FIERGS SENAI
Centro de Excelência em Tecnologias
Avançadas SENAI - CETA

MAMS
TECNOLOGIA

Developer Guide

BraTrack Optical Stereo Tracking System

BraTrack

Revision A

08/2008

MAN_BRA0002_A

FIERGS SENAI
Centro de Excelência em Tecnologias
Avançadas SENAI - CETA

MAMS
T E C N O L O G I A

Some textual information are given special formatting to make understanding easier and emphasize important aspects, as shown below.

Note:
It shows some details or explains a part of the text.

ATTENTION:
It shows aspects to be verified by the user in order to properly use and maintain the system.

WARNING:
It adverts about situations that can damage definitely the system or cause other serious problems.

www.mamstec.com.br

mamstec@mamstec.com.br

Summary

1   Introduction

This guide introduces BraTrack XML configuration file to advanced users. It allows users to change some parameters to adapt the system to work in specific configurations.

The following file can be found in BraTrack installation directory and is the only one that may be edited to adapt the system to desired conditions.

- BraTrackSettings.xml

Section 3 of this document presents a table with ranges of values allowed for each parameter. In BraTrack installation directory there is an application – *XML_validation.exe* – that is able to check the structure of the XML files associated to BraTrack. To verify whether the file *BraTrackSettings.xml* is well formatted and consistent, just drag it onto the application icon. The diagnosis will appear on a console window.

ATTENTION:

It is extremely recommended to make a backup copy of the file before editing it. The system will not work properly if a parameter has an inconsistent value or the document format is corrupted. Without a backup file, reinstall the system to restore the initial configuration.

WARNING:

Do not edit other XML files. MAMS Tecnologia and CETA SENAI-RS will not take responsibility for errors caused by changing the contents of other configuration files than the above mentioned one.

2   BraTrack Settings Structure

The file is structured in the following way:

```xml
<?xml version="1.0" encoding="utf-8"?>

<settings xmlns="http://www.w3schools.com"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.w3schools.com settings.xsd">

  <time_parameters exposure_time="1.0" frame_rate="60.0"
pixel_clock="0"/>

  <image_processing_parameters maximum_region_size="0"
multiplier="4.0" offset="70.0"/>

  <artifact_recognition_parameters marker_history_size="10"
maximum_absolute_distance_error="0.0"
maximum_expected_marker_displacement="50.0"
maximum_relative_distance_variation="0.03"
maximum_relative_error="0.05"
tolerated_absolute_distance_error="0.0"
validation_relative_error="0.05"/>

  <marker_correlation_parameters
fine_correlation_threshold="0.003"
rough_correlation_threshold="0.01"/>

  <artifact_capture_parameters acquisition_rate="30.0"
maximum_number_of_poses="300"/>

  <essential_matrix_calibration_parameters acquisition_rate="60.0"
maximum_number_of_poses="1000" pattern_size="300.25"/>

  <image_processing_parameters_slider maximum_multiplier="15.0"
maximum_offset="190.0" minimum_multiplier="2.0"
minimum_offset="20.0" slider_value="0.5"/>

  <master_camera>_NoMasterCamera</master_camera>

  <destination_network_address ip="127.0.0.1" port="3000"/>

</settings>
```

2.1   Parameters

2.1.1   Time Parameters

Tme parameters, presented as attributes of the *time_parameters* XML tag, define cameras' time-related aspects: frame rate, exposure time and pixel clock.

```
<time_parameters exposure_time="1.0" frame_rate="60.0" pixel_clock="0"/>
```

- Frame Rate

It is the value of the frame rate in fps (frames per second). It defines the number of pictures per second taken from the scene by the cameras.

- Exposure Time

It is the time in milliseconds for which the sensor of the cameras are kept sensitive to light at each image capture. Increasing this parameter makes the cameras more sensitive at the cost of increasing blurring and light interference. Avoid using values greater than 3.0.

> **WARNING:**
> **The *exposure time* parameter also defines the time for which the cameras' flash strobes are kept turned on, thus a too-high exposure time may damage the LEDs of the flash strobes due to overheating.**

- Pixel Clock

This parameter is related to camera data transmission rate through USB connection. If it is set to zero, the maximum pixel clock is used. Some USB controllers and some PC's Internal buses and transmission rates can not deal with the maximum camera transmission rate. In these cases, the pixel clock must be reduced to allow the system to work properly. However, with a reduced pixel clock, the system may not achieve the desired frame rate and the frame rate parameter must also be reduced. *Pixel clock* is an optional parameter (it may be omitted) and the default value is zero.

The three parameters above are related and some combinations of values are not allowed, since they would lead to inconsistencies.

2.1.2   Image Processing Parameters

These parameters configure aspects of BraTrack's image processing employed in marker recognition in cameras' image space. The parameters appear as attributes of the *image_processing_parameters* XML tag: maximum region size, multiplier and offset.

```
<image_processing_parameters maximum_region_size="0" multiplier="4.0"
offset="70.0"/>
```

- Maximum Region Size

It is the maximum number of pixels allowed in a group of connected pixels (8-neighborhood is employed) in camera image space, which is a marker candidate. If the marker-candidate image region has more than maximum_region_size pixels, it is discarded as a valid marker. If maximum_region_size is equal to zero, this verification is disabled. *Maximum region size* is an optional parameter (it may be omitted) and the default value is zero.

- Multiplier; and

- Offset

Multiplier and *offset* are parameters employed in calculating the threshold above which the brightness of a pixel makes it to be considered part of an image region that is a marker candidate. A set of bright pixels connected in camera image space according to the 8-neighborhood criteria is converted into a marker projection candidate. The threshold value is calculated as $offset + multiplier \times mean$, where *mean* is the mean value of pixel brightness throughout the whole image.

2.1.3 Artifact Recognition Parameters

These are parameters for configuring aspects of BraTrack's artifact recognition process. There are seven of such parameters and they appear as attributes of the *artifact_recognition_parameters* XML tag.

```
<artifact_recognition_parameters marker_history_size="10"
maximum_absolute_distance_error="0.0"
maximum_expected_marker_displacement="50.0"
maximum_relative_distance_variation="0.03" maximum_relative_error="0.05"
tolerated_absolute_distance_error="0.0" validation_relative_error="0.05"/
>
```

- Marker History Size

BraTrack keeps a history of labels and 3D positions assigned to each recognized marker alongside the frames. This parameter defines the size of that history (the number of "remembered" frames for each marker). The history, with positions and labels from previous frames, allows BraTrack to identify whether the distance between two markers varies, which indicates that they do not belong to the same artifact, thus helping in identifying cluster of markers that correspond to individual artifacts; to decide the probable actual label of a marker based on a voting scheme considering the past labels, thus reducing the effect of recognition errors; and to make markers inherit labels from past frames when the label cannot be inferred based on information provided by the current frame (this may occur due to occlusion, imprecisions or incorrect marker clusterization, for instance). The history is kept by correlating the position of the markers alongside the frames. This is done by a simple trajectory prediction algorithm applied to individual markers.

● Maximum Absolute Distance Error

When checking a matching hypothesis, during tracking, between a cluster of recognized markers (its assessed positions) and the model of an artifact obtained through previous artifact registration, the distance between each pair of recognized markers belonging to the same cluster is checked against the distance between the pair of artifact model's markers that hypothetically matches to the former pair. If the absolute difference between those two distances exceeds the value of this parameter for any pair of markers, the matching hypothesis is immediately discarded. If the value of this parameter is zero, this test will be disabled, otherwise the value is interpreted as millimeters. *Maximum absolute distance error* is an optional parameter (it may be omitted) and the default value is zero.

● Maximum Expected Marker Displacement

It is the maximum expected displacement, in millimeters, of a marker across two consecutive frames. This parameter configures the marker trajectory prediction algorithm helping in avoiding erroneous matches between a current and a former marker position.

● Maximum Relative Distance Variation

It is the maximum relative variation in the assessed distance between two markers alongside the frames during tracking (evaluated by parsing their histories) above which the markers are considered as belonging to different artifacts, since the distance between two markers from the same artifact ideally does not vary. The value of this parameter defines relative distance variations. For instance a value of 0.05 means that a variation of five percent of the assessed distance is accepted between two markers without splitting this pair of markers into two different groups.

● Maximum Relative Error

The meaning of this parameter is similar to the one of the *Maximum Absolute Distance Error* parameter, except that its value represents the tolerated relative error in the distances when checking a matching hypothesis. As this value is increased, it becomes easier to recognize and artifact, as well as the possibilities of misrecognition are increased.

● Tolerated Absolute Distance Error

It is similar to *Maximum Absolute Distance Error* and *Maximum Relative Error*. The value of this parameter defines the absolute distance error in millimeters that must be tolerated without discarding the matching hypothesis. If the absolute distance errors found during the analysis of a hypothesis did not exceed the value of *Tolerated Absolute Distance Error*, the matching is assumed as valid, independently on the results of other matching tests. If this parameter is set to zero, the validation of artifact-to-model matches according to the explained strategy is disabled. *Tolerated absolute distance error* is an optional parameter (it may be omitted) and the default value is zero.

> Note:
> Anyway, when more than one valid match is found (a tracked artifact may be acceptably linked to two or more artifact models), BraTrack chooses the hypothesis with the smallest total distance error.

- Validation Relative Error

  It is exactly the same as *Maximum Relative Error*, except that this parameter affects the matching tests performed in validating new artifacts to be inserted into BraTrack's artifact database. To validate an artifact, it is necessary to verify whether it matches to any other already registered artifacts. Similar registered artifacts would lead to misrecognition during tracking, therefore similarities must be avoided. The higher the value of this parameter is, the more difficult the registration of new artifacts will be. This parameter is also used in verifying the possibilities of pose misrecognition, which is done by checking the artifact against itself. This test avoids the use of artifacts with symmetrical marker distributions.

2.1.4 Marker Correlation Parameters

These parameters configure the correlation algorithm that establishes correspondences between marker projections from different cameras using epipolar geometry. They appear as attributes of the *marker_correlation_parameters* XML tag.

<marker_correlation_parameters fine_correlation_threshold="0.003" rough_correlation_threshold="0.01"/>

- Fine Correlation Threshold

  The value of this parameter defines the maximum distance at which a marker projection onto the image plane may be from an epipolar line to allow a correspondence to be established. This distance is given in camera normalized space, where one is a distance equal to the focal length, and the image plane is at a distance of one from the projection center. The greater the value of this parameter is, the greater the number of false correspondences will be. However, too-small values may lead to unrecognized correspondences and thus missing reconstructed 3D markers.

- Rough Correlation Threshold

  Also known as Coarse, it is the same as *Fine Correlation Threshold* except that the value of this parameter is used in checking the correspondence between marker projections from different cameras before the system is fully calibrated (after origin calibration using the L-shape calibration pattern, and during calibration using the rotating calibration pattern). It must be greater than Fine *Correlation Threshold*, since the system is not precisely calibrated yet when this parameter is used.

2.1.5   Artifact Capture Parameters

These parameters appear as attributes of the *artifact_capture_parameters* XML tag and define aspects of the process responsible for registering artifacts.

```
<artifact_capture_parameters acquisition_rate="30.0"
maximum_number_of_poses="300"/>
```

- Acquisition Rate

It is the acquisition rate of the artifact registration process, i. e., the number of frames captured per second while recording an artifact. The value of *acquisition rate* must not exceed the value of *frame rate* parameter.

- Maximum Number of Poses

It is the maximum number of samples (frames) taken from the artifact during the registration process.

2.1.6   Essential Matrix Calibration Parameters

These parameters appear as attributes of the *essential_matrix_calibration_parameters* XML tag and define aspects of the essential matrix calibration process. This process correspond to the calibration stage that is based on the rotating calibration pattern (the wand).

```
<essential_matrix_calibration_parameters acquisition_rate="60.0"
maximum_number_of_poses="1000" pattern_size="300.25"/>
```

- Acquisition Rate

It is the acquisition rate of the essential matrix calibration process, i. e., the number of frames captured per second while taking samples of the calibration pattern throughout BraTrack's work space. The value of *acquisition rate* must not exceed the value of *frame rate* parameter.

- Maximum Number of Poses

It is the maximum number of samples (frames) taken from the calibration pattern during the calibration process.

- Pattern Size

It is the actual distance between the two markers of the rotating calibration pattern. It is used to estimate the actual scale of the work environment. If it is set to zero, the scale correction is not performed and thus artifact translations measured during tracking may present a scale error, I. e., the assessed translation coordinates are the actual translation coordinates affected by a multiplying constant whose value is near one. *Pattern size* is an optional parameter (it may be omitted) and the default value is zero.

2.1.7   Image Processing Parameters Slider

These parameters appear as attributes of the *image_processing_parameters_slider* XML tag and are responsible for

defining the range of the parameters that control the brightness sensibility of the image processing algorithm employed in finding marker projections in images captured by the cameras. The slider linearly varies the *multiplier* and *offset* parameters described in section 2.1.2 from their specified minimum values to respective maximum values.

```xml
<image_processing_parameters_slider maximum_multiplier="15.0"
maximum_offset="190.0" minimum_multiplier="2.0" minimum_offset="20.0"
slider_value="0.5"/>
```

- Maximum Multiplier

The maximum value of the *multiplier* parameter controlled by the brightness sensibility slider.

- Maximum Offset

The maximum value of the *offset* parameter controlled by the brightness sensibility slider.

- Minimum Multiplier

The minimum value of the *multiplier* parameter controlled by the brightness sensibility slider.

- Minimum Offset

The minimum value of the *offset* parameter controlled by the brightness sensibility slider.

- Slider Value

This parameter defines the initial position of the brightness sensibility slider that appear on the *Setup* tab of BraTrack's graphical user interface. This parameter records the last position of the slider when a section with BraTrack application is ended. There is no reason for manually adjusting this parameter, since BraTrack graphical user interface provides direct control over it. *Slider value* is an optional parameter and the default value is zero, which means that *offset* and *multiplier* have their minimum values.

2.1.8   Master Camera

This parameter stores the ID of the current master camera (which is automatically selected as master when BraTrack starts) or the following special IDs. There is no reason for manually adjusting this parameter, since BraTrack graphical user interface provides direct control over it.

_NoMasterCamera	No master camera defined (no camera synchronization).
_ExternalMasterCamera	All local cameras are slaves.

2.1.9   Destination Network Address

The attributes of the `destination_network_address` XML tag define the network address to which BraTrack send its output data packages. There is no reason for manually adjusting these parameters, since BraTrack graphical user interface provides direct control over it.

```xml
<destination_network_address ip="127.0.0.1" port="3000"/>
```

Centro de Excelência em Tecnologias
Avançadas SENAI - CETA

2.1.10 Pose Filtering Parameters

This set of parameters, represented as attributes of the *pose_filtering_parameters* XML tag, is responsible for configuring the pose smoothing of BraTrack artifact pose calculation.

```
<destination_network_address history_size="0"/>
```

- History size

It defines the number of former poses of each artifact that are used in interpolation in order to smooth BraTrack's artifact pose assessment. It is an optional parameter (it may be omitted) and its default value is zero, which means no pose smoothing.

2.1.11 Selected Cameras, Remote Cameras and Selected Remote Cameras

There are also some XML tags related to storing data about currently selected cameras, remote cameras and currently selected remote cameras. However, there is no reason for manually adjusting these parameters, since BraTrack graphical user interface provides direct control over it.

3 Parameter Values

The table below summarizes BraTrack's parameter and respective allowed range of values.

Tag	Attributes	Range
time_parameters	frame_rate	From 10.0 to 70.0
	exposure_time	From 0.1 to 15.0
	pixel_clock (optional)	Integer from 5 to 40 or zero
image_processing_parameters	multiplier	Greater than or equal to zero
	offset	Greater than or equal to zero
	maximum_region_size (optional)	Integer greater than or equal to zero
artifact_recognition_parameters	marker_history_size	Integer greater than zero
	maximum_absolute_distance_error (optional)	Greater than or equal to zero
	maximum_expected_marker_displacement	Greater than or equal to zero
	maximum_relative_distance_variation	Greater than zero
	maximum_relative_error	Greater than zero
	tolerated_absolute_distance_error (optional)	Greater than or equal to zero
	validation_relative_error	Greater than zero
marker_correlation_parameters	fine_correlation_threshold	Greater than zero
	rough_correlation_threshold	Greater than zero
artifact_capture_parameters	acquisition_rate	From 10.0 to 70.0
	maximum_number_of_poses	Integer greater than zero
essential_matrix_calibration_parameters	acquisition_rate	From 10.0 to 70.0
	maximum_number_of_poses	Integer greater than zero
	pattern_size (optional)	Greater than or equal to zero
image_processing_parameters_slider	minimum_multiplier	Greater than or equal to zero
	minimum_offset	Greater than or equal to zero
	maximum_multiplier	Greater than or equal to zero
	maximum_offset	Greater than or equal to zero
	slider_value (optional)	From zero to 1.0
pose_filtering_parameters	history_size (optional)	Integer Greater than or equal to zero
destination_network_address	ip	A string representing the IP address of an actual host of the network or the address for broadcast
	port	A valid integer port number