final report

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Knife Sharpening - Blade Inspection

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1 Introduction

Knives are the main tool for most of the food industry. Knife sharpness affects many aspects of quality and personnel safety. Issues of availability of trained personnel and the cost of training new personnel to understand and perform knife maintenance are increasing.
The thought of automating the process of knife maintenance and at the same time saving labour costs may be able to be achieved by putting together technologies that are now developed.

To this end trials have been conducted to look at different options for:

- Sharpness assessment. i.e. can camera and computers assess sharpness.
- Shape assessment. i.e. can camera profile shape of knife.

The results of the trials are used to determine if cameras and other computerised sensing can detect the condition of the knife blade with the expectation that such information would be used to robotically sharpen the blade an appropriate amount.

1.1 Knife Edge Geometry

As the knife is repeatedly sharpened, the edge thickness becomes thicker. Eventually the blade must be reground to reduce the thickness of the edge. Victorinox (being the brand of the sample knives) specify geometry as shown in Figure 2.

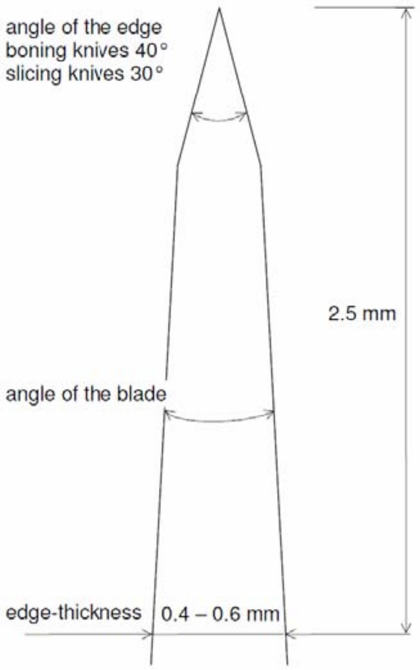

Figure 2. Victorinox Knife Edge Geometry

2 Experimental Setup

For initial experiments, a camera was setup on a stand in the lab, and knife blades were positioned underneath. A similar setup was used for initial tests with the laser profiler.

Further experiments were conducted using a robot to hold the knife and trigger the inspections / record results. For the IVC 3D profiler the robot was programmed to move backwards and forwards whilst inspections were carried out.

For the laser distance sensors a jig was made to mount the sensors and guide the knife into the middle of the sensing range.

3 Sensors

3.1 Vision – Profile

For the overall knife blade profile a large backlight was used behind the blade and the machine vision camera was used to take a single image of the entire blade. The blade edge is very sharply defined allowing accurate measurements to be made. By splitting the image into vertical strips and using edge detect tools, the edge shape can be analysed. Major imperfections may be visible, but most will still be too small to detect in this image. The width of the blade and the shape or curve of the blade can be assessed.

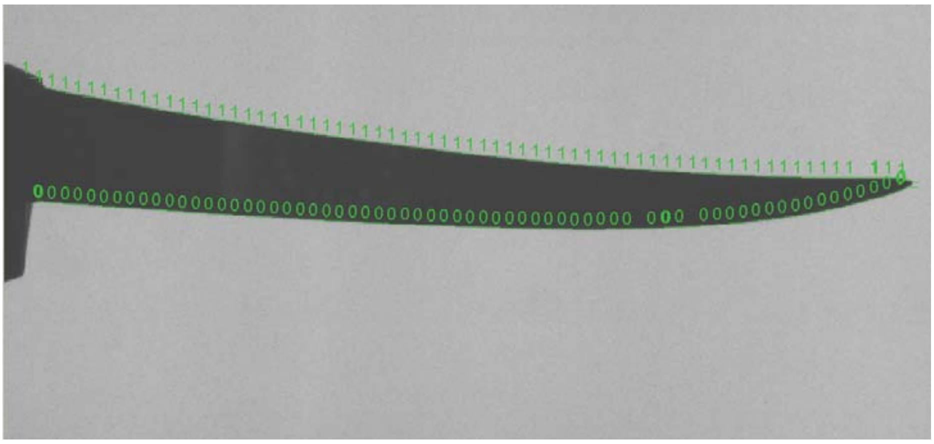

Figure 3. Overall Knife Profile Detection

One of the limitations is that for a correct measurement of blade width and curve, the camera's optical axis must be normal to the blade plane. The camera is calibrated using a grid of dots to allow measurements to be returned in millimetres. Due to non telecentricity, the blade must be positioned in the calibration plane that is at a constant distance from the camera.

3.2 Vision – Edge Close Up

The overall knife profile does not have enough detail to examine the actual condition of the knife edge, so a different lens setup is used with a smaller backlight to look at a few millimetres of blade in each image, a process repeated over the length of the blade.

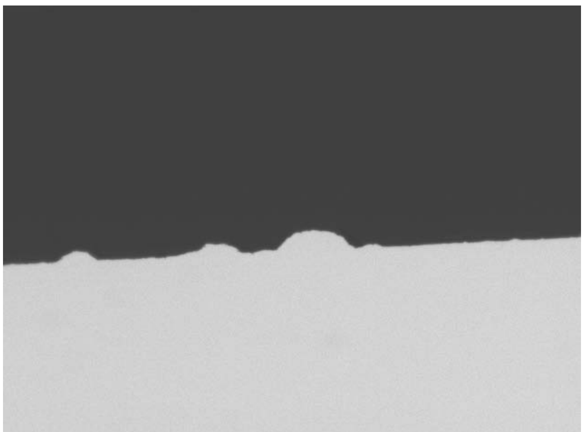

Figure 4. Damaged Edge Profile - Backlit

Due to the curve of the blade and varying angles of the blade edge with respect to the handle, a completely automated system would need to use the vision system to track the blade edge, supplying feedback to the robot in order to keep the edge within the field of view. Alternatively blade profile information from an earlier overall image could be used to direct the robot path. Again, the camera's optical axis must be normal to the blade plane. Calibration is also required to quantify the depth of notches and chips, this would require a specially manufactured calibration reference due to the small scale involved. As the camera is imaging an extreme close up, the depth of field is low and the blade must be accurately positioned to be in sharp focus, and secondly to be in the calibration plane if a non telecentric lens is used.

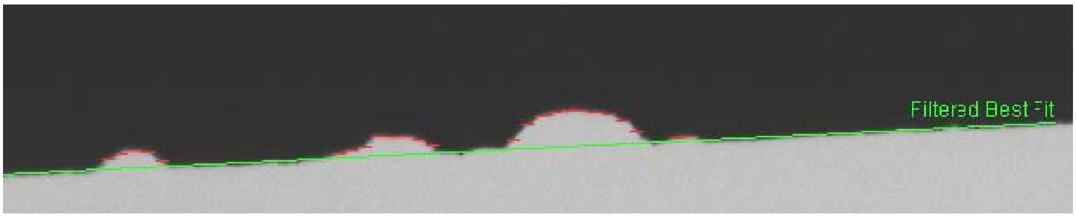

Figure 5. Damaged Edge Profile with analysis

It should be noted that this method cannot determine if the blade is actually sharp – a smooth blunt edge for example the spine of a knife will look the same as a smooth sharp edge that is free of chips and notches.

3.3 Vision – Edge Facing

Part of experimentation with lighting involved the use of a backlight and front spotlight to highlight the cutting edge or secondary bevels.

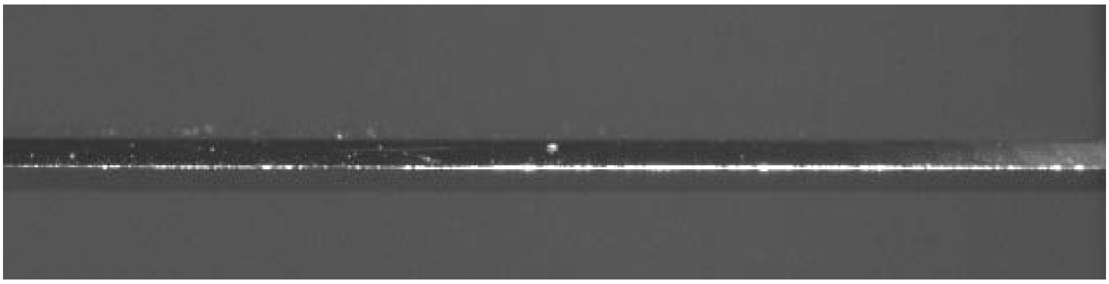

Figure 6

Highlighting the edge of the blade produces a bright line that is subject to specular reflection variations, unless saturated as in the centre of the image.
This could perhaps be used to gain an indication of the width of the secondary bevel of the blade. Further investigation would be necessary to determine the effectiveness and reliability of this form of inspection.

3.4 Vision – Secondary Bevel Highlight

Keeping the blade plane normal to the optical axis, and using the backlight and a direct line light facing the edge, it is possible to highlight the secondary bevel i.e. the main cutting edge. This may be useful to measure the width of the edge.

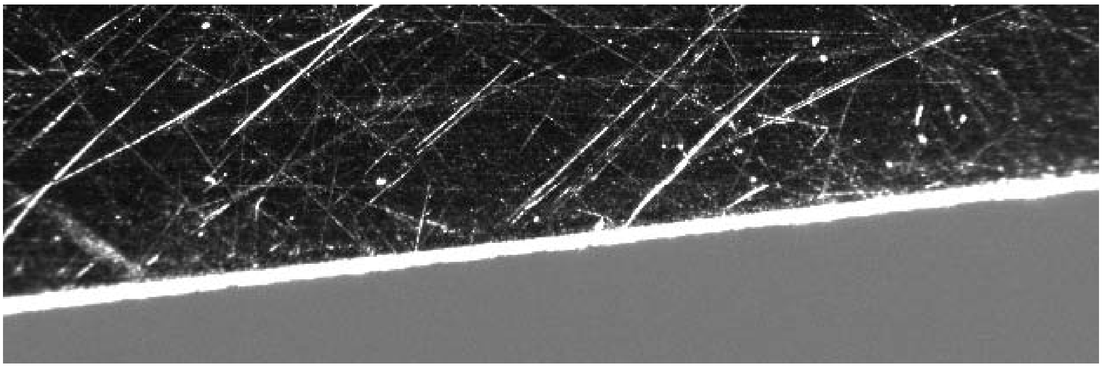

Figure 7. Combined Backlight and front spotlight – Bevel Facing

This setup was very sensitive to changes in angle and position, also the grind and geometry of the blade can greatly effect the clarity of the result. Further investigation would be necessary to determine the effectiveness and reliability of this form of inspection.

3.5 Laser Distance – Thickness

Two opposing laser distance sensors can be used to measure the thickness of the blade. This could be used to build up a profile of the edge. Depending on the accuracy of sensors used and the stability of the measurement rig, the shape of the blade edge could be assessed either transversely or longitudinally. For this trial, two Sick OD Max OD85-20T1 sensors were used. Any further work should be carried out with the OD30-05T1 sensor heads, which have a smaller range and smaller light spot, with increased accuracy. Care should be taken to align the light spot (which is rectangular) to allow the best accuracy. The alignment of the sensors compared to the bevel angle of the knife should also be chosen to maximise the accuracy by scattering reflected laser light away from the blade rather than back onto itself.

Figure 8. Laser Distance Thickness Profiling

This method may also be used to identify the orientation of a blade after being picked up by a robot, prior to use of all the other sensing methods considered. The robot could then adjust for deviations in the angle and orientation of the knife blade.

3.6 Laser Profile – Bevel Facing

The Sick IVP IVC-3D sensor was used to build up a 3D profile of the bevel of the blade, by using the robot to move the blade at a constant speed longitudinally within the field of view.

Figure 9. Sick IVP IVC 3D sensor inspecting a blade moved by a robot.

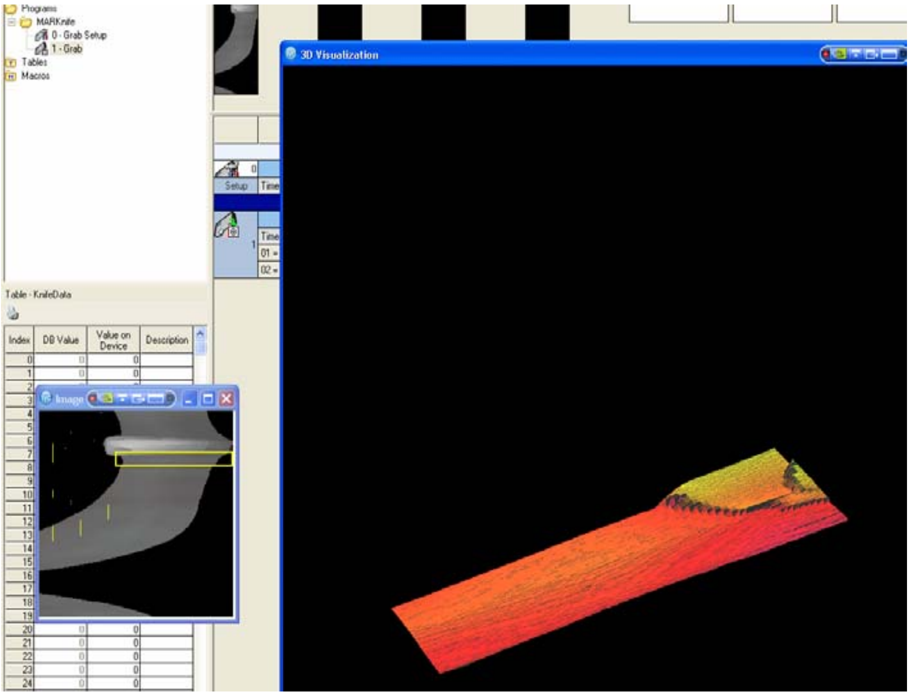

Figure 10. Butcher Knife Edge 3D Profile

In the scan above, the greyscale overview is shown on the bottom left, and part of the handle is visible as the yellow raised area at the top right of the 3D visualization. The oscillating motion of the robot caused the mirror image effect in the overview. The bevel of the blade is visible but not sharply defined.

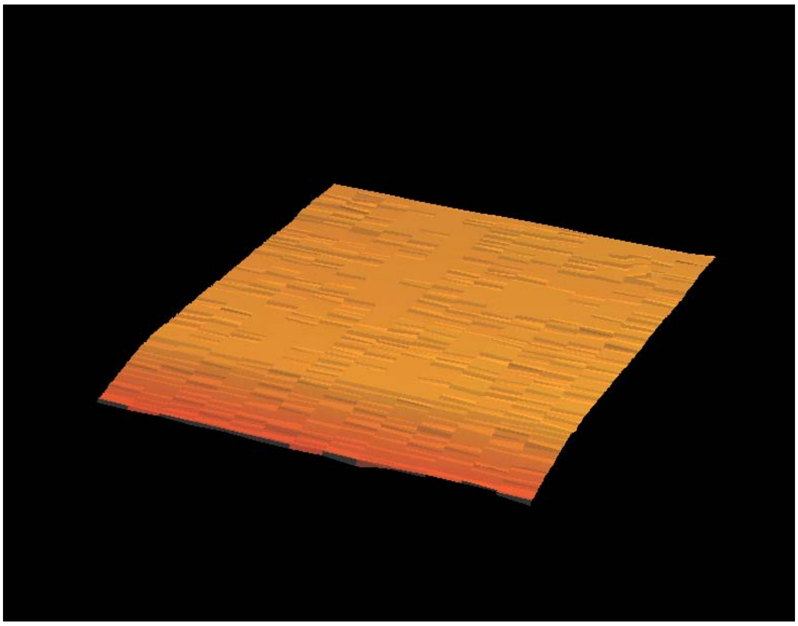

Figure 11

As shown above, the finely ground bevel on the new fish knife was clearly visible in the profile. However detail does diminish along the edge itself, and may not be sufficient for analysis of grinding requirements. One idea which was not investigated is to scan one side, flip the knife over and scan the other side – perhaps with a suitable reference surface also in the field of view. The two scans could then be combined to provide a 3D model of the blade. Again, the level of detail at the blade edge may not be sufficient to detect any chips but it may give the thickness of the edge. The secondary bevel is not visible, and the resolution would need to be at least an order of magnitude lower in order to detect this detail.

3.7 Laser Profile – Edge Facing

In this method, the edge faces the laser, and again the robot moves the blade longitudinally within the field of view. The curve of the blade must also be accounted for. Unfortunately, the results from this method were unusable, due to the difficulty of imaging such a fine edge. The results were masked by noise from light reflected off the bevel surface, and the resolution required needs to be at least an order of magnitude lower.

4 CONCLUSIONS AND RECOMMENDATIONS

Various methods of sensing the condition and profile of a knife edge have been investigated and the results discussed above. It is straightforward to measure the overall profile of a knife using a backlight and machine vision camera. It is also possible to examine the condition of the knife edge in detail using a camera and appropriate lenses to look at a few millimetres of the blade in each image.

The above machine vision methods do not provide a means of measuring the sharpness of the blade, only the profile and smoothness of the edge. By highlighting the edge of the blade, it may be possible – with further investigation – to assess the sharpness to some degree using machine vision.

The use of opposing laser distance sensors to measure the thickness profile of the blade may be of assistance in determining the need for a re-grind, and identifying the primary grind angle and type. These sensors may also assist in detecting and accounting for minor variations in the knife position in the robot gripper alleviating the need for highly accurate fixturing.
The use of a 3D profiling sensor was investigated and showed reasonable results in the bevel facing scenario, for which further investigation may be required to assess the viability of building a thickness profile or full 3D model. However no information on the secondary bevel is gained with the current range of IVC 3D devices. Attempting to scan the blade with the edge facing the device did not yield any usable data.

From these results a completely automated robotic knife sharpening cell is possible assuming that blade edges sustain some visible damage prior to inspection. As stated above a smooth but dull edge is very similar in appearance to a smooth sharp edge; however a minimum routine sharpening may be all that is required in such cases to restore the edge in the absence of any visible damage.

In conclusion it is recommended that a better understanding of the measurement requirements of an automated robotic knife sharpening cell must be obtained in order to further evaluate the results of this investigation. The difference between knives in good condition and those requiring sharpening with a steel, a stone or grinding must be further investigated to evaluate the effectiveness and sufficiency of the sensing technologies that have been tested. Input from processors is required for each of these areas.