A new method for getting the three-dimensional curve of the groove of a spectacle frame by optical measuring

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A new method for getting the three-dimensional curve of the groove of a spectacle frame by optical measuring

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Abstract. Precise measuring of spectacle frames is an important field of quality assurance for opticians and their customers. Different supplier and a number of measuring methods are available but all of them are tactile ones. In this paper the possible employment of optical coordinate measuring machines is discussed for detecting the groove of a spectacle frame. The ambient conditions like deviation and measuring time are even multifaceted like quantity of quality characteristics and measuring objects itself and have to be tested. But the main challenge for an optical coordinate measuring machine is the blocked optical path, because the device under test is located behind an undercut. In this case it is necessary to deflect the beam of the machine for example with a rotating plane mirror. In the next step the difficulties of machine vision connecting to the spectacle frame are explained. Finally first results are given.

1. Disadvantages of the tactile measurement of spectacle frames
After the costumer has chosen his spectacle frame and his defective vision is checked out it is necessary for the optician to measure the groove of the spectacle frame with a so called tracer. In the next step the optician could grind the eyeglasses for the costumer. The measurement of the spectacle frame is needed, because of the huge range of the different designs and their manufacturing inaccuracies. There are almost no regulations to the design and especially to the groove. Furthermore spectacle frames are very elastics but also easily to warp.

Each tactile measurement depends on a contact force and this force is able to warp the spectacle frame. The contact force can also shift the spectacle frame in its holder. By the movement through the groove of the spectacle frame there will always be stick-slip-effects between the stylus and the different possible materials of the spectacle frame. All this leads to incorrect measurements of the three dimensional curve. The last disadvantage due the contact force is represented in the abrasion of the stylus. So there is a call for a stylus change after several measuring times. This will coast time and money for the optician, when the machine is standing still and the part has to be replaced.

But there is also a general problem by tracing spectacle frames and not just due to the tactile measuring method. The stylus is held in the groove of the spectacle frame only through the contact force in the direction of the ground of the groove. Therefore the stylus is able to follow the groove over a wide range and it is possible to get a three dimensional curve.

Nowadays it is commend to have corrective eyeglasses even in sport spectacle frames. They are strongly curved to protect the patient against wind for example. It will happen if these sport spectacle
frames are measured with a normal tactile tracer that the stylus will fall out of the groove. So there is no direct way to measure these sport spectacle frames.

1.1 The problem of measuring behind an undercut with tactile coordinate measuring machines

In a first step it was also discussed if tactile coordinate measuring machines are more appropriate to measure a spectacle frame than the specialised tracers of the optician. But even for these machines it represents a large problem to measure surely undercuts, which is represented by the ground of the groove. “First of all a lot of measuring room is need for reaching the area of interest. For this a star stylus, angulate stylus or even a huge stylus radius has to be used to reach points of interest of the device under test. This can be quite impossible, when the inner diameter of the cylinder does not provide enough space for geometrical volume of the stylus.

![Figure 1. A principal design to measure behind an undercut by using tactical coordinate measuring machines [1].](image)

Even if adequate space is present a correct measurement is assured. In case, when the stylus does not get touch to the searched measuring point because of the structure of the object under test” [1], see Figure 1. There is always an offset between the ground of the groove and the detected point, depending on the radius \( r \) of the stylus and the angle \( \alpha \) of the groove. E.g., a fine stylus with a radius of 1,5 mm and a typical groove angle of 90°; the radial error of measurement is almost \( b = 621 \mu m \) (1).

\[
b = r \left( \frac{1}{\sin \frac{\alpha}{2}} - 1 \right)
\]  

(1)

Of cause this is a systematic error. So the error can be calculated and charged to correct the result. But there are a lot of influences on the offset because of different tolerances like: the groove angle is not constant over all or even unknown, the centre of the stylus and the ground of groove will not be on the same level and there are manufacturing inaccuracies.
For this reason it is expedient to use optical measuring machines for detecting deviations behind an undercut. They are able to measure in very small inner diameter of a cylinder with an appropriate beam deflexion element, see also Figure 2. Furthermore in case of groove measurement light is reflected sufficiently at the ground of the groove back to the camera and the reflections at the shoulder of the groove cannot be detected. Therefore only points at the ground will be found [1].

2. Parameters for optical measuring the groove of a spectacle frame
A common optical measuring machine has got an uncertainty of measurement around 4 \( \mu \text{m} \) and a confocal incident light [2] and the results of the measurement should also reach this region. Therefore an optimal image is essential for getting the three-dimensional curve of the groove of a spectacle frame by optical measuring. As shown in [3] a high magnification with several small areas of interest, so called AOI, should be used. The middle size of the AOI is depending on the magnification but should be around 40 \( \mu \text{m} \times 40 \mu \text{m} \). Beside this the scattering focus is more appropriate to this measuring task than the normally used contrast criterion.

![Figure 2. A principal design to measure the groove of a spectacle frame by optical measuring [4].](image)

If the confocal light is not powerful enough to illuminate the measurement scene sufficient, a ring light has to support the task. This is especially the case of measuring the grooves of the spectacle frames, because of their often elliptic form there are fields of interest which are far away from the deflexion element. The best results will be reached if the ring light has got separately controllable segments. Then the object under test should be illuminated indirectly from the opposite side of the viewing direction to get enough light to the area of interest and stable measuring points [1].

In [1] there is explained how to measure a groove, which ground is in one layer. But the groove of a spectacle frame is a three dimensional curve with an extension along the z-axis so called frame curve, see also Figure 2. It is necessary to see the whole spectacle frame to get the correct frame curve. On one hand a huge mirror could be used which is as high as the extension along the z-axis. Sport spectacle frames have got a frame curve about 30 mm. So a 45° mirror with a diameter at least 30 mm
has to be taken. But with this mirror it is not possible to measure small reading glasses like metal-rimmed glasses. The mirror has to be changed depending on the spectacle frame.

On the other hand the rotary mirror should have a rotary and a linear stepper along the z-axis. With the separate linear stepper a small mirror could be used and the system is able to follow the frame curve over a large distance.

3. Machine vision for optical measuring the groove of a spectacle frame

As already mentioned the field of view of the plane mirror is small, because it has to be placed in totally different designed spectacle frames. Therefore it is required to rotate the mirror step by step for a 360° dimensional curve depending on the size of the mirror.

The AOI will be placed at the groove if it is in the field of view within such a step. The z-measuring takes place in the form of an autofocus after the marking of the groove. Therefore the camera is moved along the z-axis and the processes of the focus values of the individual AIOs are determined in the image at the same time, see Figure 3. The maxima of these processes are computed by interpolation with the software and the coordinates (x, y, z) are expensed for each AOI. Over the angle of the current mirror positions and by coordinate transformation the run of the groove can be calculated.

![Figure 3. Image of the ground of the groove with AOs.](image)

This would be procedure, if the groove is always in the middle of the field of view and the direction of the groove is known at the beginning of the measurement. The direction of the groove is addicted to the rotary step, but not exactly defined. Because of the different designs of the spectacle frames it is not possible to have the ground of the groove exact in the middle of the field of view. These facts are just accounts for an intermediate step to fully automatically measurement, the contour tracing.

The ground of the groove is a fine line as mentioned in [3] which can be detected well between the shoulders of the groove. As per description the location of the fine line is unknown and also because of its size difficult to find. Therefore it is easier to detect the contour on both sides of the spectacle frame by contour tracing. The contour tracing is state of the art and not be part of this paper. After that the location and the direction of the groove is known and AOs can be placed on the ground of the groove to find it.

All the measured points by contour tracing in one step build a function by approximation polynomial for each side of the frame. These functions reflected exactly the contour on both sides of the spectacle frame. The crossover function out of the contour functions is the polynomial function for the direction of the AOs for finding the ground of the groove. Depending on the typical form of the spectacle frame it is excluded that the mirror is in the middle of the frame and has got the same distance to the frame. Thus a dynamic autofocus has to be done when the function for the AOs is known.
Also it can be predicted the location and the direction of the spectacle frame out of the contour for the next measuring step. With all these information it is possible to measure three dimensional curve over 360°.

3.1 Obstacle detection on a spectacle frame

![Obstacle on a spectacle frame.](image)

Figure 4. Obstacle on a spectacle frame.

The contour of the frame is not as clear as seen in Figure 3. The spectacle frame has got additions like the closing block, the side, pad and pad arm, see Figure 4.

The contour tracing is a sequential procedure. It detects points along a searching line perpendicularly to the contour. If one point is detected, then the next point is searched with similar characteristics into direct neighbourhood. So it can happen that the contour tracing ends at the frame of the image because of the side or the pad for example. This is shown in Figure 5. The detected points are green pictured.

![Contour tracing in an image with a side (wrong contour detected).](image)

Figure 5. Contour tracing in an image with a side (wrong contour detected).

![Contour tracing in a masked image.](image)

Figure 6. Contour tracing in a masked image.

To avoid this, the image contend is masked and the needless ranges of it are overwritten uniformly in the bit map memory [4]. Now the contour of the spectacle frame could be detected completely over the whole field of view, see Figure 6. For masking the image it is necessary to have the coordinates of the its middle point, the direction of the groove and the needed length and width.
4. Conclusion

It is necessary to trace every groove of a spectacle frame for well grinding results. Nowadays this happens with tactile tracers. But this technique has got several disadvantages displayed in this paper. It is possible to trace the spectacle frames by optical measuring machines, if some boundaries are kept. First of all the beam of the machine has to be deflected, sufficient light must be on the spectacle frame and some parameters [1] should be set up to measure the ground of the groove in one image correct. Reliable and stable results can only be reached, if the groove is measured automatically step by step for every image around the 360° curve. This can be solved with a 45° planar mirror which can move linearly and rotary in the spectacle frame. With the contour tracing on both sides of the spectacle frame and their compensation it is possible to place the areas of interest accurate on the ground of the groove for the dynamic autofocus. With the angle of the current mirror positions, its location and the detected points it is possible to calculate the run of the groove by coordinate transformation for each image. Also the direction of the groove is known by contour tracing and with the last detected point it is now possible to measure automatically step by step for every image around 360° for getting the three dimensional curve of the ground of every spectacle frame.

Further inspections should speed up the measuring task by several filter algorithms for contour tracing and by intelligent activation of the steppers. Then the optical measuring will be an alternative to tactile tracers.

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5. References

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