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A MODERN INSIDE OPTICAL DETECTION AND MEASURING PROCEEDING FOR THE THREE-DIMENSIONAL GROUND OF A GROOVE

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ABSTRACT

For a well grinding result of the eyeglass lens a highly exact measuring of the spectacle frame is necessary. Therefore an accuracy of ± 150 µm for the measuring of the circumference of the lens should be reached. A lot of different supplier for spectacle frames and a number of measuring methods are available on the market but all of them are tactile ones. In this paper there will be an overview on a possible optical measuring method for detecting the groove of a spectacle frame. The main challenge for an optical 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. In this study it is done with a rotating plane mirror. In the next step the difficulties of machine vision connecting to the spectacle frame are explained and some first results are given. But the main focus of this paper is on the image processing for finding stable measuring points on the ground of the groove of the spectacle frame. Therefore the demand is discussed of several steps of contour tracking for following the frame with its obstacle. Also the different filters and their combination for finding the measuring points are explained. Finally a three dimensional curve of the groove of the spectacle frame is spent.

Index Terms – machine vision, contour tracking, inside optical detection, spectacle frame, filter, detection of obstacle

1. THE NEED FOR TRACING

Eyeglasses are today not only a vision aid, they also are fashion articles for the customers. The customer preference for various forms of spectacle frames grows and is served by the different eyeglass manufacturers. This development leads to an increased effort for the production of adapted eyeglass lenses 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 [1]. Each eyeglass lens belongs to and is grinded for its certain spectacle frame.

This is done on one hand via measurement of the spectacle frame and on the other hand with grinding or milling the eyeglass lens blank compatibly the measured data. For this measurement tactile measuring systems are in use excluding at present. The necessary measuring data are logged by touching the internal contour of the spectacle frame. With the measured data a spatial model can be calculated as the base of the controlling of the grinding machine.

2. BOUNDARY FOR THE TACTILE MEASUREMENT OF SPECTACLE FRAMES

The detected points can be seen as the ground of a groove. The stylus of a so called tracer is unexpended in the groove through the contact force. This tactical measuring method has got several disadvantages, as shown in [4], like stick-slip-effects between the stylus and the different possible materials of the spectacle frame. Also the contact force is able to warp the spectacle frame. Opticians have got huge problems to trace high curved sport spectacle frames. There the stylus often dropped out of the groove. Consequently these frames can not be measured with the standard tactile proceeding.

Another general disadvantage is that the stylus is not able to get touch down to the ground of the groove because of its finite extension. There will always be an offset error. This systematic error can be calculated out but all these lead to incorrect measurements of the three dimensional curve.

For this reason it is expedient to use optical measuring machines for detecting the ground of the groove. They are able to measure in very small inner diameter of a spectacle frame with an appropriate beam deflexion element, see also Figure 1. A beam deflexion element is necessary due to the fact that the ground of the groove can not be detected directly. The ground of the groove is an undercut for the optical system. Furthermore the run of the groove has to be calculated by coordinate transformation for each image because of the deflection element. With the angle of its current position, its location and the detected points in the image it is possible.

In case of groove measurement light is reflected sufficiently at the ground of the groove back to the optical system and the reflections at the shoulder of the groove cannot be detected. So only points at the ground will be found [1].

3. POSSIBILITIES FOR THE OPTICAL MEASUREMENT OF SPECTACLE FRAMES

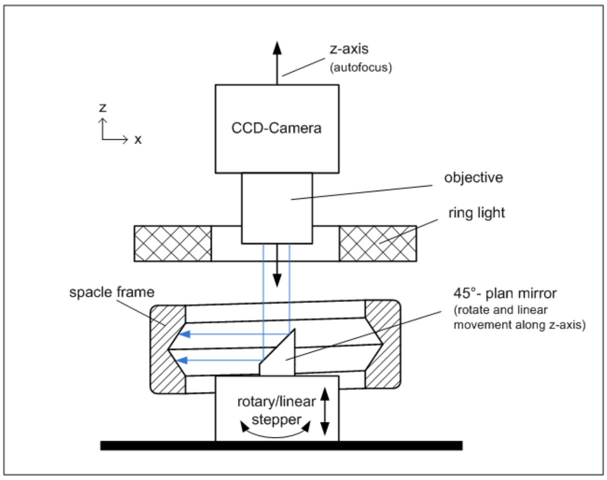

Figure 1 A theoretic design to measure the groove of a spectacle frame by optical measuring [3].

A common optical measuring machine has got an uncertainty of measurement around 4 µm and a confocal incident light [2]. This result should also be reached by the inside optical detection. Therefore an optimal image is essential for getting the three-dimensional curve of the groove of a spectacle frame by optical measuring.

First of all the beam of the machine has to be deflected because of the blocked optical path, 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 [4].

Reliable, stable and quick results can only be reached, if the groove is measured automatically step by step for every image around the 360° curve of the spectacle frame. This is solved with a 45° planar mirror here, which can move linearly along the z-axis and rotary in the spectacle frame for the 360° look-around, see also Figure 1.

These are the conditions to measure each spectacle frame. The main focus of this paper is know, how to detect the ground of the groove automatically.

4. EXPIRATION OF THE MEASUREMENT IN ONE IMAGE

At first the mirror is placed in the middle of the spectacle frame and moved in the start position. The grove of the frame should be expletive in the image and almost in the focus level, see also Figure 2.

The ground of the groove is located in the middle of the spectacle frame under test. But its position and its direction are not known exactly. For getting this information a contour tracing takes place at the beginning on both sides of spectacle frame. The detected points of the contour are filtered and examined afterwards on different characteristics, which describe an obstacle like the closing block. From the filtered points of the contour are determined sections functions by polynomial approximation, which describe a part of the contour of both sides of the frame. These functions are the basis for a master function, which is computed between them. The master function describes the direction of a new Area-Of Interest (AOI) array and should also be congruent to the ground of the groove. Afterwards the ground is detected by the dynamic autofocus ride system and the points are calculated by coordinate transformation. The auto focus system has to be dynamic. It has to detect in every marked AOI (green square in Figure 2) a point. The different designs of the spectacle frame exclude the same distance between mirror and frame in very step.

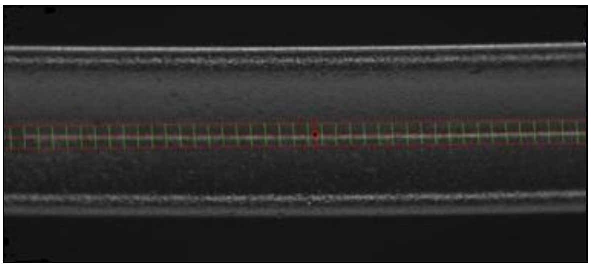
Figure 2 Groove of a spectacle frame.

5. FILTERING THE CORRECT CONTOUR

The contour tracing is state of the art and not be part of this paper. But there are a lot of detected points by it and they have to be filtered. The contour of the frame has got obstacles like the side, the closing block, pad and pad arm, see Figure 2.

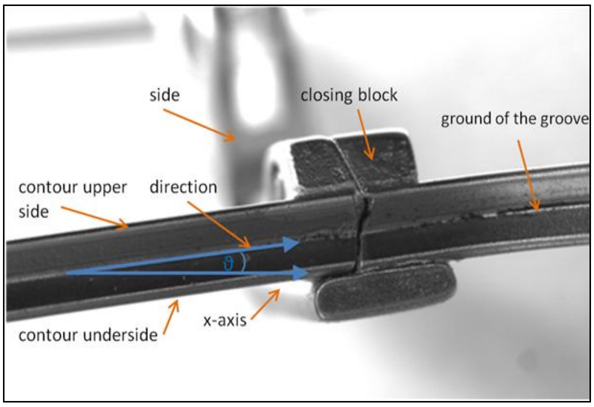

Figure 3 Obstacle on a spectacle frame.

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 4. The detected points are green pictured.

To avoid this, the image contend is masked and the needless ranges of it are overwritten uniformly in the bit map memory [3]. Now the contour of the spectacle frame could be detected completely over the whole field of view, see Figure 5. 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].

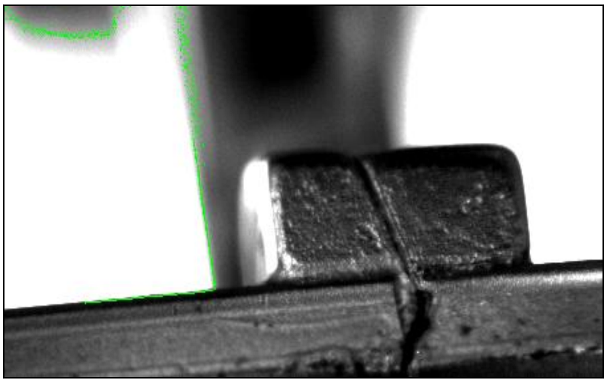

Figure 4 Wrong contour detected in an image with a side.

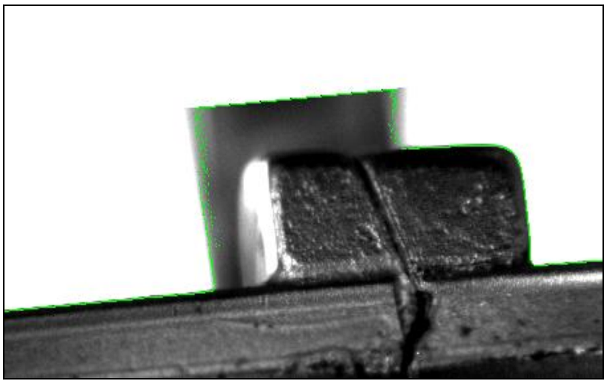

*Figure 5 C*ontour detected in a masked image.

The data points detected by the contour tracing are first vectored in order to separate afterwards relevant from redundant information. Therefore the vector is computed between two sequential data points. The difference of the both position vectors presents the length and the angle of the vector looked for.

After the transformation of the points in vectors different operation can follow to simplify and reduce the data volume. In the first step vectors are removed, which deviate substantially from main direction of the spectacle frame in the current image. Although the x-axis is the basis for the so called direction angle ϑ, see Figure 3. This angle stands in direct connection to the angle of rotation of the mirror. In the case of a rotary step of the mirror, not only the observable part of the spectacle frame is shifted exactly about this angle, also the spectacle frame in the image is shifted around the mirror center. Due to the different designs there must be a range of tolerance to the direction angle. Several experiments showed a range of ±20° [3].

In a next step sequential vectors are summarized, which resemble each other in their direction and fall below a so called border length. The border length is necessary to be introduced because otherwise a contour with a continuous curvature is combined into only one vector. The curvature would be lost. Therefore, as seen in Figure 6, the starting point of the first and the ending point of the second vector build the resultant vector. After that the length and the angle of this vector has to be calculated.

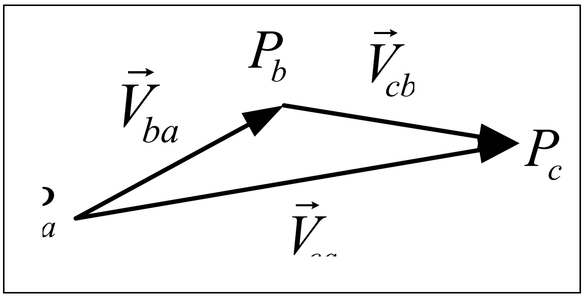

Figure 6 Summarization of vectors.

The data is now sufficient filtered and the gaps in the data, due to the filtering, have to be closed with filling vectors from point to point. The difference between the basic data and the filtered data can be seen in Figure 7 with an obstacle on the contour.

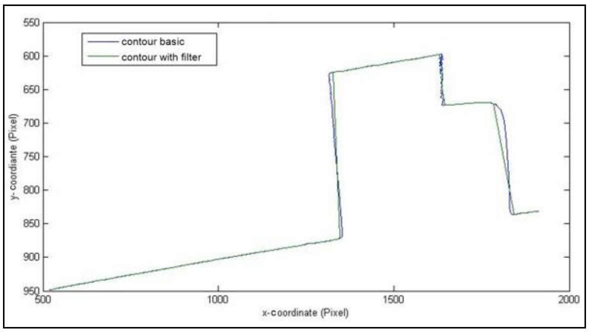

Figure 7 Comparison of basic and filtered contour.

6. DETECTION OF OBSTACLES

Obstacles have to be identified and removed from the data set. In Figure 7 can be seen that the shoulders of an obstacle have got a huge change in the direction angle. It can be recognized by the angles whether the shoulder is increasing or decreasing.

But the vectors for the shoulder are also very long. The reason for this is the main direction filtering. This filter removes a lot of vectors which describe such a shoulder and the gap is closed with one large vector. In this example the obstacle consists of one increasing and two decreasing shoulders, as seen in Figure 8. There are also the length and the angles of the vectors to the main direction visible.

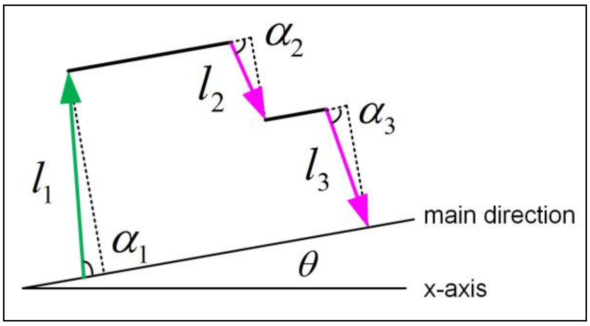

Figure 8 Shoulder-vectors of an obstacle.

Ideally the summation of the opposite leg should be result in zero.

$$l_1 \cdot \sin\alpha_1 + l_2 \cdot \sin\alpha_2 + l_3 \cdot \sin\alpha_3 = 0 \quad (1)$$

Therefore it is easy to form a quotient out of the modulus of the sum of opposite leg and the sum of the modulus of the opposite leg.

$$Quote = \frac{|\sum(l_i \cdot \sin\alpha_i)|}{\sum|l_i \cdot \sin\alpha_i|} \quad (2)$$

Is this quote equal to zero the ideal case happened and the obstacle is past. Is quote almost to one, it is in a position in the first shoulder. The quote is decreasing with every shoulder on the opposite side of the obstacle. A quote which equals exactly to zero will never happen in praxis, so the tolerance should be about 0,1 for an ending obstacle. The result can be seen in Figure 9.

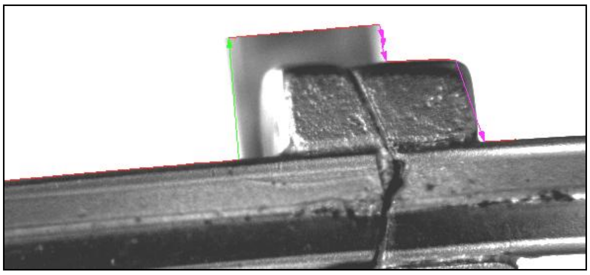

Figure 9 Detected obstacle with marked shoulders.

Now the contour is filtered and thre are no obstacles in the data set. After that the polynomials ($y_i(x)$) for each side of the spactacle frame are computed as explaned above. The master function is formed out of the polynomals:

$$y_{master}(x) = (y_1(x) + y_2(x))/2 \quad (3)$$

This is the trail for the AOIs for detecting the ground of the groove [3]. With this procedings it is possible to measure the ground of a groove of a spactacle frame automaticly. Out of the results of the measuring in one image the direction and the position of the spactacle frame in the next image can be calculated for the 360° look around.

7. CONCLUSION

It is necessary to trace every groove of a spectacle frame for well grinding results. Tactile tracers have got several disadvantages explained in this paper. A new innovational method for optical tracing is given here. Therefore a rotary plane mirror and an auto focus system are used. With the described filters and possibilities for the detection of obstacles a reliable automatically measuring is possible.

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