Ryng)yng

Archery Analytics GmbH 2020 ©

Manual for Installation and Calibration

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1. Introduction

RyngDyng© by Archery Analytics supports archers by autonomously detecting arrows hitting the target. All arrow positions will be measured accurately and stored in a database, together with other useful information such as bow tuning parameters, weather conditions, etc.. Thus, all data will be available for later analysis.

High performance digital cameras and advanced image processing algorithms similar to those used in artificial intelligence applications deliver a high accuracy in a live environment.

RyngDyng© is an easy to handle and highly autonomous system. Archers can perform their training or participate in tournaments without being occupied with complex calibration procedures and pressing buttons or other interactions with the running system.

In the following, some familiarity with the functions of the RyngDyng© App will be helpful (see https://www.archery-analytics.com/en/public/ryngdyng/app).

2. Installation

There is no need to have a very accurate positioning of RyngDyng© relative to the target. It is good enough to have a distance of **300 ± 10 cm** from the foot-point of the center of the target to the front of the RyngDyng case. This distance is about the same as three times the length of the RyngDyng case from the front of the target.

Important note: The ground RyngDyng© is standing on should be firm and solid. If it is too soft or flexible, the stands might sink down after calibration of the system, resulting in a high inaccuracy of the position measurement. If necessary, use wooden boards or stone plates.
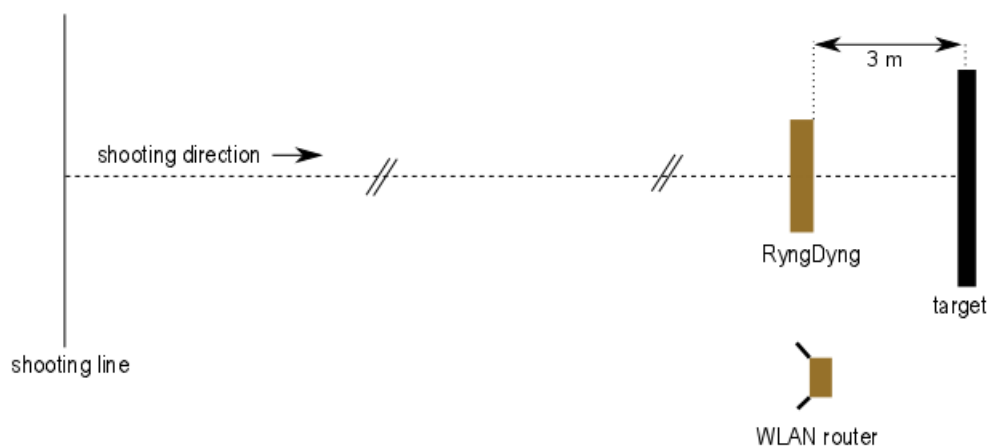
Set-up of Wi-Fi router and RyngDyng©

The optimal position for the Wi-Fi router is in proximity to RyngDyng and **1-2 meters above ground**. The antennas should point outwards, see figure above. This gives the maximum reach of the network in direction towards the shooting line. If reach is not far enough you can place the router closer to the shooting line, but no more than 10 meters away from RyngDyng.

3. Networking and powering on

The RyngDyng© type RD600 is designed to operate independent of the main supply and on a wireless network. Type RD720 in addition offers an Ethernet interface and has got its own power supply.

Any device connected to the RyngDyng Wi-Fi network can run the browser based RyngDyng© App and interact with the system.

First, the Wi-Fi router is powered on by connecting it to a USB charger or USB power pack. After one minute, the orange LED will light up and indicate that the RyngDyng wireless network is available. Then, RyngDyng© can be powered on by connecting it to the USB power pack resp. to the charger[1]. After about another minute, RyngDyng© will be up and running and automatically connected to the network. Now, connect the RyngDyng© App with your RyngDyng©.

4. Orientation

The RyngDyng cameras should be oriented towards the center of the target. This orientation procedure is supported by means of test images including a hair cross. To retrieve test images, in the RyngDyng© App go to `calibrations -> test image` and press button `acquire test images`.
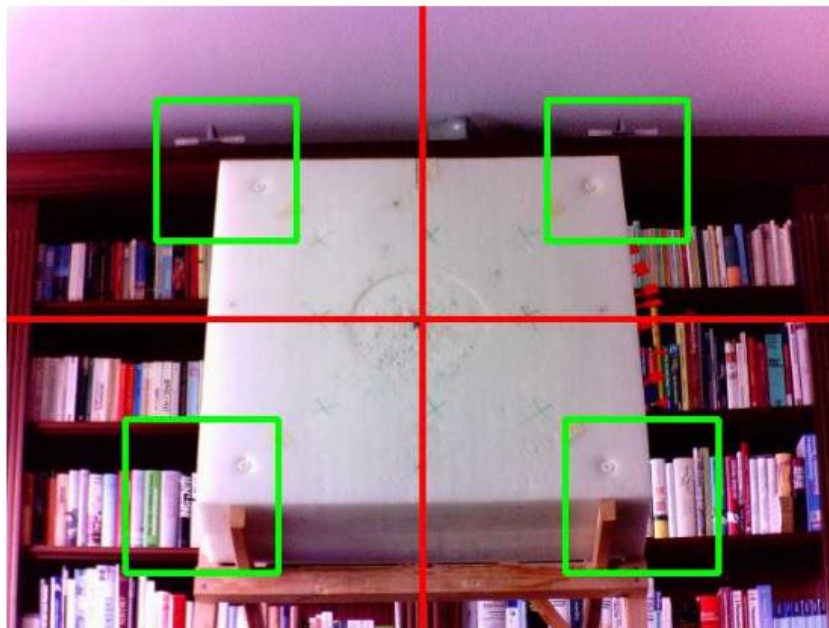

Hair cross in test image

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[1] RD720 usually is powered by a special charger and therefore needs a main supply

The hair cross should point to the center of the target. An accuracy of 10 cm is good enough for this adjustment. To alter the horizontal position, slightly rotate the RyngDyng© case. Vertical adjustment is done by the adjustable stands:

Adjustable stand

For adjusting the position, it can be helpful to switch on the live view. In this mode new test images are automatically retrieved every two seconds. Switch off the live view after correct position has been found.
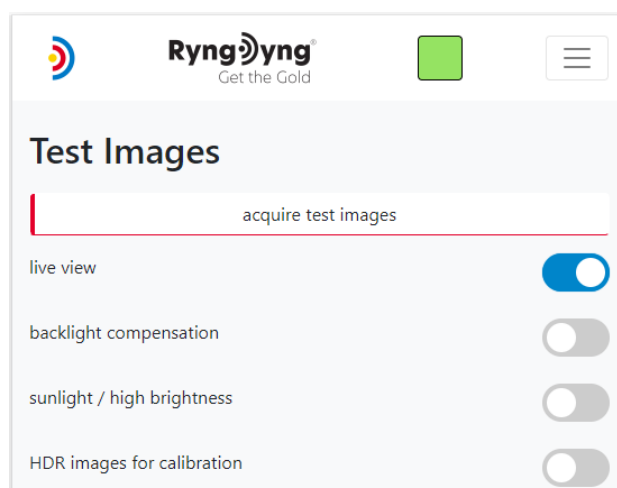
Live view switched on in the RyngDyng© App

When checking the test images, also look for obstacles that might hinder the sight of the cameras. E.g., remove all blades of grass directly in front of the cameras.

5. Geometric Calibration using the Chessboard

Geometric calibration is done with the help of 'chessboards'. First, pin the upper chessboard plate onto the target. The bottom chessboard will be held by the flexible bands between:

*Chessboard plates on target, the required right angle marked in red*

Please check the following conditions when pinning on the chessboard plates:

1. The upper chessboard plate should be horizontally aligned with the target
2. The target center should have the same distance to the upper and lower chessboards and to the left and right vertical bands. In other words: the center of the target is aligned with the center of the 4 chessboards.
3. The vertical bands start from the upper edge of the upper chessboard plate and end at the upper edge of the lower chessboard plate.
4. The bands may not be twisted. If twisted, untwist by rotating the band around their mounting pins in the chessboard accordingly.
5. There is a right angle between the upper chessboard plate and the vertical bands (see red marks in image above)
6. The chessboard plates are tightly aligned with the surface of the target, i.e., they do not protrude or bulk out. If necessary, use further pins to hold them down (but keep the chessboards themselves clear of pins).

It is good enough to check these conditions by the sight of eye; no special measurement equipment is needed for that.

It does not matter if there is already a target face on the target or whether the target is blank. Important is that the chessboards and the target surface are all 'in one plane' and no target pins are under the chessboards and lift them up.

The position of the chessboard can also be checked by retrieving a test image:
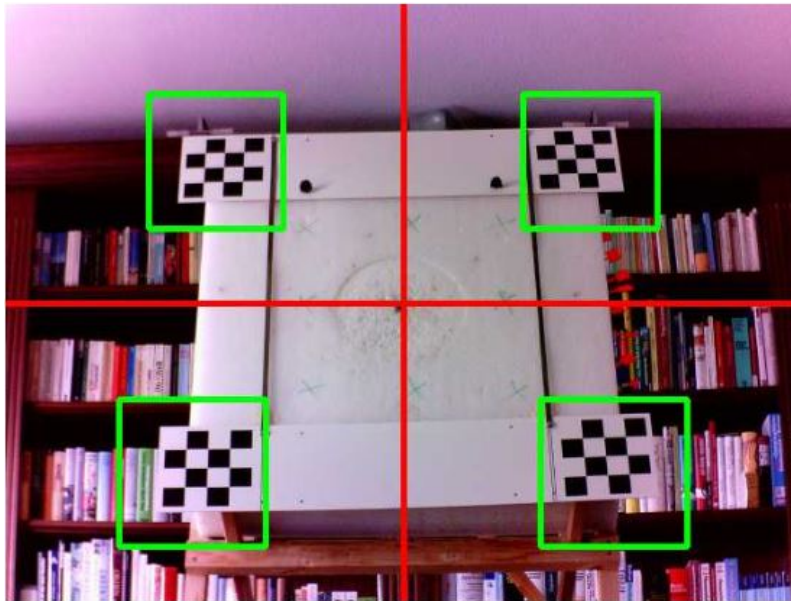
Test image of chessboard with green position markers

The chessboards will be located within the green markers, if they are mounted as described above.

If position of chessboards is ok, go to `calibrations -> chessboard calibration`:

Chessboard calibration menu in RyngDyng© App

Various standard target sizes are offered for calibration. Furthermore, you can add your own size to the list. It is important to select a target size as small as possible. Only the area with the target faces should be included, not the background with trees and sky. You can switch on the `round mask` for 122 cm target faces. Then, only the circle area of the target will be observed.

After target size is selected, press the button `do calibration`. After a few seconds, the result of the calibration will be displayed: three identically looking images, one for each camera, and showing

the target from a central perspective. The size of the image area is according to the selected target size:


Calibrated central perspective for one camera and with size 125 x 105 cm

In the example image above, the selected target size was too large, as the background is visible around the real target (the library of the author of this document 😊).

In case of insufficient light conditions or partially hidden chessboards, the calibration procedure can take up to 1 minute, as RyngDyng will try many different camera settings in order to find the chessboards.

In the view `calibrations -> status` you will find the status of the calibration. The date of the last chessboard calibration is shown as well:

RyngDyng

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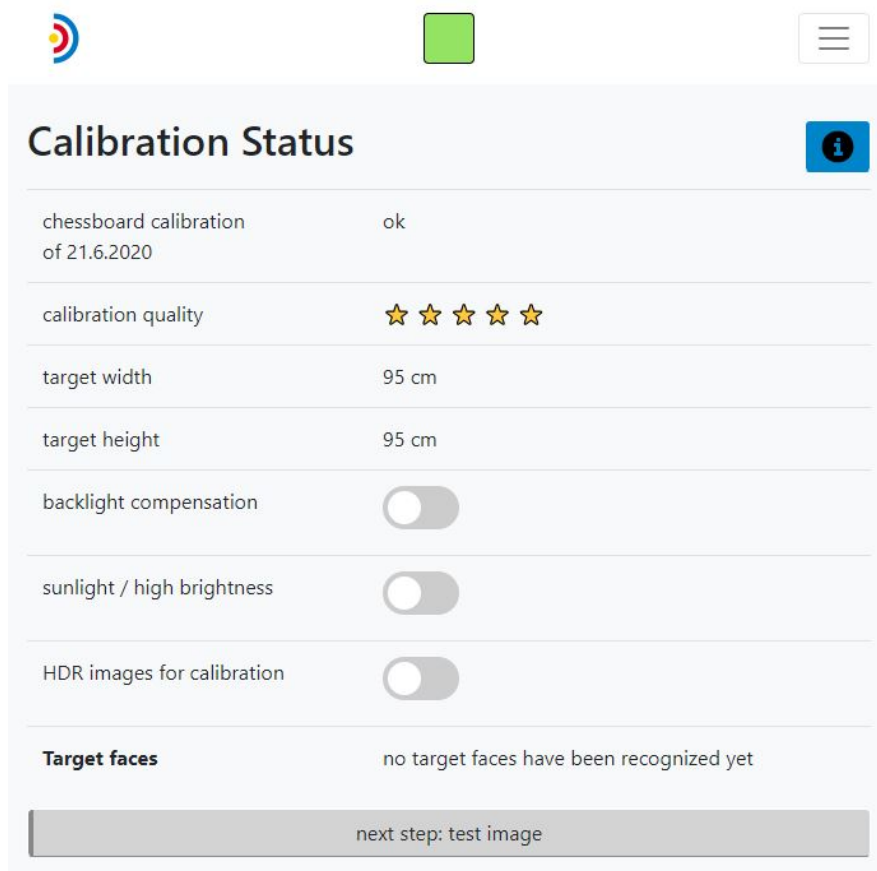
Status of chessboard calibration as shown in the RyngDyng© App

RyngDyng© stores the result of the chessboard calibration permanently and therefore it will be available after a reboot of the system. If the positions of target and of RyngDyng© have not changed, there is no need to re-calibrate after a reboot.

However, even a small change of the positions **after** chessboard calibration will decrease the accuracy of the position measurement. The system is quite sensitive in that respect. The `calibration quality` shows such displacements. This quality measure is calculated during every target face recognition activity and during every start detection procedure.

If only 1 or 2 yellow stars are left, better re-calibrate or bring back RyngDyng and target to their original positions. It may be helpful to mark the exact positions of target and RyngDyng© on the ground to have information on whether something moved.

Usually, chessboard calibration does not pose any problem for the cameras in most light conditions. There are, however, some special conditions to pay attention to.

First is backlight. The image below shows a recorded test image of a situation, where there is full sunlight behind the target (a small 80 cm target leaving a lot of bright sky around). The chessboards can hardly be recognized as they appear much too dark.
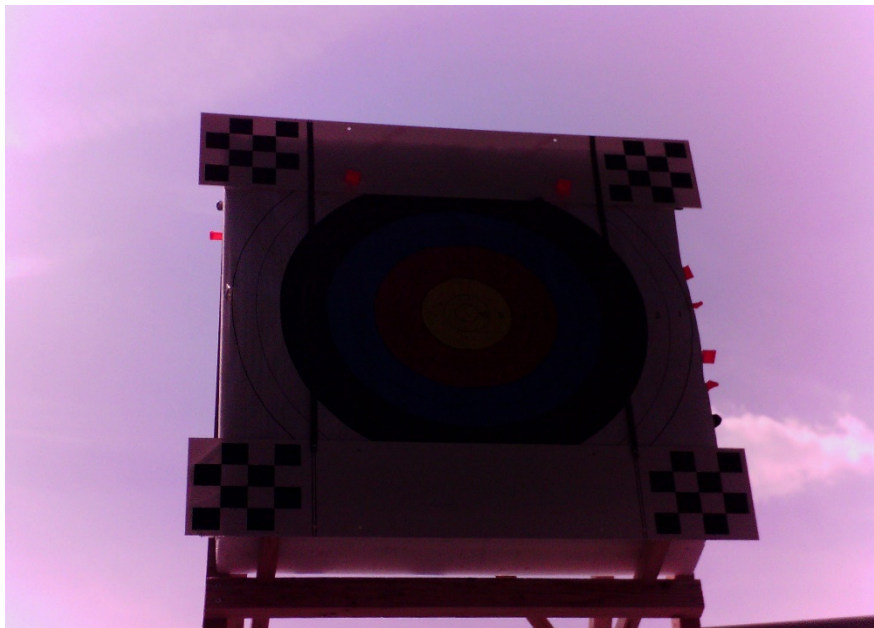
Backlight situation in bright sunlight

The problem can be solved by activating the backlight compensation of the cameras. Go to `calibrations -> status` or to `calibrations -> test image` and switch on the backlight compensation. The next image shows the same situation with activated backlight compensation:
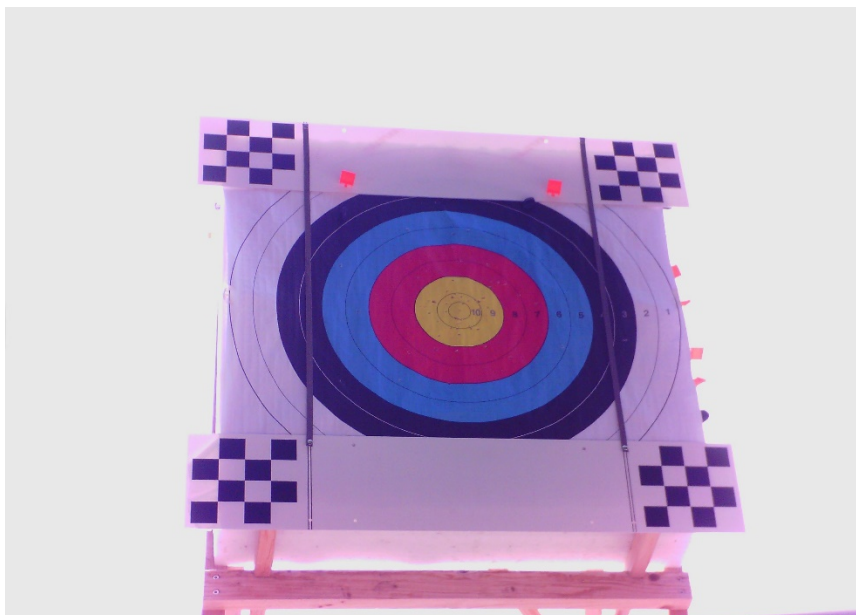
Activated backlight compensation

In such situations, let the backlight compensation be switched on all the time during usage of the RyngDyng© system.

The second potential problem with light conditions is a sharp shadow edge on the chessboard. In the image below you can see edges of shadows crossing the chessboard corners and therefore disturbing the chessboard recognition algorithm:
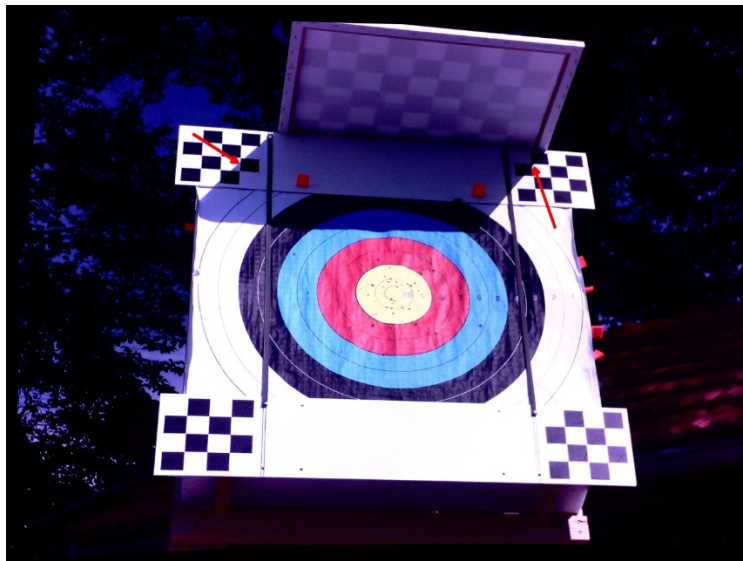
Shadow edges on the chessboard corners

Shadows will in not cause problems in general. In the following image, one of the chessboards is in the shadow while the others are in the sun. With this image, chessboard calibration did work without any problem:

Shadow on chessboards without causing problems

In case there are shadow edges on the chessboards, just provide more shadow in order to remove the edges and chessboard calibration will work as expected.

In case there are still problems with the recognition of the chessboards in difficult light situations such as mixed sun / shadow situations or light reflections on the chessboards, there is another option that may help: HDR = High Dynamic Range.

HDR images for calibration	🔵
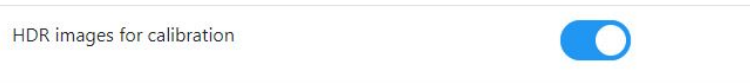
Activated HDR switch

If switched on, two images will be taken at different brightness levels. These two images will then be overlaid using a special algorithm. As a result, dark areas with shadow will be lightened up and very bright areas with light reflections will be darkened (see e.g. the image above that was taken with HDR on; the chessboard in the shadow does not appear too dark).

If you find that with HDR a difficult light situation could be solved, keep HDR switched on during the following usage of the system. Note that calibration and starting arrow detection will take a few seconds longer when HDR is activated. Therefore, if HDR is not needed, do not turn it on.
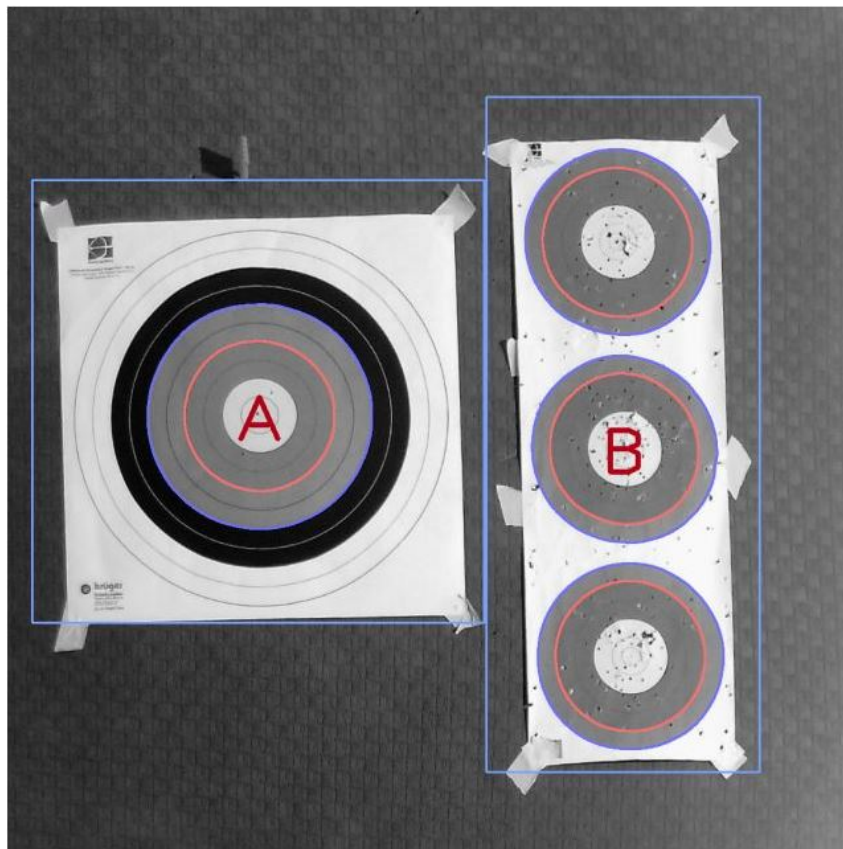
7. Target face recognition

After the chessboard calibration, remove the chessboards and put the target faces onto the target. Make sure they are tightly pinned down, especially in windy environments. The more even the target face is and the closer it is pinned to the target surface, the higher will be the accuracy of the position measurement.

RyngDyng© will automatically recognize standard target faces and their layouts according to WA 600, WA 720, WA 1440 as well as Las Vegas spots[2].

In the RyngDyng© App, go to `calibrations -> target faces` and press `recognize target faces`. After a few seconds the result is being displayed as a gray image with some color marks:

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[2] Those with yellow-red-blue rings in standard colors

Recognized target faces with tournament letters A and B

The outer border of the blue rings of the recognized target faces are redrawn in blue color and the border of the red rings with red color. The target is labeled with the possible letters for the archers in a tournament. Around the paper there is a thin blue line indicating the area that is observed for arrows for that target.

In the RyngDyng© App a summary of all calibration data is available under `calibrations -> status`:

Calibration status for a complete calibration of the system with 2 target faces

In contrast to the chessboard calibrations, data on target faces is not stored permanently. That is, after each reboot of the system, recognizing target faces is a necessary step.

The `shift of target faces` indicate whether target faces and/or target have been displaced from the position that was measured during target face recognition procedure. E.g., if you replace target faces and put them on at 2 cm distance from the previous position, this will result in less yellow stars. If only 1 or 2 yellow stars are left, repeat the target face recognition step.

Using the function `Change letters` you can assign different tournament letters to the target faces. For example, you can assign the same letter A to two 3-spots and the shoot 6 arrows at these two 3-spots. As a result, 6 arrows will be recorded for target A instead of 3 arrows each for targets A and B.

8. Configurations for archers

It is possible to assign archers to individual target faces. This can be done using the RyngDyng© App under `users and configurations -> configurations`:

![RyngDyng logo]

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Configurations menu for archers and their settings

In the category 'target', archers can be assigned to the recognized target faces, as well as the distance to the targets:

Assignment of archers to targets and distance configuration

For details, please see the App manual, https://www.archery-analytics.com/en/public/ryngdyngapp/.

For the purposes of the present document it is important to note that archers can be assigned to one or more target faces, together with the shooting distance and some other parameters such as the arrow shaft diameter. If no archers are assigned to the target faces, RyngDyng© is fully functional anyway, but there are some important differences to note:

- If no archer is assigned to a target face and an arrow is detected for that face, one hit message is sent out and the name field in that message is `ryngdyng<sn>@archery-analytics.com` where `<sn>` is the serial number of the device. This way, anonymous arrows are assigned to this 'user'.
- If no archer is assigned to a target face, the bow type is unknown. RyngDyng© assumes a recurve bow and calculates the scores accordingly.
- If no archer is assigned to a target face, the measured arrow shaft diameter is used to determine the score (especially in close proximity to a ring border)
- If an archer is assigned to a target face, the configured arrow shaft diameter is used instead of the measured one. The hit messages contain the name of the assigned archer.
- If several archers are assigned to a target face and an arrow has been detected, one hit message is sent out for every archer[3].

If archers have been configured and assigned to target faces, this information is also displayed on the App page to start and stop arrow detection, `Arrow Detection`:

*Arrow detection page showing archers assigned to target faces*

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[3] Archery Analytics is working on solutions that aim at distinguishing individual arrows and assign them to the archer they belong to.

9. Detection of arrows

Starting and stopping arrow detection

If all calibration steps have been successfully completed, it is possible to start arrow detection and the button on page `Arrow Detection` will be labeled `start arrow detection`. Otherwise, hints are being displayed on what is missing.

When pressing this button, RyngDyng© will automatically perform another calibration step to compensate for small movements of the target or of the target face that might have happened during an end. After some seconds, this start-up phase is completed and the arrow detection is active:
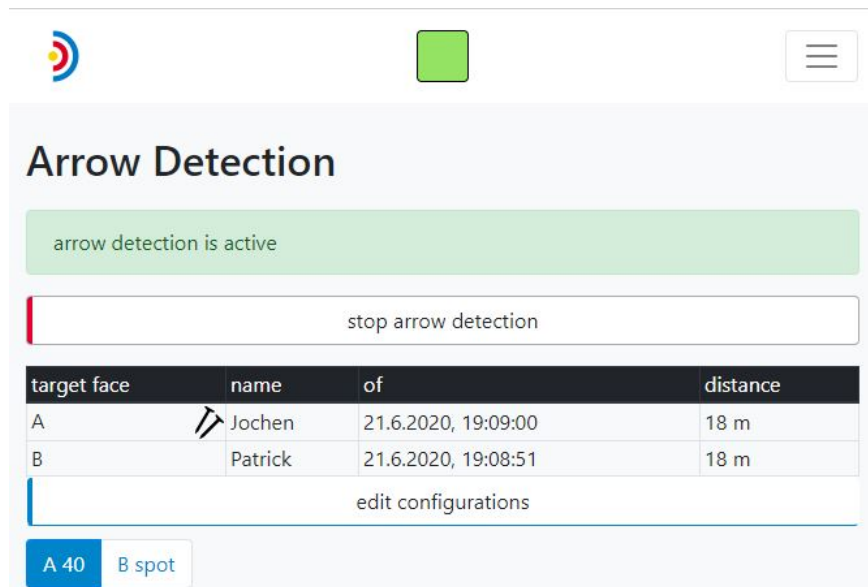
Active arrow detection

In the App, the target faces can be selected in order to have a live view on the detected arrows.

To stop arrow detection, press the button that now is labeled with `stop arrow detection`.
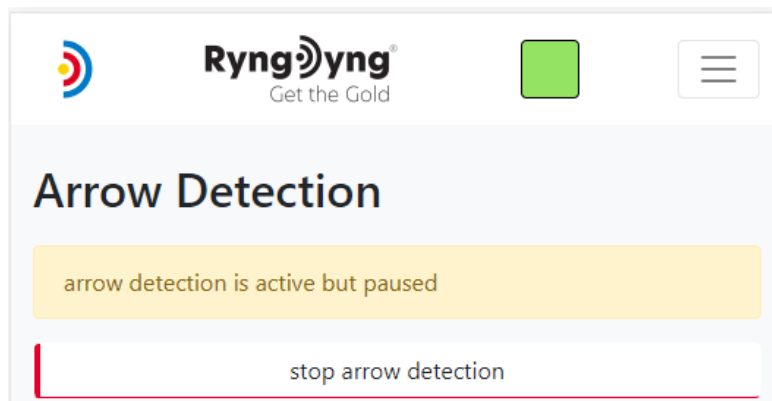
Person recognition

RyngDyng© is able to automatically recognize if persons are moving between cameras and target, e.g., when pulling arrows. This feature can be turned off or on, as required, in the App under `system -> RyngDyng`.[4]

During training sessions, automatic person recognition will enable a fully automatic operation, as no buttons need to be pressed for starting and stopping arrow detection. During tournaments, a central system might better control start and stop mode instead of automatic person recognition.

When person recognition is enabled and persons are detected, RyngDyng© enters the paused mode:

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[4] For RD720, the default setting for person recognition is ‚disabled'

Paused arrow detection because of recognized persons

When all persons have left the space between cameras and target, RyngDyng will automatically start arrow detection again and a new end will be initiated.

If there is wind and the target face has not been fixed well, the movement of the target face could also trigger the person detection algorithm. Therefore, it is recommended to pin down the target faces tightly, and secondly, consider to not use automatic person detection during tournaments in windy environments.

10.   Requirements for optimal results

Any optical system requires appropriate light conditions in order to function correctly. Furthermore, the quality and stability of the object being observed also has an impact on the accuracy of the results.

Light conditions

RyngDyng© automatically adapts to various light conditions, from in-door to bright sun. However, there are some extremal conditions where digital cameras will no longer work as expected. Situations to avoid include:

- **Direct sunlight into the lenses of the cameras**, i.e., when the sun is directly ‚behind' the target and the sun shields of the cameras can no longer avoid direct sun light falling into the lenses. In such situations, also the archers will be 'looking into the sun' and have difficulties seeing the target.
- **Strong light reflections on the target faces.** Those can be recognized as white spots in the test images; note that the RyngDyng© cameras are equipped with polarization filters that filter out most reflections.
- **Too few light** during evening or night hours (images will appear too dark in that case)

If light conditions are within the normal range, calibration and arrow detection will succeed (see below).

Wind

RyngDyng© recognizes arrows on basis of differences in subsequent images. Only the relevant area defined by the recognized target faces will be observed. Moving objects in the background such as trees will be masked out.

If, however, the target face itself is moving because of wind, RyngDyng© will start to search for arrows. In some cases this could result in a 'false positive', that is a detected arrow is reported while there isn't one. Or, the processor of the computer is constantly busy working on arrow recognition, leading to slow recognition times or even missed arrows.

Therefore, in windy environments, it is essential to use enough pins to tightly pin down the target face. You could e.g. use black pins to further tighten the target face within the black ring. If the target face is larger than the target, wrap the paper edges around the target and pin them down:

122 cm target face on a straw target with wrapped around edges

Moving shadows

If the target is half in the sun and half in the shadow, there are mechanisms provided to cope with this difficult light condition (see section on calibration below). However, if the shadows are fast moving such as those from tree leaves in the wind, RyngDyng is triggered to search for arrows all the time. This could lead to a heavy load of the processor so that real arrows may be missed.

Therefore, make sure that there are no fast moving shadows on the target. Slow movements of shadows such when the sun is turning over time, will not cause problems.

Quality of target faces

RyngDyng© can reliably work with used target faces, but there are some limitations.

Tattered target faces will diminish the accuracy of position measurement. You should consider replacing used faces if the lines separating the rings have too many holes or parts of the paper are missing. Of course, single holes from arrows will not cause problems.

Also, too uneven or creased target faces can lead to inaccuracies in position measurement, like shown in the following image:

Creased target face in the sidelight

Depending on your requirements on the accuracy of the position measurement, you can go with rather used faces, or, just use fresh and even faces.

Rain

Short showers of rain will not cause harm to RyngDyng©, but the housing is not full waterproof. So, if you want to use it during extensive rain, there is a need for further rain protection. For example, you could place a second and waterproofed housing over RyngDyng©. Make sure that the cameras still have a clear view onto the target.

In very heavy rain, it might be possible that the view of the cameras is affected and big rain drops trigger the arrow detection algorithm. However, when big rain drops are disturbing the view on a distance of 3 m, archers at a distance of 50 m or 70 m most likely will no longer be able to see the target at all.