# Analysis of Colour Distributions of Anodised Titanium Clips and the Heart Surface for Tracking

Martin Gröger, Klaus Arbter and Gerd Hirzinger

Institute of Robotics and Mechatronics,
German Aerospace Center (DLR), 82234 Oberpfaffenhofen,
Internet: www.robotic.dlr.de
Email: martin.groeger@dlr.de

**Abstract.** Intraoperative organ motion, induced by heart beat and respiration, poses special demands to robot-assisted surgery. Recognition of this motion is required for motion compensation by robotic systems. Colour markers allow for robust motion estimation by colour tracking schemes. Anodised blue titanium clips, which can be attached to the heart surface, are proposed as colour markers. Analyses show that their colour distribution is separable from the colour distribution of the heart surface, allowing for robust colour tracking.

## 1 Introduction

Intraoperative organ motion, induced by heart beat and respiration poses special requirements to robot-assisted surgery. Motion compensation is a highly desired issue particularly in minimally invasive beating heart surgery [1]. Recognition of this motion is required for motion compensation by robotic systems. The proposed colour tracking approach uses small markers attached to the heart surface. The fulfillment of the basic requirement of separability is shown by colour analyses of the proposed titanium clip viewed from different perspectives and of the heart surface.

Estimating local motion of the beating heart by natural landmarks is attractive since no further materials have to be introduced, but poses special demands to image tracking such as dealing with distorsions of the heart surface [2] and disturbances by specular reflections on the heart surface [3].

Approaches based on artificial landmarks are generally independent of these imaging demands. Conventional markers attached firmly to the heart surface for tracking as in [4, 5], however, occupy a significant area of the operating field and, since glued to the heart surface, may harm the patient when removed again.

Instead of conventional markers, the proposed approach uses small titanium clips, which can be clamped to the heart surface easily. Moreover titanium can be coloured by anodic oxidisation in a spectrum not appearing on the heart surface. Meeting this demand allows for colour tracking of these clips – a robust and efficient approach with realtime capabilities, which is based on colour classification to detect the clip in subsequent frames [6].

## 2 Materials and Methods

Titanium clips are commonly available during surgery for clamping blood vessels. Anodic oxidisation of titanium is a process which allows the creation of a differently coloured and consistent superficial layer on titanium, where the colour impression is created by interference [7]. Anodised titanium clips are commercially available in blue, e.g. by Ethicon Endo-Surgery. They fulfill the basic requirements posed to tracking on the heart surface, such as biocompatibility, sterilisability and removability [8]. Figure 1 shows the surface of the heart with three blue titanium clips attached. The colour properties of these clips are analysed in more detail in the following to show how the requirements of clip detection by colour classification are met.

Firstly, the colour spectrum of the anodised titanium clips needs to be separable from the spectrum of the heart surface to allow for correct detection by segmentation in the colour space. Secondly, the colour spectrum of anodised titanium is required to be stable under different angles of sight and distances, since these parameters change for clips attached to the heart surface.

Colour analysis is performed in the HSV (Hue Saturation Value) colour space, using the Colour Classifier Design Tool (CCDT) [9]. The HSV colour space offers to analyse the colour components of *hue* ($H$) and *saturation* ($S$) independently of the achromatic component of *value* ($V$). The colour components ($H$, $S$) enable robust colour detection in presence of changes in illumination intensity. The HS colour plane is discretised by a regular grid of $n \times n$ bins to create colour histograms showing the frequency distributions of the colour components. For the analyses below, $n = 63$ is used. The colour distributions of the recordings are assessed by histogram plots in the hue-saturation colour plane, which show the frequency of particular colours. The colour distribution of the heart surface is analysed in recordings from several different patients. The blue titanium clips are attached to the heart surface and recorded. The colour behaviour of blue titanium clips viewed from different perspectives is investigated in vitro.

## 3 Results

The colour stability of the clip viewed from different angles and distances is investigated in vitro. The clip is attached to a white background plane and recorded by an endoscopic camera (with inbuilt cold light). The viewing direction of the endoscope is placed at angles of 30°, 45°, 60°and 90° towards the clip. Additionally, viewing distances from 1.5 cm to 7.0 cm, as occurring in endoscopic application, are investigated. Figure 2 shows colour distributions for two example configurations, one with a small viewing distance of 2.5 cm, and another rather distant at 7.0 cm. The corresponding colour distribution is very compact in the close view, while it becomes more spread in the distant view but is still sufficiently clustered in the blue area. The examples show that different viewing angles and distances keep the general location of the colour distribution, such that the criterion of separability is maintained.

**Fig. 1.** Heart surface with blue titanium clips.

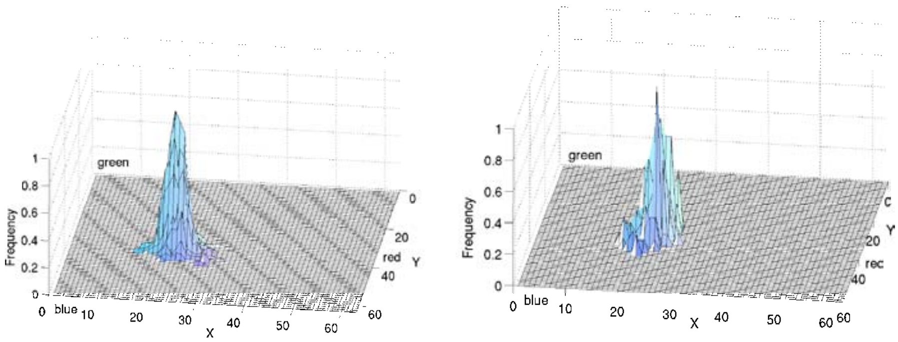


**Fig. 2.** Colour distribution of blue titanium clip at different viewing distances and angles (left: 2.5 cm and 60°; right: 7.0 cm and 30°).

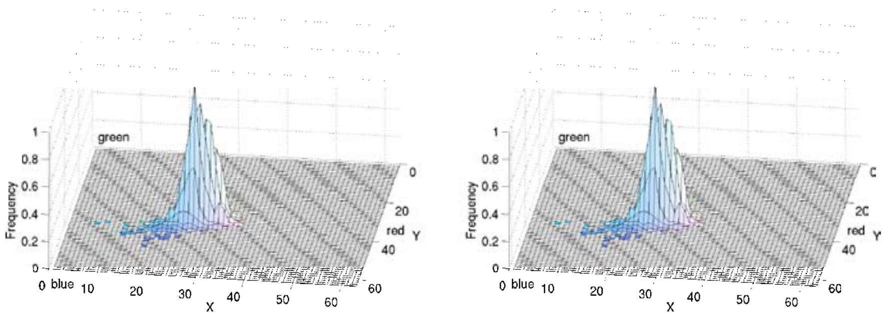


**Fig. 3.** Colour distribution of blue titanium clips (left) on the heart surface and the heart surface itself (right).

As shown in the in vitro experiments, blue titanium clips attached to the heart surface appear as a compact cluster between blue and cyan in the hue-saturation colour plane. The colour distribution of the clips at different times in the image sequence of the beating heart remains rather constant in the cyan-blue area. Figure 3 shows the summary colour distribution of clips in a number of images on the heart surface. The colour distribution of the heart surface is calculated from real data recorded from several different patients. The histogram plot in Fig. 3 shows the resulting frequency distribution in the hue-saturation colour plane. The colour analysis yields a distribution clustered in the red colour range, sometimes extending slightly towards magenta and yellow. The most frequent colour, indicated by the peak of the histogram plot, is clearly located in the red colour spectrum. The local maximum, located around the achromatic point, is due to specular reflections on the heart surface. The colour distributions of blue titanium clips and the heart surface only overlap in the center of the hue-saturation colour plane (see Fig. 3). This area corresponds to low saturated colours, however, and is therefore not considered for colour tracking anyway.

## 4 Conclusion

The requirements for using anodised titanium as a colour marker are fulfilled. The colour distribution of blue titanium clips is well separable from the heart surface and stable under different perspectives. This enables to establish a colour tracking approach to estimate the heart motion using blue titanium clips.

## References

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