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MAMS TECNOLOGIA

User Manual

BraTrack Optical Stereo Tracking System

BraTrack

Revision B

08/2008

MAN_BRA0001_B

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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.

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Summary

1 Introduction

BraTrack is a stereo optical tracking device that uses at least one pair of USB monochromatic cameras, with infrared flash strobes, connected to a dual-core PC, to track spherical markers grouped into rigid structures (3 to 5 markers) whose position and orientation (6 DoF) are assessed and sent to client applications.

BraTrack tracking system was developed to be used with VR (Virtual Reality) and AR (augmented Reality) applications as a low-cost accurate tracking solution.

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2 Device

The equipment is delivered in a fiberglass suitcase containing the following items:

- 2 x BraTrack Camera (including Cable Plug Connector)
- 2 x Wall-mounting Bracket
- 2 x Camera Power Supply
- 2 x Power Supply Cable
- 1 x Trigger-Connection Cable
- 1 x CD with BraTrack software
- 1 x 5.5 mm Coach-wrench
- 1 x 7 mm Coach-wrench
- 6 x 3 mm Screw
- 2 x 4 mm Screw
- 6 x 4.8 mm Screw
- 6 x 3 mm Screw Nut
- 2 x 4 mm Screw Nut
- 6 x 8 mm Screw Plastic Anchor
- 6 x 3 mm Spring Lock Washer
- 2 x 4 mm Spring Lock Washer
- 2 x Plastic Protection Covering
- 100 x 20 mm-Diameter Reflective Markers
- 1 x Static Calibration Pattern (“L” Shaped Pattern)
- 1 x Dynamic Calibration Pattern (“Wand”)
- 1 x User Manual (this document)

BraTrack system also comprises a Dell Optiplex 745 computer with 1Gbyte RAM and an Intel Core 2 Duo E6300 processor.

WARNING:
This is a fragile product. Please handle and transport it carefully. The suitcase was projected to give the equipment the best possible protection during transportation without compromising mobility. It is not a package for load transportation.

2.1 Installation

2.1.1 Wall Mount

Wall mount requires drilling three 8 mm holes, into which 8 mm screw plastic anchors must be inserted. Wall-mounting camera bracket and screws must be mounted. Cameras are to be mounted on top of camera brackets.

2.1.2 Cameras' Positions

With respect to BraTrack's accuracy, it is recommended to settle the cameras with a near-orthogonal orientation in relation to each other, as shown in Figure 1. BraTrack's working volume is the intersection of the volumes covered by each camera, thus the orientation of the cameras must also maximize this intersection. Regarding the distance between cameras, it is assumed a trade-off between accuracy and work range. As the distance increases, the work range is enlarged and the accuracy decreases.

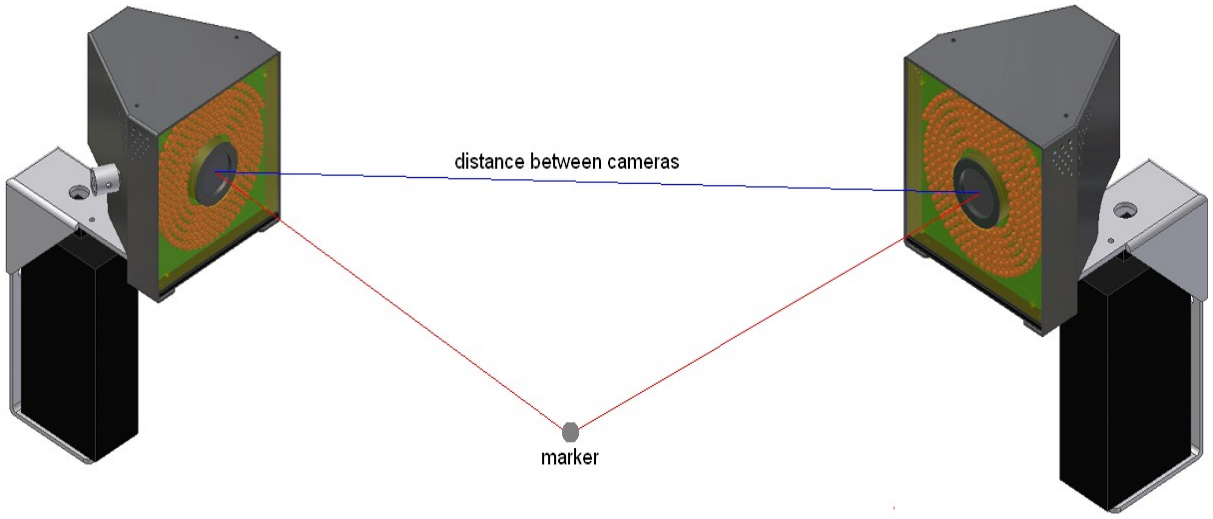

Figure 1: Recommended camera positioning

2.1.3 Flash Strobes

The infrared flash strobes are used to illuminate markers while the cameras are taking pictures. The flash pulses at a rate of 60Hz, which is the frame rate of the system, and the pulse length is 1ms, which is the exposure time of the cameras. The intensity of the emitted light can be controlled by turning the flash intensity adjustment knob on the camera hardware modules (position 5 corresponds to the highest intensity of emitted light).

WARNING:
Avoid looking directly at camera flash strobes. Although the emitted light is infrared thus invisible for humans, it is very intense and may cause eye discomfort.

2.1.4 Electrical Connection of Flash Strobes and Connection between Cameras

The activation of flash strobes of BraTrack camera hardware modules depends on the power supply – to be connected to the camera hardware module – and proper connection of camera internal output terminals to the set of terminals at the camera hardware module (backplane), as shown in Figure 2. On both cameras, the yellow camera terminal must be connected to the 24V terminal and the green camera terminal to the T24V (24-Volts trigger input) terminal.

Camera synchronization for simultaneous image capture is usually obtained using a master-slave configuration, which is connecting the trigger output of a master camera to the trigger input of a slave camera (see Figure 2). This way, when the master camera captures an image, it immediately starts the image capture by the slave camera. Master-slave configuration requires connecting master camera's green terminal to slave camera's white terminal using an extra connection cable to link the cameras – the NC (not connected) terminal can be used to build this connection (see Figure 2) – and connecting slave camera's brown terminal to the GND terminal in the camera hardware module's terminal set. The GND terminal of both camera hardware modules must also be connected to each other using the extra connection cable, which must be a two-wired cable.

There is also another possible master-slave camera configuration, having no connection between GND terminals: slave camera's white terminal connected to master camera's green terminal and slave camera's brown terminal connected to master camera hardware module's GND terminal (see Figure 3).

Both cameras can also be slaves of an external high-active trigger signal from 9V up to 24V. This signal must be connected to white (positive) and brown (negative) cameras' terminals. Cameras' trigger inputs are active on low-to-high border (see Figure 4). However, an often better way to synchronize both cameras by an external trigger signal is connecting one camera directly as slave of the trigger signal (by making the electrical connections mentioned earlier in this paragraph) and the other camera as slave of the first one (using the electrical connections mentioned in the former paragraphs). This way, the user is able to change between master-slave mode and both-slaves mode by simply choosing the appropriate generator of the synchronization signal: master camera or external device (see section 3.3). In fact, this last connection scheme is identical to the one of the master-slave configuration except that the master camera has the external trigger connected to its trigger inputs, which are ignored when the system is configured to operate with that camera as master. Figure 5 and Figure 6 summarize the two possible connection schemes that define this synchronization mode.

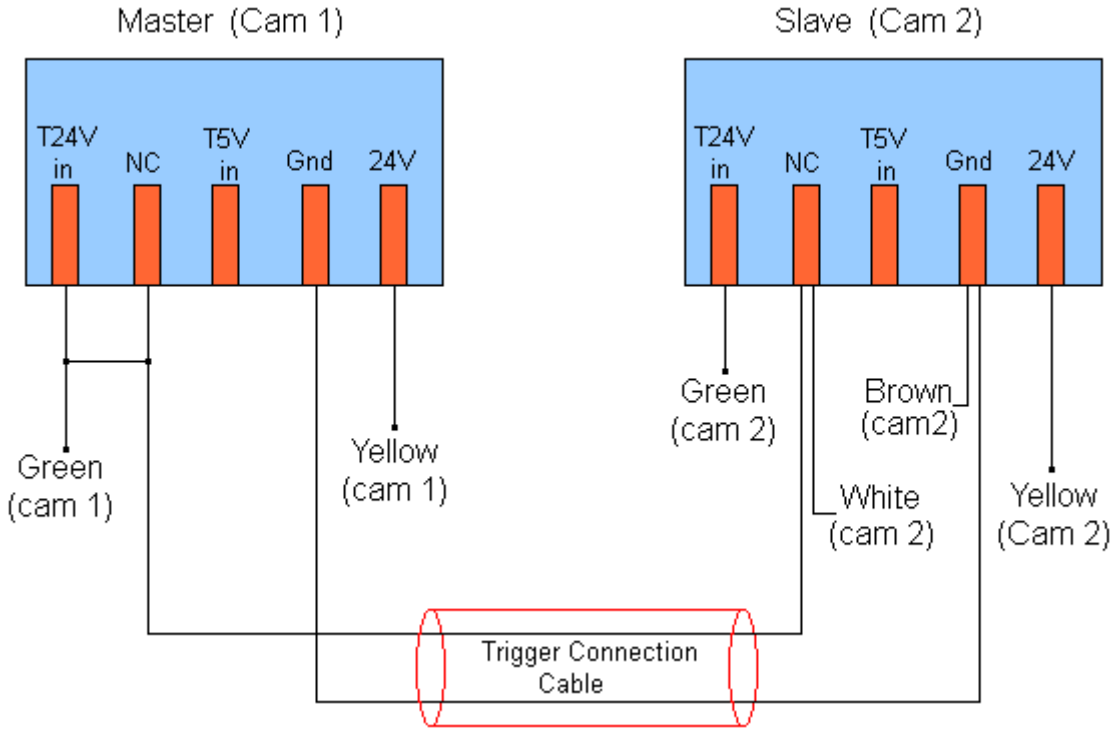

Figure 2: Connection between cameras in master-slave configuration

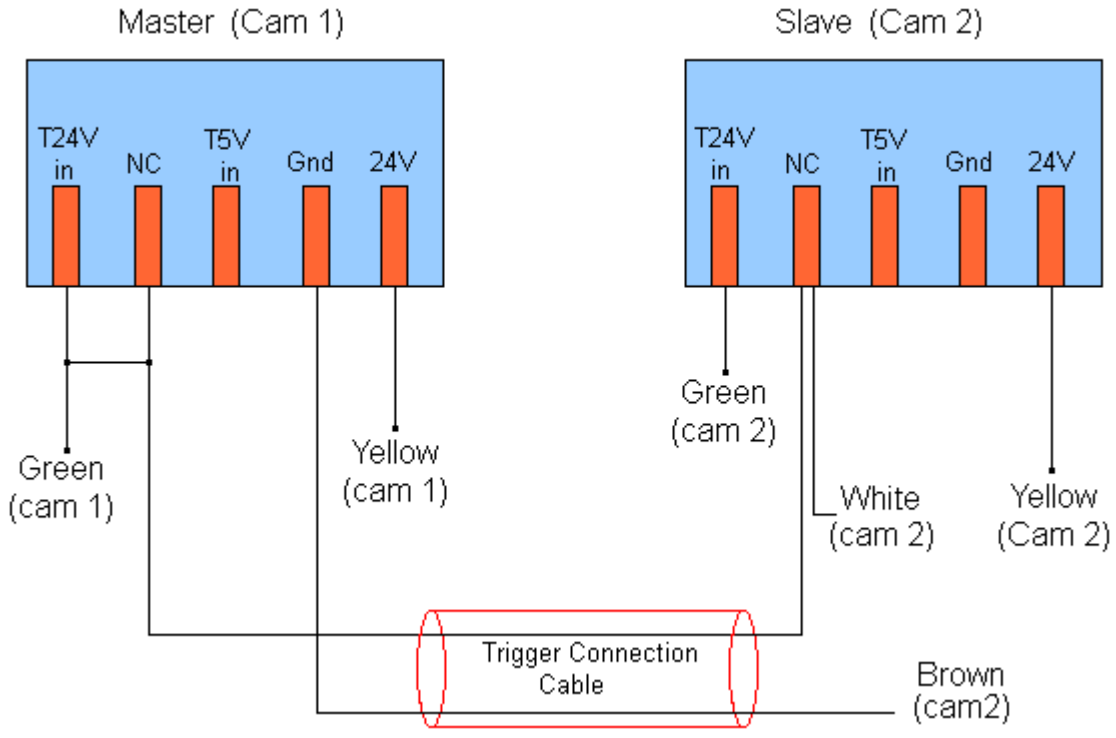

Figure 3: Another possible connection in master-slave configuration

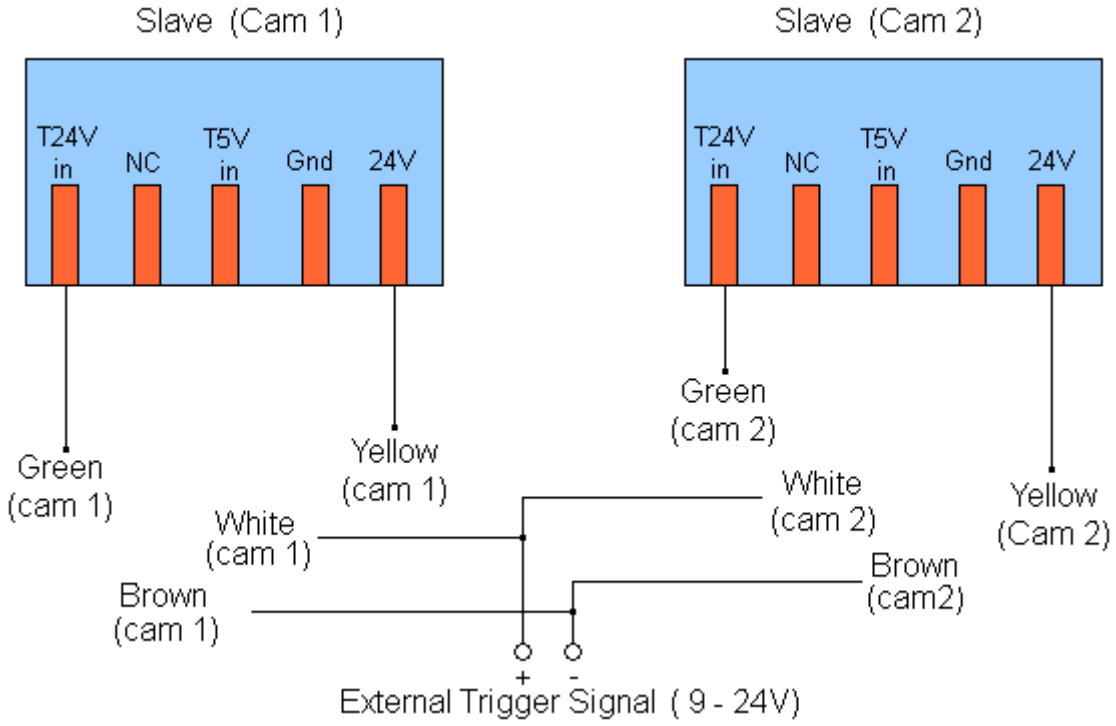

Figure 4: External trigger signal connection

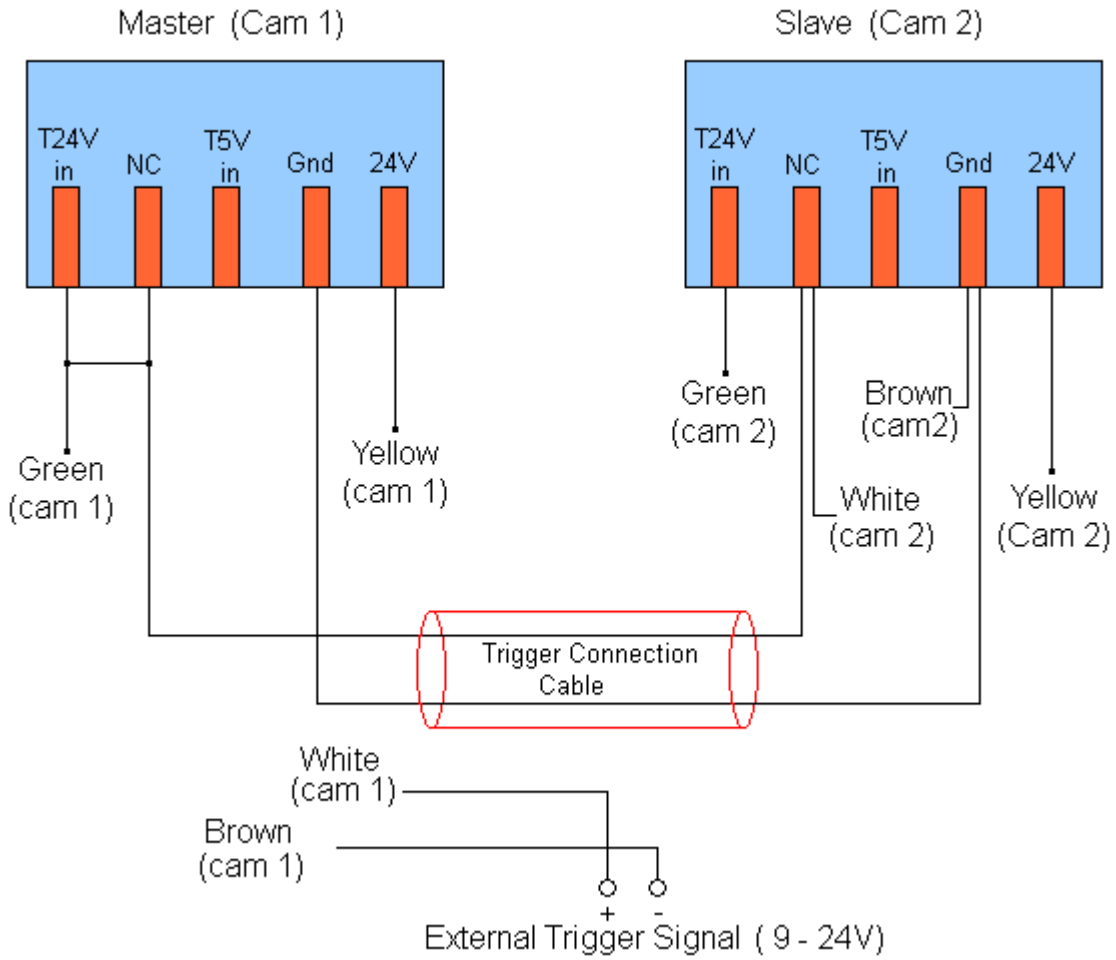

Figure 5: Electrical connections for master-slave or both-slaves with common GND

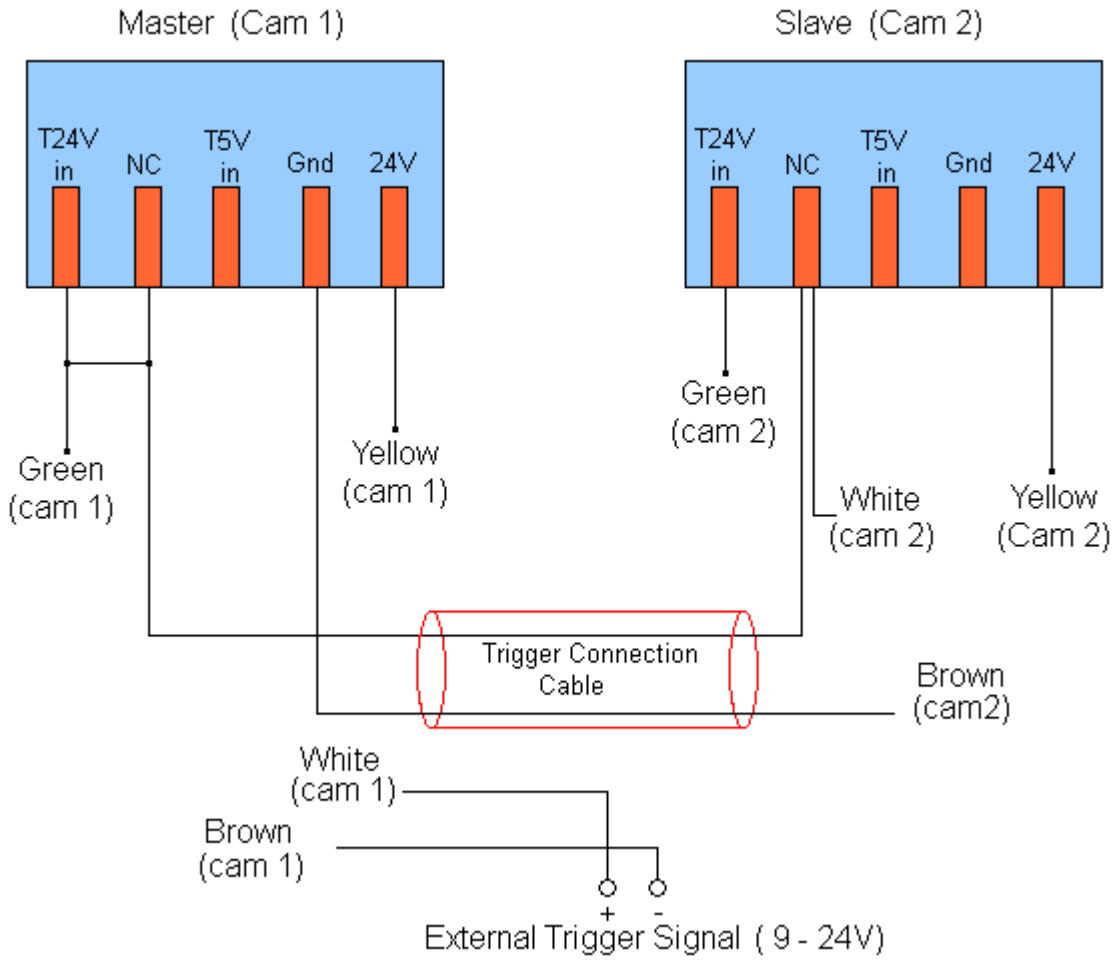

Figure 6: Alternative electrical connections for master-slave or both-slaves (without common GND)

2.1.5 Computer Connection

The connection between cameras and computer is simple. Just plug the cameras' USB connectors into the PC's USB ports.

> **ATTENTION:**
> Camera driver must be installed in the computer before connecting cameras and using the system.

Make sure that the cameras are connected to different USB 2.0 controllers. Each BraTrack camera requires an exclusive USB 2.0 controller, however a PC may have only one controller, allowing connecting only one BraTrack camera. When the PC used to run BraTrack has only one USB 2.0 controller, two PCs may be used, being one of them responsible for a remote BraTrack camera (see details in sections 4.2 and 4.3). Usually, each PC's USB 2.0 controller is responsible for a specific subset of USB physical ports. If two BraTrack cameras are connected to the same USB 2.0 controller, the system will not work properly. The PC provided as part of BraTrack equipment has two independent 2.0 USB controllers and can perfectly handle two cameras.

Figure 7 and Figure 8 show the USB ports of the computer (Dell Optiplex 745) provided within BraTrack hardware set. Ports from 1 to 4 are internally connected to one of the USB 2.0 controllers and ports from 5 to 8 are internally connected to the another one. BraTrack's cameras must be connected to different USB 2.0 controllers. Ports 4 and 6 may be used, for instance.

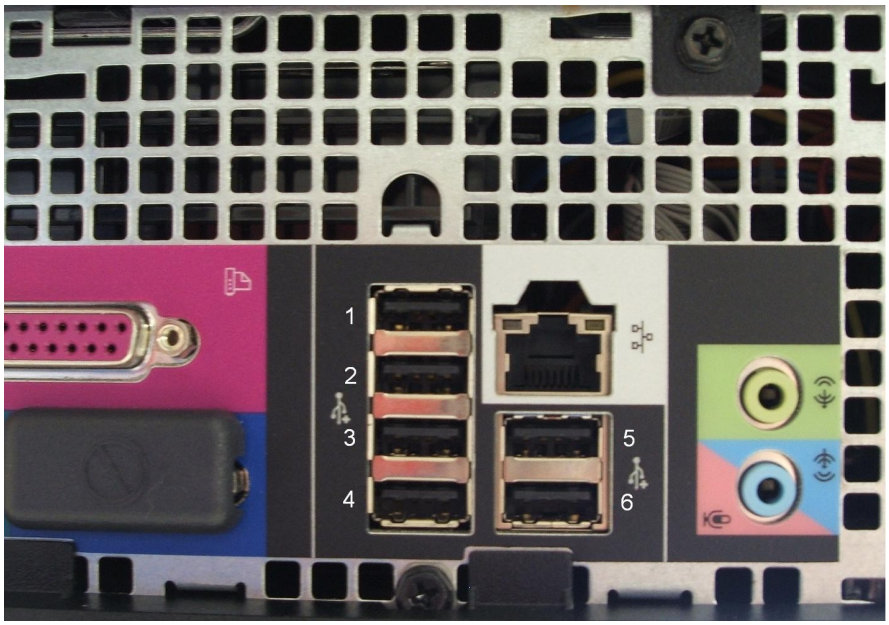

Figure 7: Rear view of Optiplex Dell 745

Figure 8: Front view of Optiplex 745

ATTENTION:
Avoid connecting and disconnecting USB cables during system operation.

2.1.6 Power Connection

The power supply input voltage ranges from 100V up to 240V AC, 50/60Hz, providing 24V DC as output. Just connect the power supply to the AC power and plug its output into the camera hardware module.

2.2 Accessories

BraTrack users may request the items below – markers in different diameter sizes – besides the equipment provided as the BraTrack package. They can be used for replacement or building additional artifacts.

Table 1: Commercial codes of BraTrack's accessories

BRA0110	10 mm marker
BRA0114	14 mm marker
BRA0120	20 mm marker
BRA0201	Power Supply Cable
BRA0202	Power Supply
BRA0203	USB Cable
BRA0301	Acrylic front plate
BRA0401	Static calibration pattern
BRA0402	Dynamic calibration pattern

3 BraTrack Software

3.1 Installation

To install the software, insert the provided CD into the drive and wait for installation wizard to start. If the software does not start automatically, go to the 'Start' menu and then 'Execute'. Select the CDROM drive and run the 'BraTrack_Install_v1.05.exe' program.

Table2: Minimal Requirements

Operating System	Windows 2000 or XP
Hardware	
Processor	Intel Core 2 Duo
System Memory (RAM)	1GB
Processor Cache Memory	2Mb
Disc Usage	40 Mb
Communication	2 x USB 2.0 controllers
Graphics Card	Minimum 128MB of memory
Drive	CD reader

3.2 Selecting Cameras

More than two (up to four) cameras may be connected to BraTrack software as local cameras (see section 4.2). However, this version of the system does not support multiple-camera tracking.

The user must select two, and only two, cameras to be able to perform tracking or system calibration. Local and remote cameras may be selected. Sections 4.2 and 4.3 show how to configure remote cameras.

To choose a pair of cameras, go to the 'Setup' tab and then select or deselect remote or local cameras by clicking on the respective checkboxes in the camera lists (local and remote). When two cameras are selected, calibration and tracking (if the system is already calibrated for the selected pair of cameras) is allowed.

3.3 Selecting Master Camera

BraTrack's master camera is the camera whose output electric trigger signal activates a slave camera, providing synchronization. With respect to camera synchronization, BraTrack is able to work in three modes: master-slave configuration (a master camera triggers a slave camera); both slaves (both cameras are slaves of an external trigger signal); or free-camera configuration (both cameras just take pictures at the predefined frame rate, with no synchronization). Remember that synchronization requires proper electrical connections between camera hardware modules.

To set the synchronization mode, one must go to the 'Setup' tab and select the master camera at the proper combo box widget, named “Master Camera” (see Figure 9). By selecting one of the local cameras as master, all other local cameras operate as slaves of the selected master camera (master-slave configuration). The option 'None', in master camera selection, disables synchronization (free-camera configuration), which is not recommended and usually severely deteriorates BraTrack's precision and reliability in tracking moving objects. The option 'External' makes all local cameras slaves of an external synchronization signal (both-slaves configuration), possibly provided from a remote camera (see section 4.2).

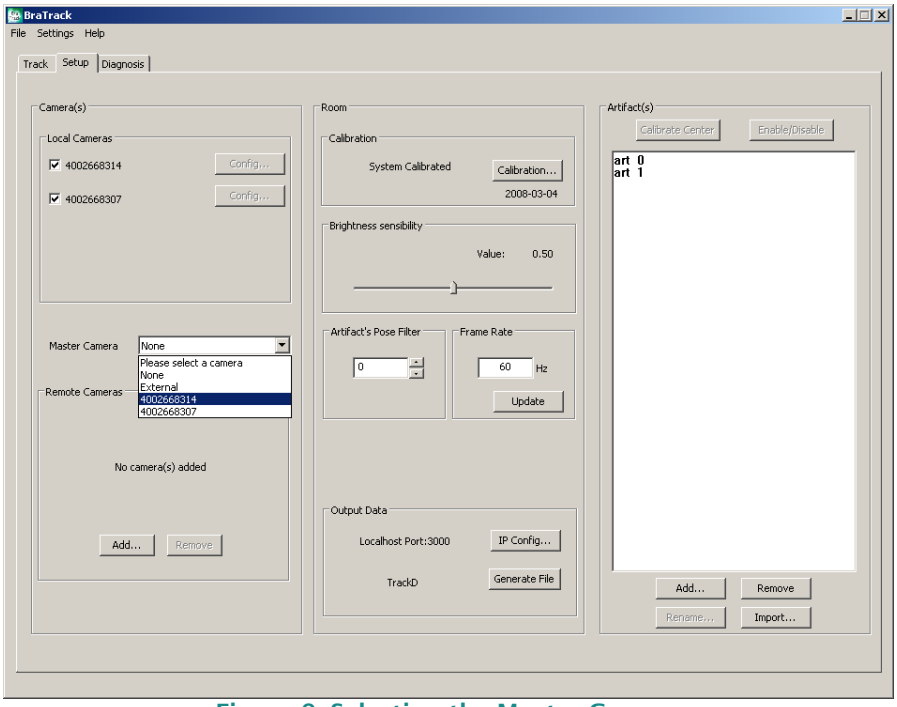

Figure 9: Selecting the Master Camera

3.4 Camera Sensibility

The light sensibility of the cameras may be adjusted using the sensibility control (“Brightness Sensibility” slider, Figure 10) in the “Setup” tab. Light sensibility affects recognition of markers and its control allows the user to choose the most suitable sensibility for each environment where the system is to be used.

The user must assume a compromise: as the sensibility increases, the markers are better perceived by the cameras, but it may cause blur effects and might make other bright or reflective objects be wrongly interpreted as markers. A greater sensibility is recommended when using small markers or working at a greater distance from the cameras. In this case the user must ensure that there are not other bright or reflective objects at the work environment. A smaller sensibility is recommended when working near the cameras or when the work environment suffers from light interference.

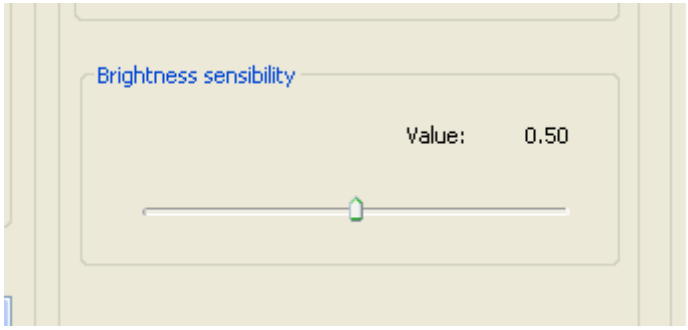

Figure 10: Brightness sensibility control

To verify the suitability of a sensibility setting, start a capture process (tracking, calibration or artifact registration – see sections 3.7, 3.8 and 4.1) and check whether the number of markers in scene is the same as the number of markers perceived by the cameras. Explore all the intended workspace, specially the regions far from the cameras.

The default sensibility value (0.5) is suitable for most environments. Changing the sensibility while the cameras are taking pictures is not allowed.

3.5 Artifact's Pose Filter

The artifact pose filter control (see Figure 11) allows specifying the number of last poses of each artifact that must be used for interpolation to smooth the pose variation of the artifact alongside the frames. The pose filter reduces the “vibration” (noise) of the assessed poses, but it causes a small delay in system's response. The control may be accessed on BraTrack's 'Setup' tab.

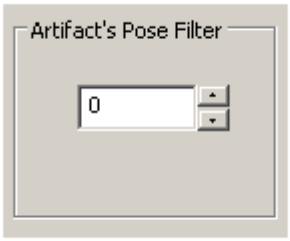

Figure 11: Artifact's Pose Filter Control

3.6 Frame Rate

The frame rate control may be accessed on BraTrack's 'Setup' tab. The user can change BraTrack's frame rate by typing a valid value and pressing the 'update' button. Changing the value of the frame rate does not affect the system while a tracking process is active; or if the cameras are operating as slaves of an external signal; or if the master camera is being controlled by a remote computer (in this case the frame rate should be set on that computer).

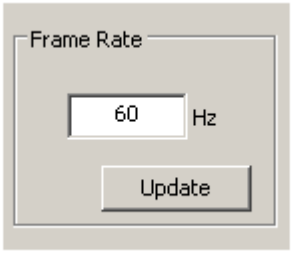

Figure 12: Frame Rate Control

3.7 System Calibration

System calibration requires two steps: Room Calibration and Space Calibration.

ATTENTION:
It is necessary to perform both calibration steps before using the system. Results of calibration are much better when camera synchronization is employed.

To calibrate the system, go to the 'Setup' tab and select two cameras between available local and remote cameras. The calibration status ('not calibrated' or the date of the last calibration) of that pair of cameras is shown beside the 'Calibration' button.

Pressing the 'Calibration' button starts a wizard that guides the user through calibration steps, which are described below.

3.7.1 Room Calibration

In this first calibration step the reference frame (origin and x-, y-, z-axis direction) of BraTrack's three-dimensional workspace is defined. The wizard guides the user through the process, which consists of placing the L-shaped calibration pattern at the intended origin of BraTrack reference frame taking into account the intended orientation of x, y and z axis, as depicted in Figure 13. The calibration pattern must be fully seen by both cameras and must be the only visible marker set in the room.

After positioning the L-shaped calibration pattern, the user must press the wizard's 'Start' button to finish the first calibration step. The wizard shows the number of markers seen by the cameras, which helps the user to know whether all calibration pattern's markers were identified. If no error occurred, the reference frame is calibrated and estimated parameters of geometrical transformations from BraTrack's reference frame to the reference frame of each camera are shown. The user can also repeat or cancel the process by pressing the respective buttons ('Repeat' and 'Cancel').

If the user has a sufficient knowledge on geometrical transformations, it is important to criticize the inferred parameters before going to the next calibration step. Notwithstanding, BraTrack will very likely obtain accurate transformation parameters.

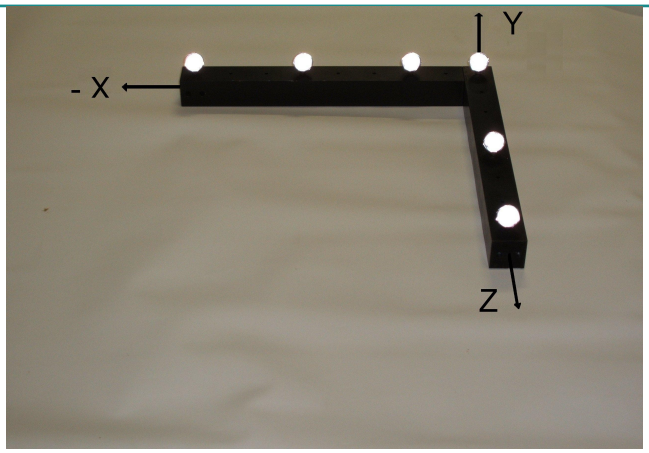

Figure 13: L-shaped Room Calibration Pattern

3.7.2 Space Calibration

After finishing room calibration, space calibration can be performed. The L-shaped calibration pattern may be removed from the room (or hidden), which makes space calibration calculations faster, or maintained in front of the cameras, which allows a more precise calibration of the origin of the world reference frame.

To accomplish space calibration, get the rotational calibration pattern (see Figure Figure 14) and, again, follow the wizard, which shows how many markers are perceived by the cameras. The L-shaped calibration pattern and the rotational calibration pattern are the only marker sets allowed in this calibration stage.

To perform this calibration step, press 'Start' button and keep the rotational calibration pattern spinning and moving throughout BraTrack's workspace (the region of 3D space seen by both cameras) trying to uniformly cover the widest possible volume. This must be done for around 25 seconds.

This process calibrates the geometrical relationship between cameras more accurately and may be cancelled or repeated. As a measure of quality of the calibration process, the wizard shows how many pictures were taken by the pair of cameras and how many of these pictures could be used for calibration calculations.

Figure 14: Space Calibration Pattern

3.8 Artifact Registration

BraTrack maintains a database that stores all known artifacts. Each artifact is represented as an artifact ID (artifact name) and a list of the three-dimensional positions of its markers in artifact's local reference frame. The 'Setup' tab has a few widgets for artifact database management.

An artifact, selected from the list of artifacts (see Figure 15), may be enabled (default condition), disabled (it will not be recognized during tracking) or removed from the database. These actions are respectively associated to the 'Enable/Disable' button and the 'Remove' button. It is also possible to rename an existing artifact by clicking on the 'Rename' button and typing a valid and unique artifact ID. An artifact name must not have space characters nor special characters except for underscore (_), which must not be the first character of an artifact name. Digits are allowed.

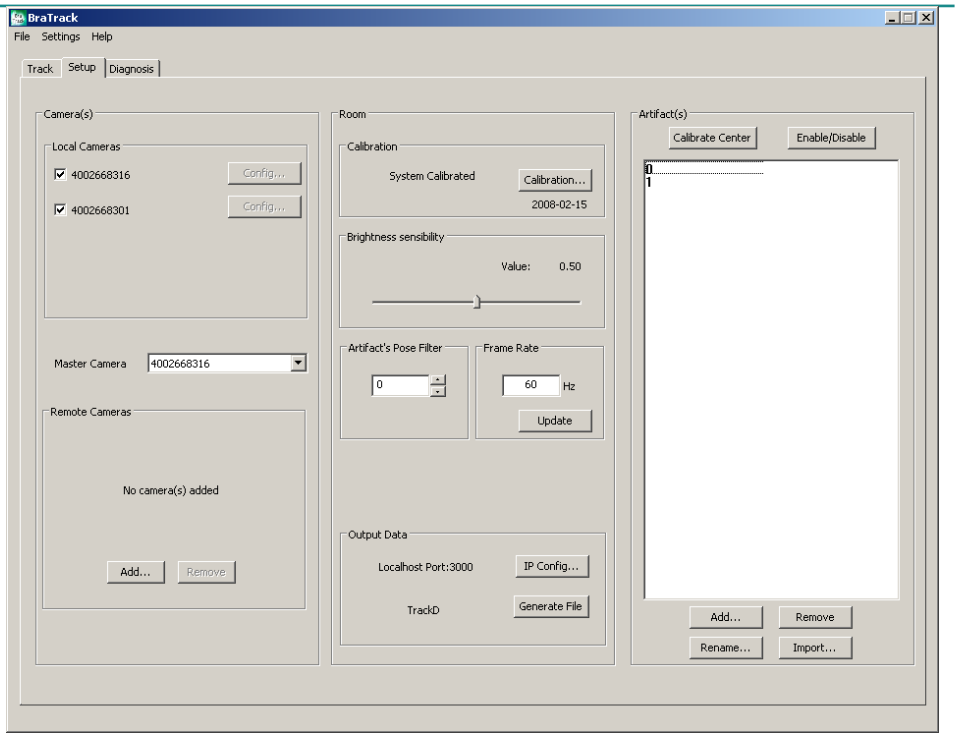

Figure 15: List of artifacts in 'Setup' tab

The 'Add' button starts a wizard for registering new artifacts. After building a new artifact and having the system calibrated for the selected pair of cameras, the user is able to insert the new artifact into the artifact database by starting the wizard and following the instructions. The user must press the wizard's 'Start' button to start the artifact registration process. During this process, which takes around 10 seconds, the artifact must be kept moving in front of both cameras, performing mainly random rotational movements. At the end of the registration process, the captured artifact (its markers' spatial distribution) is analyzed in order to verify the existence of geometrical ambiguities, i. e., markers' distributions that can not be given a unique marker labelling, such as isosceles and equilateral triangles (Figure 16). For instance, isosceles triangles can not be uniquely identified because a mirrored isosceles triangle is equal to the original one. Equilateral triangles have even more labelling ambiguities.

The new artifact to be registered is also checked against the artifacts that are already recorded in the database to verify similarities that might cause misrecognition. If the new artifact has geometrical ambiguities or is too similar to a previous registered artifact, an error occurs, avoiding registering the new artifact.

BraTrack was designed to be able to recognize any artifact (identity and pose) if at least three of its markers have their 3D positions reconstructed. Therefore, if any subset of the new artifact's markers containing three markers has a geometrical ambiguity; or is too similar to some other subset of markers of the same artifact; or is too similar to any subset of three markers of any known artifact, the built artifact is considered invalid. In case of similarity, the system tells the user which known artifact the built artifact is similar to.

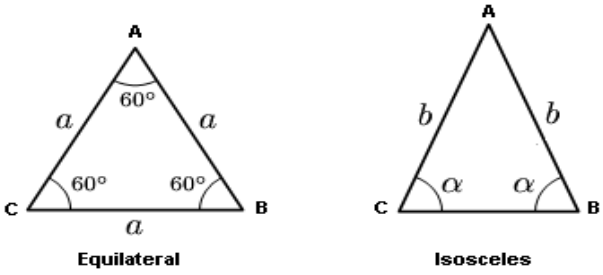

Figure 16: Examples of invalid artifact geometry

If no error occurs during artifact registration (the new artifact is valid), the marker positions of the new artifact are shown (to be criticized) and the user, by pressing the 'Finish' button, may record it into the artifact database after giving the new artifact a name (artifact ID), which must be different from any other artifact's name. By double clicking on an artifact name from the list of known artifacts, the respective markers' positions are shown.

It is also possible to import artifact definitions from an already created artifact database. To do this, press the 'Import' button and select the XML file containing the artifact database to be imported (the default name of a BraTrack's artifact database is 'ArtifactDatabase.xml'). The artifact database file descriptor 'artifacts.xsd' must exist in the same directory as the XML artifact database file. All imported artifacts that do not conflict with any already existing artifacts (non-similar and with different ID) will be inserted into BraTrack's artifact database. An error message will be displayed for each artifact that could not be imported.

3.8.1 Artifact's Center Calibration

BraTrack calculates the position of a recognized artifact as the position of the artifact's center, thus calibrating artifacts' center may be necessary. The center of an artifact is initially set to the mean position of its markers' positions (centroid), but it can be calibrated by the user.

Artifact's center position specially affects the way rotational movements are perceived. If the user wants to perform pure rotational movements handling an artifact, the user must rotate the artifact around its center, which is often very unintuitive when the artifact center is the centroid of the markers. The user will likely perform undesired translational movements when trying to only rotate an artifact with non-calibrated center.

To calibrate the center of an artifact, go to the 'Setup' tab, select among the registered artifacts the artifact whose center must be calibrated, and press the 'Center' button in 'Calibration Group'. Keep moving the respective artifact (it must be the only artifact in scene) in front of the cameras for a few seconds (look at the progress bar) performing only the intended pure rotational movements (try to rotate the artifact around the desired rotation center, without translation). If the operation succeeds, the registered artifact geometry will change to reflect the new center's position.

3.8.2 Artifact's Orientation Calibration

To calibrate the orientation of an artifact, go to the 'Setup' tab, select among the registered artifacts the artifact whose orientation must be calibrated, and press the 'Orientation' button in 'Calibration Group'. Keep the respective artifact static, making its intended new local reference frame aligned with the global (world) reference frame. The artifact to be calibrated must be the only artifact in scene and it must be kept in front of the cameras

for a few seconds (look at the progress bar). If the operation succeeds, the registered artifact geometry will change to reflect the new orientation of the artifact's local reference frame.

4 Operation

To start using the system, at first it is necessary to set some parameters in the 'Setup' tab. If the client application (the one that receives tracking data from BraTrack) runs on the same host computer, receiving data through localhost:3000 network address (which is the usual configuration – see section 5.1), the user just needs to select the pair of cameras and choose the master camera before starting the tracking process. However, BraTrack saves settings from previous sessions avoiding need for camera reconfiguration at every system new start.

4.1 Tracking

To start the tracking process, go to the 'Track' tab (default initial tab) and press the 'Start' button (see Figure 17). If the button is not enabled, it is probably due to non-set or wrong configurations. Two cameras must be selected to make BraTrack able to start tracking. The main settings are saved every time the software is closed. To erase BraTrack settings go to the 'settings' menu and choose 'Restore Default Configuration'.

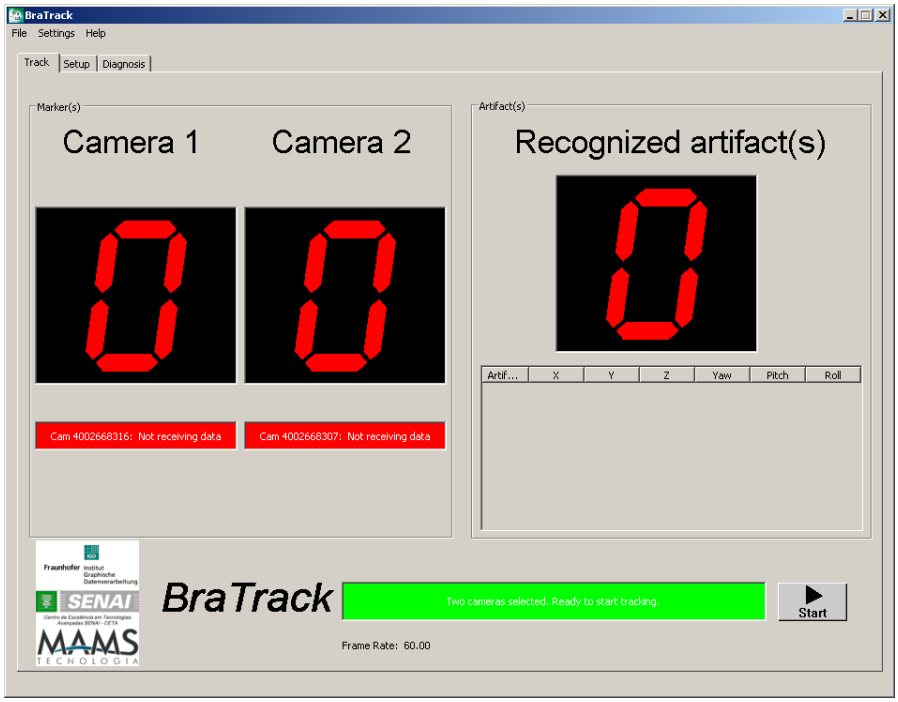

Figure 17: Track Tab

While running the tracking process, BraTrack's 'Track' tab displays how many markers are detected by each camera as well as the number of recognized artifacts. The ID and pose (X , Y and Z positions and yaw, pitch and roll angles) of each recognized artifact are displayed as a list (see Figure 18).

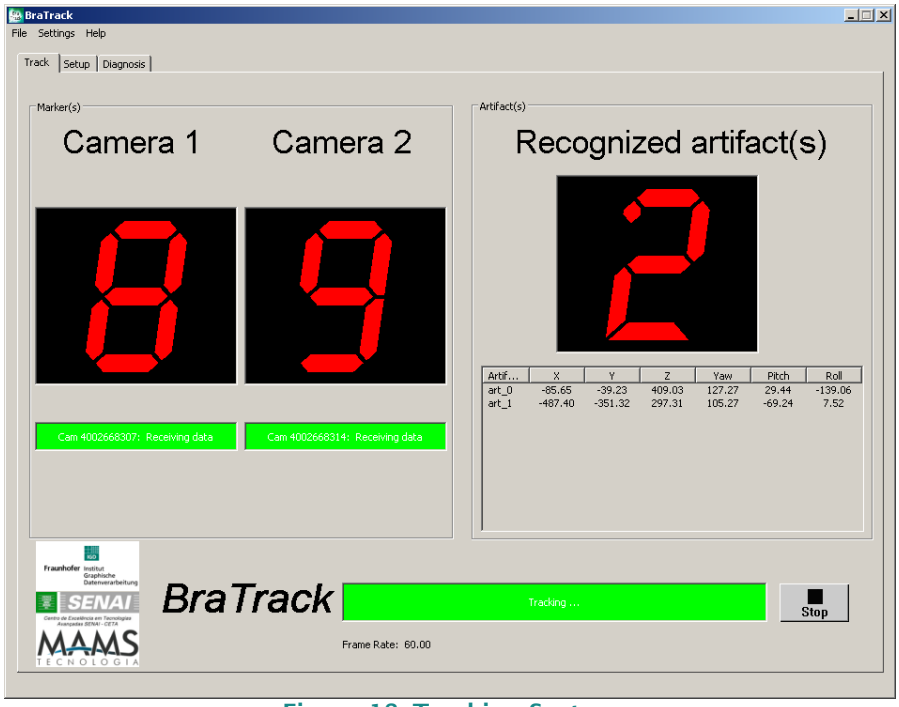

Figure 18: Tracking System

4.2 Converting Local Camera to Remote Camera

BraTrack cameras may be connected to different host computers. The tracking process, however, runs on a single computer, which requires that cameras connected to other hosts be configured as remote cameras.

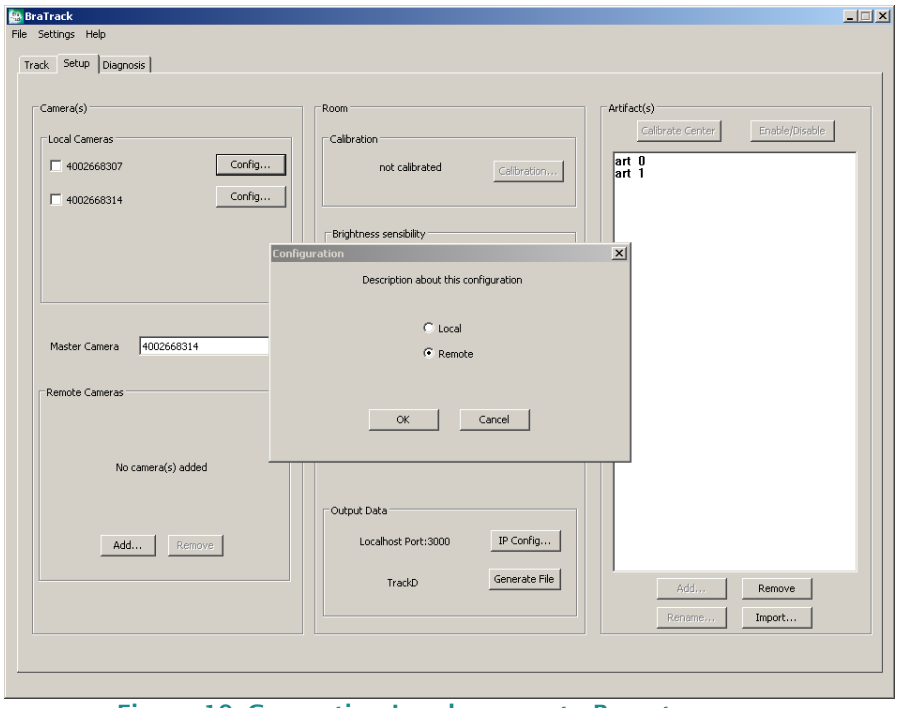

Figure 19: Converting Local camera to Remote camera

To configure a host computer's local camera as a remote camera for other instance of BraTrack software (which usually will run on other host), press the 'Config' button beside the camera ID in the list of local cameras (the camera must be deselected), and then select the 'Remote' option (see Figure 19). Configure the camera as 'Master' or 'Slave' and set the IP and port number of the network address to which camera's capture data must be sent (see Figure 20). If the operation has succeeded, 'Remote Mode' appears beside the camera in the local camera list. To stop a remote camera, configure it as 'Local'.

WARNING:
When using any kind of network communication, it may be necessary to change security settings such as firewall configuration.

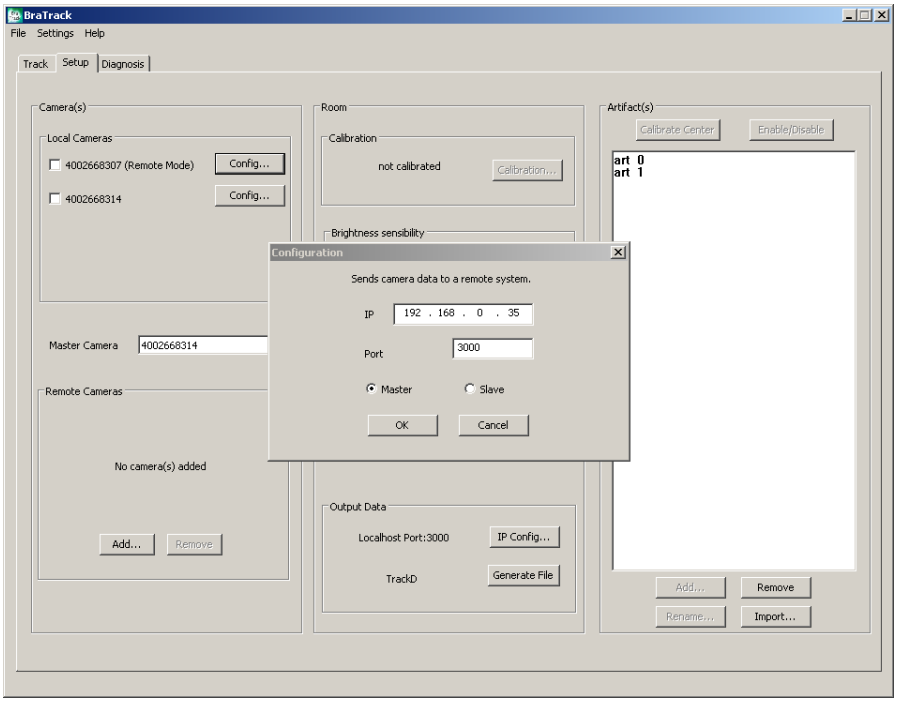

Figure 20: IP Address, Port and Camera mode configuration

4.3 Registering a Remote Camera

To register a remote camera on the BraTrack instance that will be responsible for tracking, you need to have already configured a remote camera on the remote instance of BraTrack software.

In the local instance of BraTrack, go to the 'Setup' tab and press the 'Add' button in the 'Remote Cameras' group (see Figure 21). Then, configure the network address (IP and port number) for receiving camera capture data – the same address used for sending camera data to at the configuration of the respective remote camera. Press 'OK' and wait a few seconds while the remote camera is being detected. If no error occurs, the user starts to count on a remote camera for system calibration and tracking that may be selected

the same way as a local camera. An error occurs if the remote camera one tried to add is not working as remote camera or is sending data to other network address.

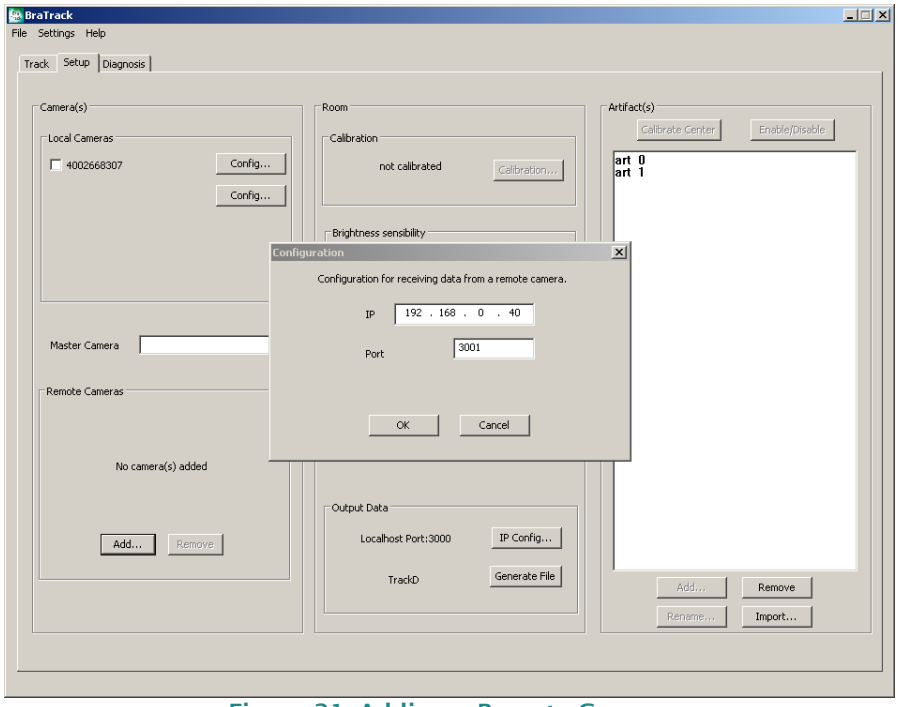

Figure 21: Adding a Remote Camera

4.4 Sending Data to a Remote Computer through Network

BraTrack's output protocol is based on UDP network communication, thus a destination network address (IP and port number) must be chosen. By default, this address is localhost:3000 (127.0.0.1:3000). The user is able to set the destination network address in order to make BraTrack's output packages reach client applications running on any network's host. To set the destination network address, press the 'IP Config' button in the 'Setup' tab, 'Output Data' group, and then type and confirm the network address, as shown in Figure 22. It is possible to set up broadcast network addresses (XXX.XXX.XXX.255) as destination addresses.

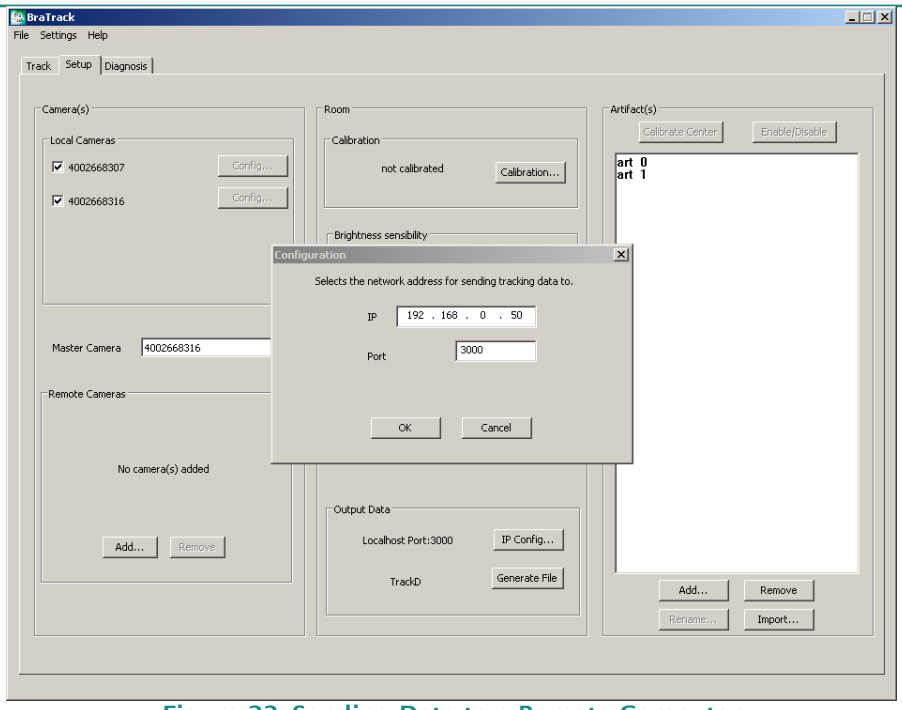

Figure 22: Sending Data to a Remote Computer

4.5 Creating TrackD Configuration File

To create a TrackD configuration file prototype containing BraTrack-related data (parameters and known artifacts), press the 'Generate' button, in the 'output Data' group, on the 'Setup' tab. The configuration file prototype will be created in BraTrack installation folder.

4.6 Displaying Camera Frames

Static images captured by cameras can be displayed on BraTrack's interface. This way the user is able to check what each camera sees. This feature may be useful to diagnose a problem such as daylight or artificial light interference. To see the captured images, go to the 'Diagnosis' tab, choose a camera (which must not be selected for tracking) and press the 'Capture' button.

4.7 BraTrack's Error Log

In the 'Diagnosis' tab there is a system error log which is constantly updated (see Figure 23). The log basically records errors related to user commands that could not be executed. The error messages are also displayed in popup windows as the errors occur in a session with BraTrack software.

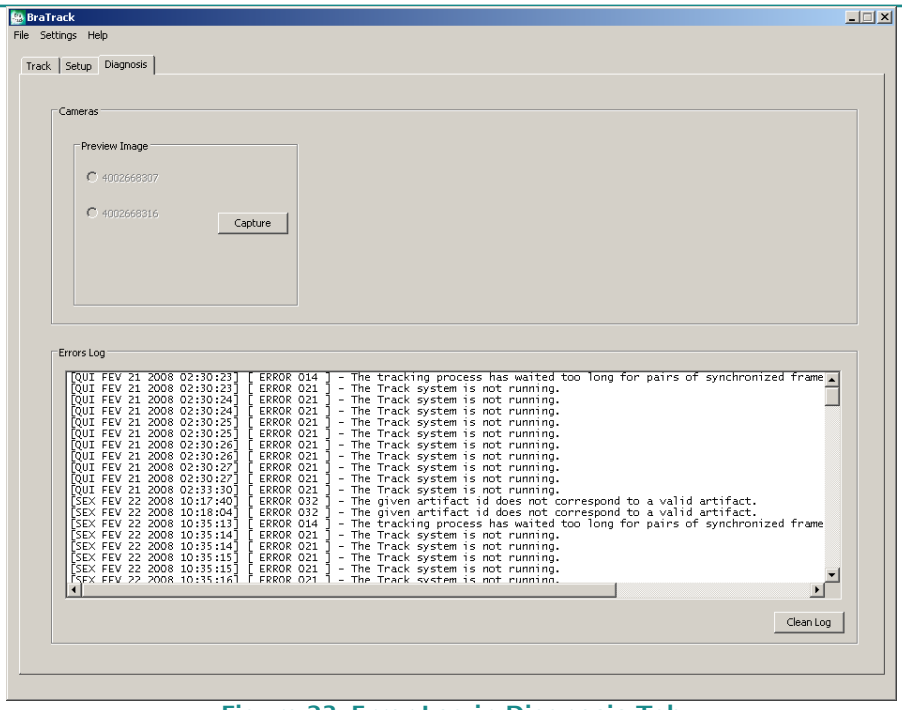

Figure 23: Error Log in Diagnosis Tab

5 Interface with VR/AR Applications

5.1 Output Protocol

BraTrack's output protocol is based on UDP network communication and byte packages – one per frame – containing the time stamp of the frame, which is an 64-bit unsigned integer value that is incremented by one every time a new frame is captured by the cameras; and a list of recognized artifacts where each element has the artifact ID and the artifact pose, which is represented as a transformation matrix. Each artifact is represented as an ID and four concatenated 3D vectors that define artifact pose: three rotation vectors and one translation vector.

The format of the package is described bellow.

Byte positions	Length	
bytes 0 to 7	8 bytes	time stamp, a 64-bits unsigned integer value;
bytes 8 to 8 + ID1 size	ID1 size + 1 bytes	the ID of the first recognized artifact: a string containing the sequence of characters followed by the null character (zero ASCII code – all bits are zero).
Bytes 9 + ID1 size to 104 + ID1 size	96 bytes	the pose of the first recognized artifact as four 3D vectors - twelve 64-bits (double precision) floating point values representing three rotation vectors (X, Y, Z, respectively) followed by the translation vector (T);
Bytes 105 + ID1 size to 201 + ID1 size + ID2 size	ID2 size + 1 + 96 bytes	the second artifact, if it exists: ID and pose. It has the same format as the first artifact;
(other artifacts, if any)		...

An example of byte package is shown below.

Time Stamp	ARTIFACT1	R1X	R1Y	R1Z	R2X	R2Y	R2Z	R3X	R3Y	R3Z	TX	TY	TZ
8	11111111111	8	8	8	8	8	8	8	8	8	8	8	8

Figure 24: Byte package format

The package may contain no artifacts (when no artifacts are recognized), having only the time stamp (only eight bytes). The numerical values are represented in little-endian byte order.

In order to implement an interface with BraTrack, one needs to create an UDP socket for receiving byte packages sent by BraTrack (the format of the packages is described above). Since UDP is a platform-independent standard, any socket API on any platform may be used, such as winsock on Windows platform. It is important to get the size of received packages, which allows

to know whether a package has a non-corrupted structure. The number of recognized artifacts in a package is obtained by parsing the package.

The system does not need a specific port to send byte packages. The default IP and port are localhost (127.0.0.1) and 3000, respectively. To change this configuration, just go to 'Setup tab' and click 'IP Config' button in 'Output Data' group.

5.2 OpenTracker Framework Protocol

OpenTracker is a well-known framework that implements a unified interface to connect VR/AR applications to tracking systems. OpenTracker provides application developers with a standardized set of routines that does not depend on the tracking system employed.

Guiding users through the utilization of OpenTracker is beyond the scope of this text, therefore one must be familiarized with the framework to use OpenTracker interfacing instead of the BraTrack's proprietary protocol. This section explains only some main points of the interface between BraTrack and applications through the OpenTracker framework and provides simple examples.

5.2.1 Installing BraTrack Module into OpenTracker

The system comprises a module for OpenTracker that allows the framework to receive tracking data from BraTrack. The source-code of the module is provided within BraTrack's installation package, inside the “opentracker” directory. The user must follow the steps described below to install the module.

1 – In the OpenTracker compilable project, update opentracker.cxx and opentracker.dtd files by replacing them by their versions herein or adding the lines, from their versions herein, related to "BraTrack". Search for "BraTrack"-like strings at the source code.

2 – Compile and build OpenTracker and BraTrack module, whose source-code files are in opentracker/src/input.

3 – Build an application. The source code of the provided example illustrates how to use OpenTracker as an interface for BraTrack. The Test.xml file is an example of configuration file.

5.2.2 Configuration File

Here we show an example of an OpenTracker configuration file for using the framework with BraTrack.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE OpenTracker SYSTEM "ROOT\opentracker\data\opentracker.dtd">

<OpenTracker>
        <configuration>
                <BraTrackConfig port="3001" maxbodies="10"/>
        </configuration>
```

```
        <Callback name="ARTIFACT1">
                <EventVirtualTransform
                        translation="0 0 0"
                        rotationtype="quaternion"
                        rotation="0 0 0 1">
                        <EventTransform
                                scale="1 1 1" translation="0 0 0"
                                rotationtype="quaternion"
                                rotation="0 0 0 1">
                                <BraTrackSource number="1"/>
                        </EventTransform>
                </EventVirtualTransform>
        </Callback>

        <Callback name="ARTIFACT2">
                <EventVirtualTransform
                        translation="0 0 0"
                        rotationtype="quaternion"
                        rotation="0 0 0 1">
                        <EventTransform
                                scale="1 1 1"
                                translation="0 0 0"
                                rotationtype="quaternion"
                                rotation="0 0 0 1">
                                <BraTrackSource number="2"/>
                        </EventTransform>
                </EventVirtualTransform>
        </Callback>

</OpenTracker>
```

The above XML document defines two callbacks, each related to the calculation of pose of a different artifact. The callbacks' names are “ARTIFACT1” and “ARTIFACT2” and correspond to “1” and “2” artifacts, respectively. When using OpenTracker, the artifacts' names must be integer numbers.

5.2.3 Source Code Example

An example of source code is shown below, where two callbacks are defined, each for a different artifact.

```
void callbackArtifact1( ot::CallbackNode & otnode, ot::State & event, void * data )
{
        cout << "CALLBACK: Artifact 1" << endl;
        cout << "Buttons 0x" << hex << event.button << " ";
        cout << "Pos x=" << event.position[0] << " ";
        cout << "Pos y=" << event.position[1] << " ";
        cout << "Pos z=" << event.position[2] << " ";
        cout << "Ori i=" << event.orientation[0] << " ";
        cout << "Ori j=" << event.orientation[1] << " ";
        cout << "Ori k=" << event.orientation[2] << " ";
        cout << "Ori s=" << event.orientation[3] << " ";
        cout << endl;
```

```
}

void callbackArtifact2( ot::CallbackNode & otnode, ot::State & event, void * data )
{ ... }

Context context( 1 );  // create a context

int _tmain(int argc, _TCHAR* argv[])
{
        CallbackModule * callbackMod =
                        (CallbackModule*)context.getModule("CallbackConfig");
        context.parseConfiguration("test.xml");     // parse a configuration file

        callbackMod->setCallback( "ARTIFACT1", &callbackArtifact1);  // sets callback
        callbackMod->setCallback( "ARTIFACT2", &callbackArtifact2);  // sets callback

        context.start();   // start the context when you are ready

        while(true){
                context.pushStates();
                context.pullStates();
        }
}
```

This example continuously writes artifact's IDs and poses to the console window.

5.2.4 Licenses

To use OpenTracker and its software components one has to fulfill conditions regarding their respective licenses (please see sections 9.4, 9.5 and 9.6).

5.3 TrackD Interface

5.3.1 Configuration File

To generate a configuration file, please see section 4.5.

6 Basic Maintenance

6.1 Equipment Cleaning

It is possible to clean the front acrylic plate gently with a slightly wet soft cloth.

WARNING:
Do not wet the equipment and do not use chemical liquids on it.

6.2 Additional Information

If you need more information or support not provided in this manual, please contact MAMS Tecnologia.

www.mamstec.com.br

mamstec@mamstec.com.br

7 Technical Specifications

The following table shows technical specifications of BraTrack Tracking System.

Table 3: Technical Specifications

	BraTrack
Precision	< 1mm (translational) and <1 deg (rotational)
Camera Reach	0,5 to 5 m (using 20 mm markers)
Working Range	Up to 30 m^3 (single stereo configuration)
System Refresh Rate	60 Hz
Latency	< 20 ms
BraTrack Cameras	752x480, 60 Hz, 86 deg FoV
Flash Strobes	240 Near-Infrared LEDs per camera
	Adjustable Illumination – 5 levels
Synchronization Option	Internal trigger with master-slave camera topology
	External trigger
Markers	Plastic spheres covered with retro-reflective material
	Available diameters: 12, 14 and 20 mm
Artifacts	Up to 10 artifacts, each consisting of 3 to 5 markers
Interface protocols	BraTrack UDP packages
	OpenTracker Framework
	TrackD Interface

WARNING:
Once power supply cables are connected, cameras are always energized. They do not have power button. Only the Flash Strobes can be turned off.

7.1 Dimensional Information

The equipment dimensions are showed in Figure 25 and Figure 26.

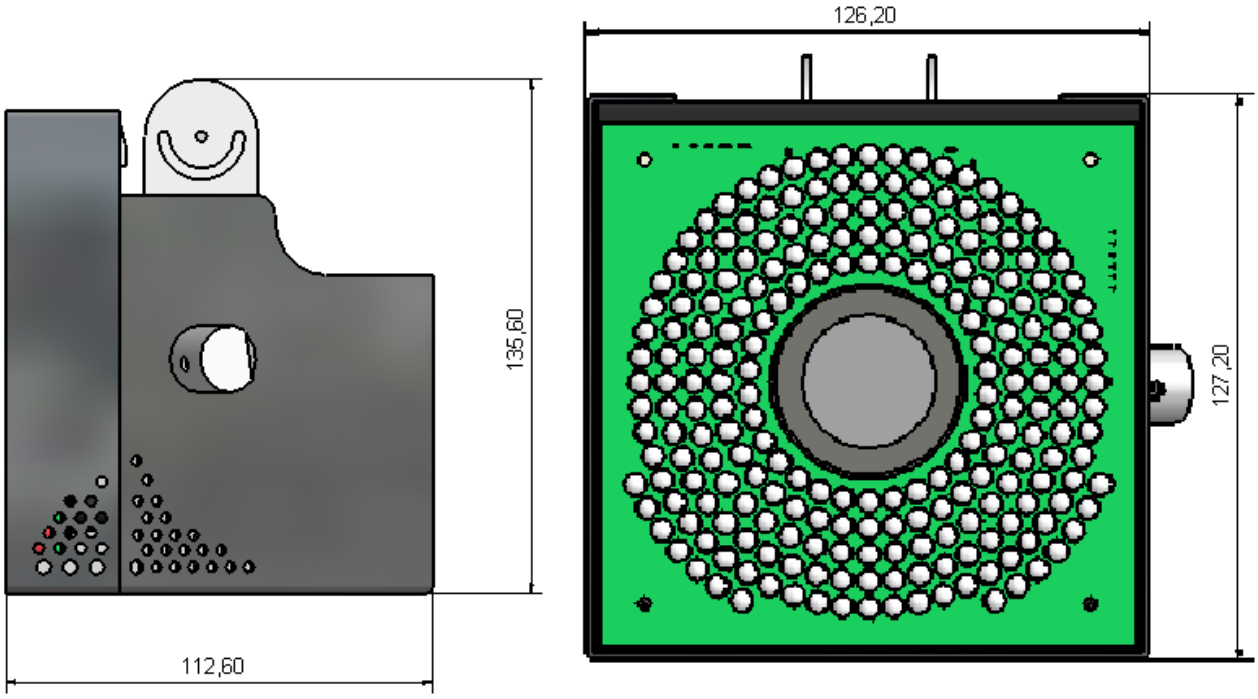

Figure 25: Dimensions of camera's housing (mm)

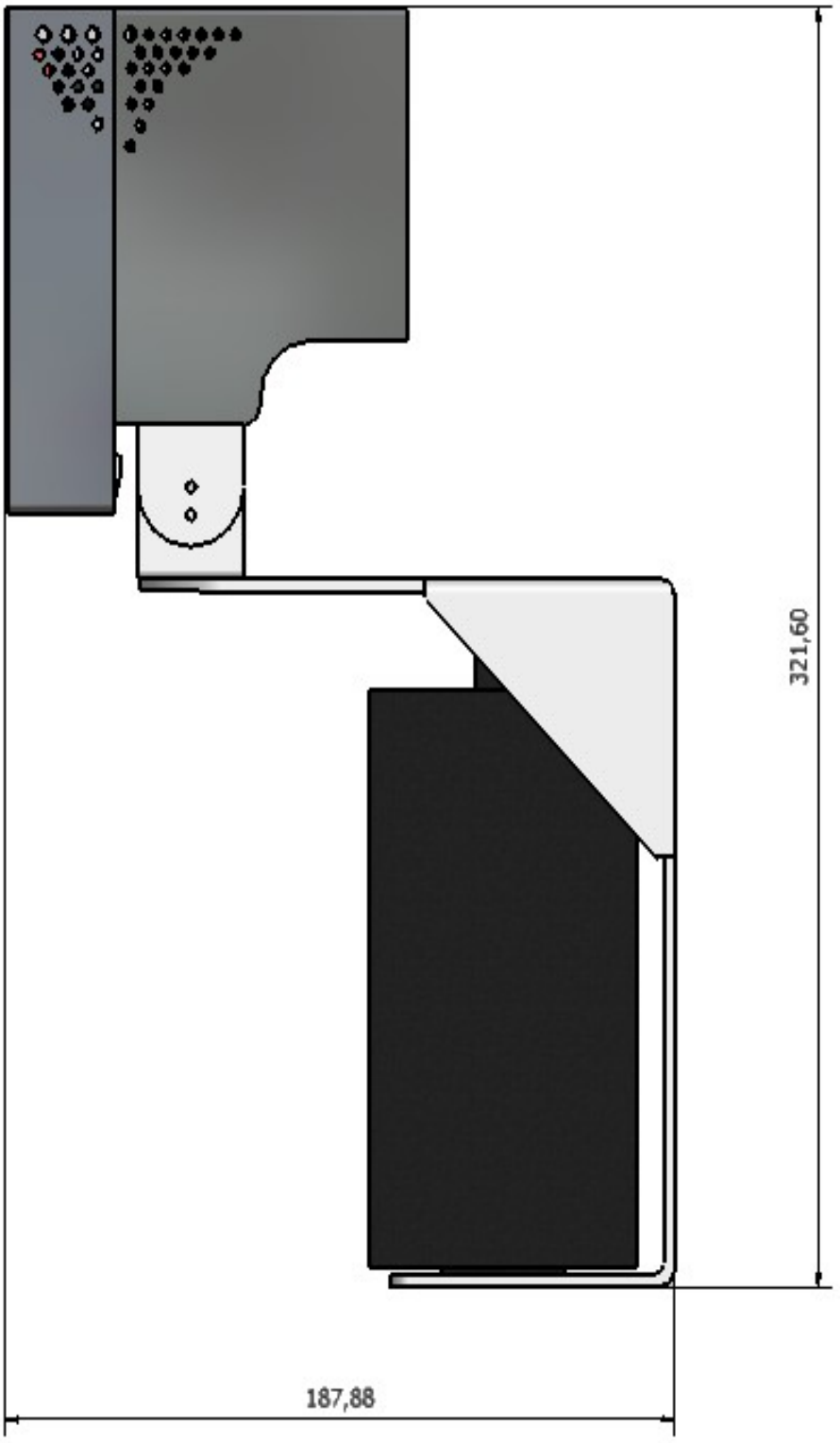

Figure 26: Dimensions of camera and wall-mounting bracket assembled (in mm)

8 Troubleshooting

Table 4: Troubleshooting

Error	Possible problem
The desired camera exists but is not available.	The user tried to select, configure or start a camera that is already selected, exporting data, or in use by BraTrack or other application.
The specified camera is already running exporting data	The selected camera is running as external camera and thus can not be selected nor used as master camera.
The specified network address is already in use for exporting/receiving data.	When starting or configuring a remote camera, the user specified a network address that is already in use by a remote camera.
The provided network address is not valid.	When defining remote cameras or destination address for sending BraTrack's output packages, the user specified a network address that is invalid or in use by another application.
There are no camera data arriving through the specified network address.	When trying to add a remote camera, the user specified a network address to which no remote camera is sending frame data. The specified network address may be wrong or the remote camera may not be running.
The tracking process has waited too long for pairs of synchronized camera frames.	One of the cameras is probably not capturing frames. Please check whether you have selected the correct camera as master and whether the synchronization signal and related electrical connections are correctly set and properly working.
The camera calibration data file could not be found.	The CalibrationData.xml file is missing. Please reinstall BraTrack Software.
A problem occurred when trying to read the contents of the file containing camera calibration data.	The CalibrationData.xml file is corrupted or was edited by hand. Please reinstall BraTrack Software.
The extrinsic parameters of a camera were not found.	Calibration data related to at least a camera are not defined yet. Please calibrate the system.
It was impossible to save the camera calibration data file.	BraTrack application could not save the CalibrationData.xml file. Check file system's free storage space and write-to-disk permissions.
A numerical error occurred when processing extrinsic calibration data.	An internal numerical error (probably underflow) has occurred when processing calibration-related data. Please try to calibrate the system again. If the error persists, try to slightly change the position or orientation of a camera and then calibrate the system.
The calibration pattern file could not be found.	The CalibrationPatterns.xml file is missing. Please reinstall BraTrack Software.
A problem occurred when trying to read the contents of the file containing calibration pattern data.	The CalibrationPatterns.xml file is corrupted or was edited by hand. Please reinstall BraTrack Software.
The calibration pattern could not be found in the calibration pattern file	Data related to the L-shaped extrinsic calibration pattern were not found in the CalibrationPatterns.xml file, which

contents.	may have been edited by hand. Please reinstall BraTrack Software.
The number of markers recognized by a camera is not the same as the number of markers of the calibration pattern.	When trying to calibrate extrinsic camera parameters (room calibration), a camera may be capturing a number of markers different from the expected one. Please make sure that all markers of the calibration pattern are being seen by both cameras and no other marker is being captured.
The number of grabbed frames are insufficient for calibrating the essential matrix.	The space calibration routine did not capture sufficient valid frames for calibrating cameras. This may be due to lack of synchronization between cameras or wrong number of visible markers in scene.
The artifact database file could not be found.	The ArtifactDatabase.xml file is missing. Please reinstall BraTrack Software.
A problem occurred when trying to read the contents of the file containing the artifact database.	The ArtifactDatabase.xml file is corrupted or was edited by hand. Please reinstall BraTrack Software.
The captured artifact has too few markers, i. e., less than three markers.	The artifact that the user tried to register has too few visible markers. Please check the built artifact, camera synchronization and scene visibility.
The geometry of the artifact is invalid due to possibilities of pose misrecognition.	The user tried to register an artifact that has an ambiguous geometry which could lead to pose misrecognition. See section 3.8 for more details. Please try to add the artifact at least twice before considering it actually not well built.
The artifact is too similar to some artifact in the database, which might cause artifact misrecognition.	The artifact that the user tried to add might be mistaken for some already registered artifact. See section 3.8 for more details. Please try to add the artifact at least twice before considering it actually not well built.
The artifact ID is invalid or was already recorded in the database.	The user tried to give an artifact a name that is not a valid artifact name or is already associated to some other artifact. An artifact name must not have space characters nor special characters except for underscores (_), which must not be the first character of an artifact name. Digits are allowed.
It was impossible to save the artifact database file.	BraTrack application could not save the ArtifactDatabase.xml file. Check file system's free storage space and write-to-disk permissions.
The file containing BraTrack settings could not be found.	The BraTrackSettings.xml file is missing. Please reinstall BraTrack Software.
A problem occurred when trying to read the contents of the file containing BraTrack settings.	The BraTrackSettings.xml file is corrupted or was edited by hand. Please reinstall BraTrack Software.
It was impossible to save BraTrack settings file.	BraTrack application could not save the BraTrackSettings.xml file. Check file system's free storage space and write-to-disk permissions.
Some BraTrack running parameter is not defined.	The BraTrackSettings.xml file were probably edited by hand. Please reinstall the system.
It was not possible to calibrate the center of the artifact.	The captured frames did not provide sufficient and suitable information to calibrate artifact center. Make

	sure that the artifact markers are the only visible markers in scene. Remember that the user must perform pure artifact rotational movements.
An error has occurred when trying to get an image from a camera.	The communication with a camera has failed. Check whether the employed computer is able to perform high-speed USB data transfer. BraTrack requires USB 2.0 controllers, which most computers have, but some computers are not able to deal with the required bandwidth.

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