is created in the configuration editor to show relevant properties of the monitoring device.

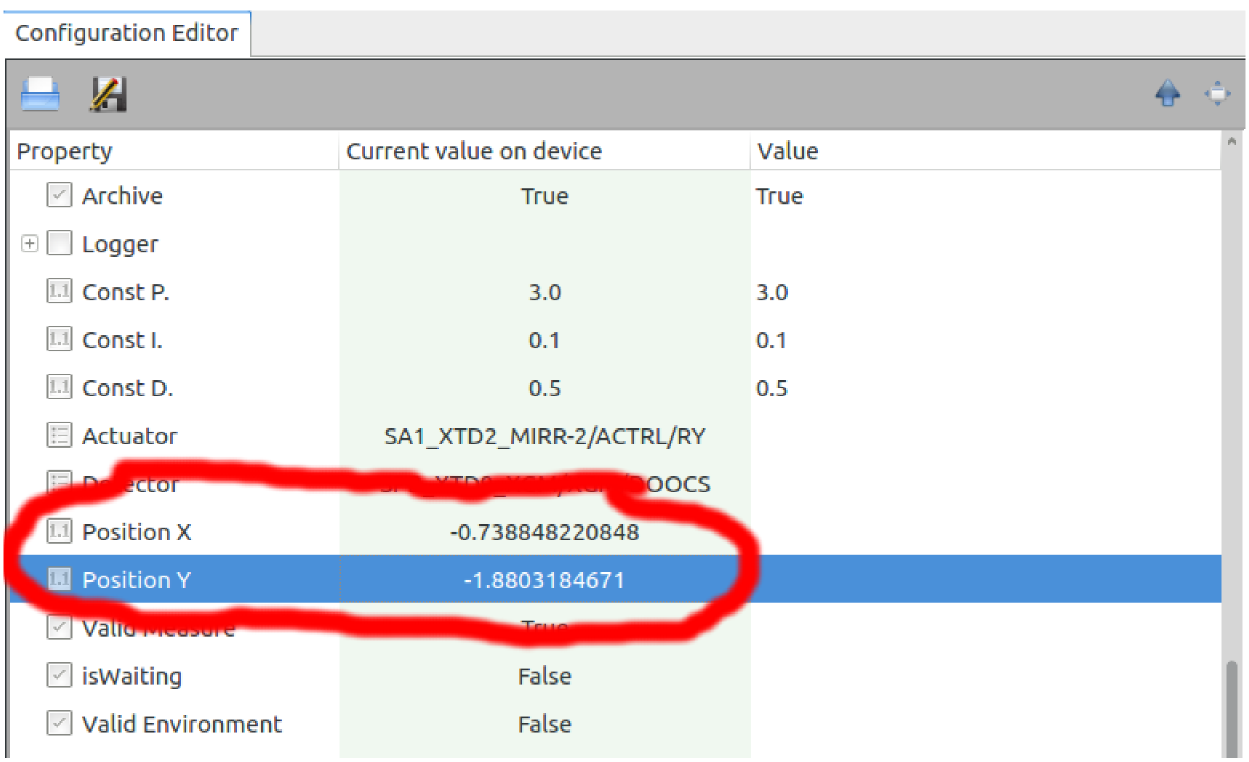

Fig. 2.3: Fig. 2.3: The beam position is constantly updated, even if XrayFeed has not performing the feedback.

CHAPTER

THREE

FEEDBACK LOOP

After initialization the XrayFeed device monitors only the beam position and the environment state without performing any feedback control, thus without taking any action to correct for any mis-positioning of the beam. The buttons “Start” and “Stop” should be used to start and stop the feedback, respectively. At the moment the device is configured to perform a feedback only along the horizontal axis of the beam trajectory.

Once the FIFO buffer is filled, the device calculates which change should be provided to the actuator in order to bring the beam back to the reference position. The calculation is performed according to the algorithm described in a dedicated section of this documentation. The actuator (motor) is actually not move automatically to the calculated new position; instead, the value is presented to the user in the property “Proposal Position”; it is responsibility of the user to move the actuator using the button “Move Proposal”. In case the beam is not in the reference position but remains in the allowed region, a status message will notify the user that no action will be taken, Fig. 3.1.

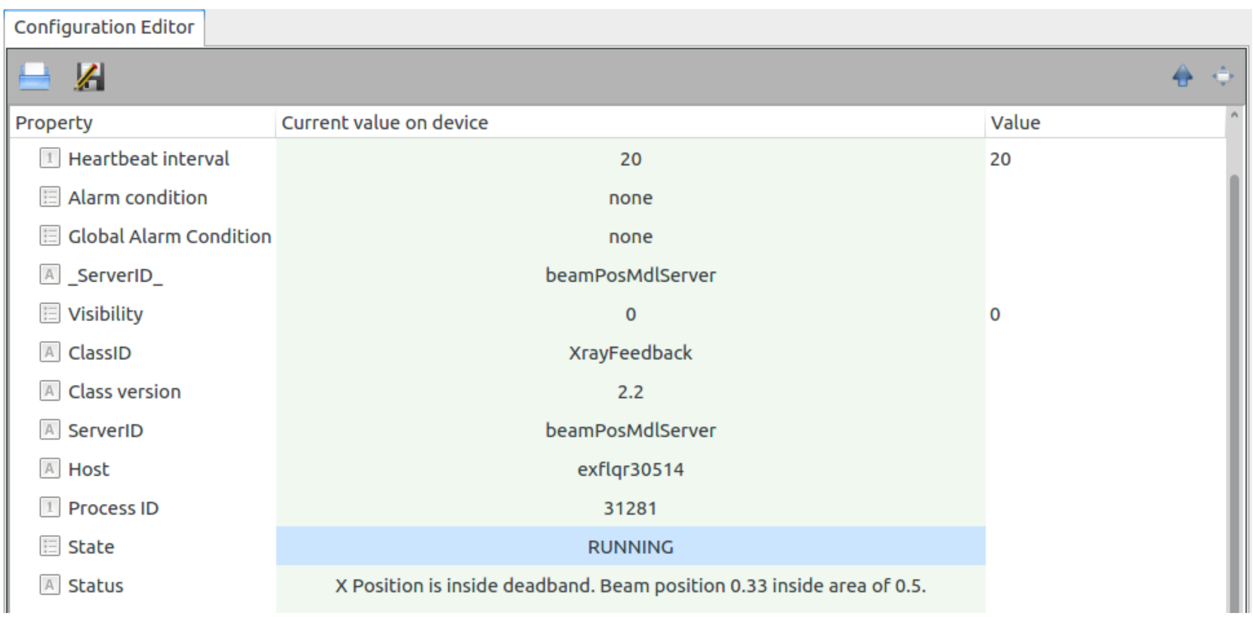

Fig. 3.1: Fig. 3.1: The device notifies the user the beam position is within the allowed region.

When needed, the operator can also move the actuator in steps of pre-defined value set in the property “Coarse Increment”. It is expected that he should be aware of what he is doing when moving the position of the actuator. Note that in case of manual movement the change can be performed only if the new value is within the allowed range given by the properties “Actuator Min Limit” and “Actuator Max Limit”.

CHAPTER

FOUR

FEEDBACK ALGORITHM

Since the feedback mechanism has to be robust to wrong configuration, it is based on the PID (proportional–integral–derivative) controller, which is a control loop feedback mechanism widely used in industrial control systems requiring continuously modulated control[3]. A PID controller continuously calculates the deviation of a measured value x with respect to the reference value (set-point SP); this deviation is typically referred to as "error value" e:

$$e(t) = x_{measured} - x_{SP}$$

The controller attempts to minimize the deviation over time by adjustment of a control variable $u(t)$, such as (in our case) the orientation of a steering mirror, Fig. 4.1. This correction is based on proportional, integral, and derivative terms of the deviation (whose constants are denoted as K_P, K_I, and K_D respectively):

$$u(t) = K_{calib} \cdot PID$$

with

$$PID = (P + I + D) = K_P \cdot e(t) + K_I \cdot \int_0^t e(t')dt' + K_D \cdot \frac{de(t)}{dt}$$

and K_{calib} being a conversion calibration constant converting the determined PID value to the actuator units (e.g. mV when dealing with piezo motors steering a mirror). In order to deliver a constant set a PID parameters a conversion factory between error value and actuator hook is implemented

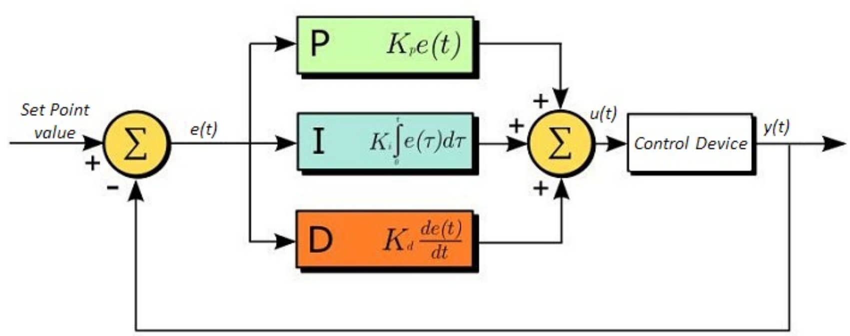

Fig. 4.1: Fig. 4.1: Working principle of PID controller.

The feedback action for the actuator position z is then build via the following steps:

- Previous actuator value: z_{old}
- Proposed actuator value: $z_{new} = z_{old} + u(t)$

[3] John Bechhoefer, Feedback for physicists: A tutorial essay on control, Rev. Mod. Phys. **77**, 783

In real data acquisition we are dealing with discrete accumulation (sum) of measurements. The position values are stored in a FIFO buffer of size ten. When the buffer is filled a new position for the actuator is calculated, and as soon as a new event is received, the first measurement which entered the buffer is removed, to allow the most recent measurement to be stored in the buffer. The integral term takes into account only the current elements in the filled buffer (i.e., the last ten provided measurements) and does a smooth (running) average to prevent an overshooting (windup) of the actuator. The derivative term is calculated as the difference of last two measurements over the difference between their timestamps.

Those three parameters K_P, K_I and K_D give the response of the control variable with respect to the deviation, the integrated (sum) deviation, and the derivative (rate of change) of deviation, respectively. Note that in the XrayFeed device these parameters are labeled as "Const. P.", "Const. I." and "Const. D.", respectively. Tuning a PID controller is the process of determining the ideal values for P, I, and D to achieve the desired response; e.g., in some systems, one may want the control variable to reach the set-point as quickly as possible limiting overshooting actions (thus without moving further the set-point). The default (hard-coded) parameters, allowed for finer-tuning in administration access mode, are:

K_P:	3.0
K_I:	0.1
K_D:	0.5

The conversion factor K_{calib}, as well as the PID parameters, is provided by the group responsible of the feedback devices, and is obtained by calibration. Using the above values for the PID parameters, and depending on the specific choice of devices, the following calibrated values (hard-coded in the software) are used:

Detector	**Actuator**	K_{calib}
SPB_XTD9_XGM/XGM/DOOCS	SA1_XTD2_MIRR-2/ACTRL/RY	0.000100
FXE_OGT1_CAM/SPROC/CAMERA	SA1_XTD9_MIRR/ACTRL/RY	0.000249
FXE_OGT1_IPM/MDL/MONITOR	SA1_XTD9_MIRR/ACTRL/RY	0.000100

CHAPTER

FIVE

XRAYFEEDBACK

5.1 Commands

Key	Displayed Name	Description	Alias	Access Level	Allowed States
coarseLeft	Coarse Left	Coarse (left) movement of the beam position		OBSERVER	ON
coarseRight	Coarse Right	Coarse (right) movement of the beam position		OBSERVER	ON
moveProposal	Move Proposal	Move the horizontal piezo to the proposed position		OBSERVER	RUNNING
start	Start			OBSERVER	ON
stop	Stop			OBSERVER	RUNNING

5.2 Properties

Key	Displayed Name	Description	Alias	Type	Access Level	Access Mode	Allowed States
actuatorLimitMax	Actuator Max Limit	The maximum limit of the actuator value		Double	OBSERVER	READONLY	
actuatorLimitMin	Actuator Min Limit	The minimum limit of the actuator value		Double	OBSERVER	READONLY	
actuatorName	Actuator	DeviceID of the horizontal actuatorused for feedback control		String	OBSERVER	INITONLY	
availableScenes	Available Scenes	Scenes from the XRayFeed		VectorString	OBSERVER	READONLY	
coarseIncrement	Coarse Increment	The coarse move increment for the piezo X		Double	OBSERVER	RECONFIGURABLE	
feedLimitMax	Feedback Max Limit	The maximum position the actuator is allowed to move during the feedback run. Is automatically set after each start.		Double	OBSERVER	READONLY	

CHAPTER

SIX

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