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VIRTUAL AND AUGMENTED REALITY FOR QUALITY IMPROVEMENT OF MANUAL WELDS

Petra Tschirner, Axel Gräser

University of Bremen, Institute of Automation
Kufsteiner Str. NW1, 28359 Bremen, Germany

Abstract: The large problem to create manual welds of constant high quality results from missing optical information during the actual welding process. Due to the extreme brightness conditions e.g. in arc welding and the use of protective glasses even experienced welders can hardly recognize details of the welding pool, the welding seam and the environment. This paper describes a new research project for the development of a system for the support of the welder. *Copyright © 2002 IFAC*

Keywords: manufacturing systems, quality control, virtual reality, adaptive image processing.

1. INTRODUCTION

Welding is one of the most important industrial manufacturing methods. The creation of manual welds is often used in production of unique pieces where an automation is impossible or uneconomic, e.g. in shipbuilding with its complicated hull geometry. A common welding method is the inert-gas arc welding e.g. manual gas tungsten arc welding (GTAW) or manual gas metal arc welding (GMAW). In all these processes the electrical arc transfers energy to the welding seam. This arc has an extraordinary high brightness and ultraviolet radiation and for observation a welding helmet with suitable protective glasses is necessary. These glasses absorb the radiation and darken the entire scene, so even experienced welders can hardly recognize details of the welding pool, the welding seam and the environment. Figure 1 shows a view of the welder recorded with a CCD camera through standard protective glasses.

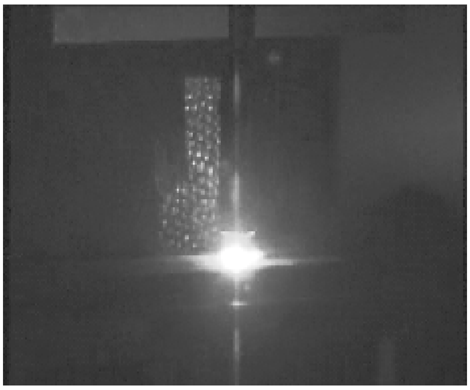


Fig. 1. Simulated view of the welder recorded with a CCD camera and standard protective glasses

A further disadvantage from protective glasses is the restricted field of view of the welder. Furthermore the welder has no additional information, e.g. the actual parameters of the welding power supply. This is particularly of importance if the welding had to be done in far distance from the welding power supply.

During the welding process the requirements at the concentration and reliability of the welder are very high because of the insufficient optical information. Due to these missing optical information the creation of manual welds with constant high quality becomes very difficult.

To increase the manufacturing quality and economic efficiency a support system for the welder is required. This can be achieved by improving the visual information for the welder as well as by supplying additional information with methods of virtual and augmented reality. The described system is based on the approach for the optimisation of PGMAW using visual online observation of the droplet transfer in combination with recording of electrical welding parameters described in (Nordbruch, Tschirner and Gräser, 2000a) and (Nordbruch, Tschirner and Gräser, 2000b).

2. VIRTUAL AND AUGMENTED REALITY

Virtual reality is a new technology, which uses a computer model to generate and present an artificial environment to a person, evoking the impression of actually moving in this environment.

Augmented reality is a new form of human-machine interface, which inserts information via head-mounted displays in the users field of view. The insertion is context dependent, i.e. compatible to and derived from the observed object, e.g. the real field of view of a mechanic is extended by the insertion of instruction sheets. Apart from this the use of wearable computers opens new augmented reality application fields, in which high mobility as well as actual process values, measured or simulated data are required.

3. DESCRIPTION OF THE SYSTEM

The system combines a conventional welding helmet with modern technology. The system consists of:

- a welding helmet combined with
  - two High-Dynamic-Range-CMOS-cameras (HDRC) for observation of the welding scene
  - a head-mounted display for visualization of the welding scene
- a wearable computer for image recording and image processing
- a computer for measuring electrical welding parameters and automatic calculation of characteristic welding process parameters.

The basic set-up of the system is shown in figure 2.

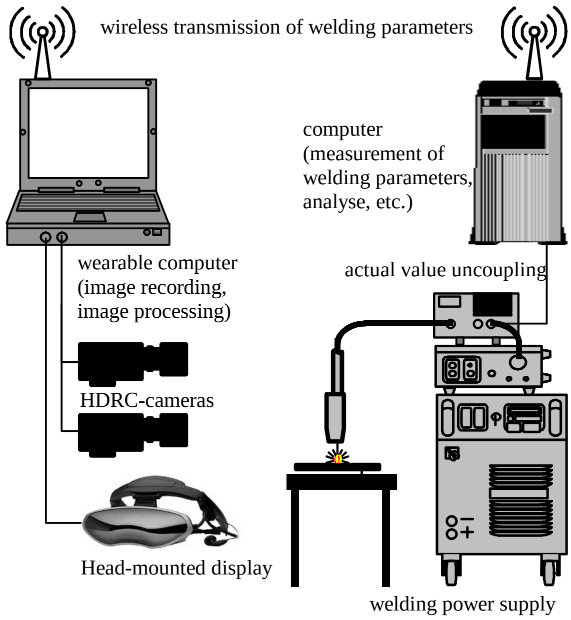


Fig. 2. Principle sketch of the system, depicted without the welding helmet

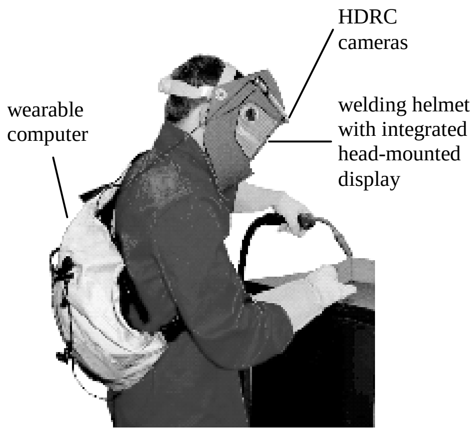


Fig. 3. System

A welding helmet is combined with two HDRC cameras for the observation of the welding scene. A portable computer enhances the image quality and displays the images on the head-mounted display, which is also integrated in the welding protective mask.

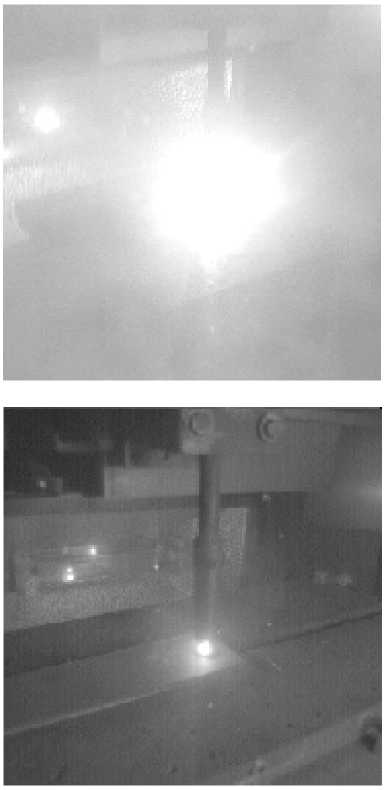
By methods of virtual and augmented reality, additional information can be inserted depending on the application. This information can be derived from the welding power supply (e.g. electrical welding parameters, wire feed), directly extracted from the images (dimensions of the arc) or transferred by another computer (constructional details, like work piece geometry).

3.1 High-Dynamic-Range-CMOS Camera (HDRC)

The principle of HDRC-cameras can be described as follows. The intensity levels in an image are essentially dependent on the irradiance and reflection properties of an object. The information of an image only depends on the contrasts resulting from varying reflections, and fewer on the absolute intensity values caused by irradiancy because the reflection property of a surface is independent of its irradiancy.

A CCD camera maps the absolute intensity values caused by the irradiance of an object. These light intensities can indicate a relation of up to 10^6:1, i.e. in high-energy processes as welding. Due to the technology the dynamic range of a CCD camera is approximately 4000:1, which is not sufficient in order to represent the high light intensities of the welding process.

The image sensor of the HDRC camera consists of CMOS transistors. Before further processing, the input signal is compressed logarithmically in every cell of the image sensor. Due to this compression the HDRC camera maps the contrast caused by different reflections between two side-by-side object points and the information content of the image is not reduced. Thus the dynamic range of a HDRC camera is circa 106:1. This corresponds approximately to the light intensities of the welding process.



a)

b)

Fig. 4. Welding scene recorded with (a) CCD camera (b) HDRC camera

3.2 Signal Processing

The signal-processing unit allows the measurement of specific parameters of the welding supply (e.g. welding current, welding voltage and wire feed) and the automatic calculation of typical characteristic process parameters from of the measured current and voltage signals, see (Nordbruch, Tschirner and Gräser, 2000a) and (Nordbruch, Tschirner and Gräser, 2000b).

3.3 Image Processing

The image processing unit allows the recording and further processing of the images. Additionally relevant welding parameters, e.g. geometry of the arc, can be automatically extracted from the image data.

Due to the extreme brightness conditions of the welding process and the characteristics of the camera the images are of low contrast. In order to give the welder a detailed view both on his environment and the welding process (e.g. melting of the electrode and the welding pool) a further processing of the images is necessary. The contrast has to be adapted to the different image areas, so that the resulting image contains all image areas with sufficient contrast. Standard image processing techniques cannot cope with the extreme brightness conditions and the characteristics of the camera. Objects in far distance the arc may differ only by few grey levels from the background. In these image areas a contrast enhancement is necessary. Objects near the are clearly visible against the background. In these areas a contrast enhancement can lead to a degradation of the image quality (e.g. by exceeding the range of the grey level images). Therefore the image processing procedure needs to be robust against varying image contents (e.g. brightness). An adaptive procedure has been developed (Tschirner, 1999), that "recognizes" the high-contrast areas which have to be maintained and the low-contrast areas which have to be improved. For contrast enhancement the procedure *Contrast Enhancement Using the Laplacian-of-a-Gaussian Filter* from *Neycenssac* (Neycenssac, 1993). was adapted to the problem. In this procedure the enhanced image $g(x,y)$ is obtained by the convolution of the original image $f(x,y)$ with a LoG filter $LoG(x,y)$, multiplication of the resulting image $g'(x,y)$ by a contrast factor β and subtraction from the original image $f(x,y)$:

$$g(x,y) = f(x,y) - \beta \cdot f(x,y) * \mathrm{LoG}(x,y) \qquad (1)$$

For the implementation of an adaptive contrast enhancement the procedure was modified by adapting the contrast factor β to the image content. To generate a priority function for β a gradient operator is applied to the original image in order to determine the contrast of the image areas. The resulting gradient image $f_{Sob}(x,y)$ is low-pass filtered to create a continuous transition between the areas. Within high-contrast areas, the low-pass-filtered gradient image $f_{Sob,TP}(x,y)$ contains high values, and β must be small in order to maintain the contrast. Within low-contrast areas, the low-pass-filtered gradient image $f_{Sob,TP}(x,y)$ contains low values, and β must be high in order to enhance the contrast. The following relationship for β was experimentally determined:

$$\beta = 200 - 40 \cdot \ln[f_{Sob,TP}(x,y)] \qquad (2)$$

Figure 5 shows the concept of the procedure. An example for a result of image processing with uniform contrast in all image areas is shown in figure 6.

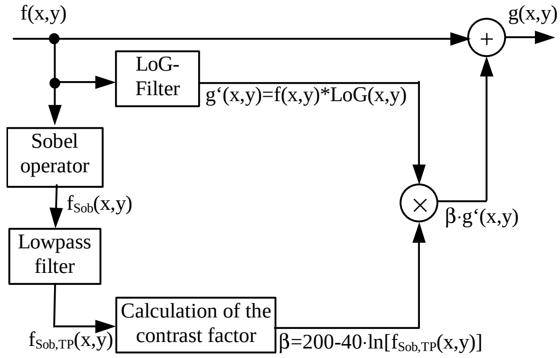


Fig. 5. Flow of the adaptive contrast enhancement procedure

a) b)

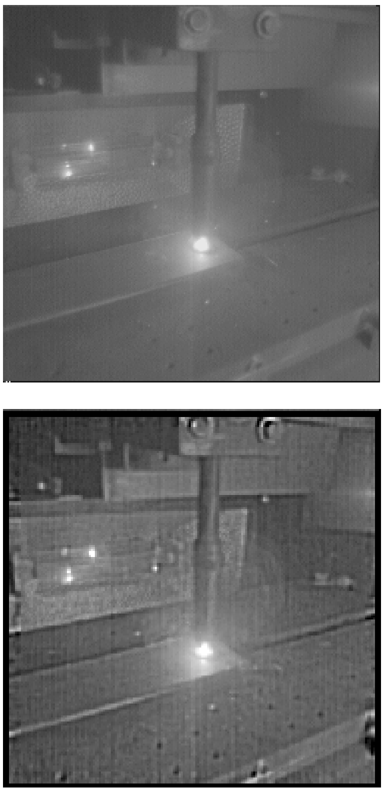


Fig. 6. (a) Original Image; (b) Result of adaptive contrast enhancement

4. POSSIBLE APPLICATIONS

In the following the possible areas of application of the system are presented. They represent the current status of the requirement specification for this research project and were determined in cooperation with experienced welders.

4.1 Welding preparation

The first application possibility is the use during welding preparation. Constructional details can be displayed, e.g. the material type, desired values of the welding power supply or the desired welding seam.

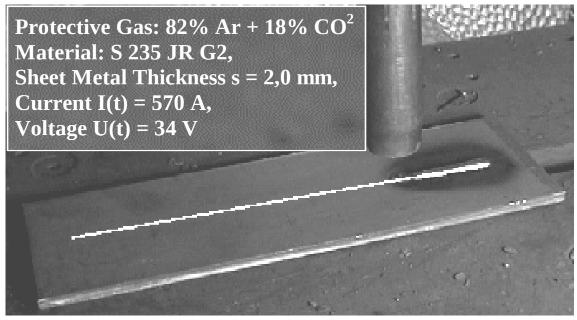


Fig. 7. Possible insertions: welding seam and welding parameters.

4.2 Welding Process

During the welding process an online quality control is possible utilizing the parameters extracted from the image data, e.g. the measurement of the welding seam geometry. This also allows an online adaptation of the welding parameters when welding long seams with changes in the work piece geometry.

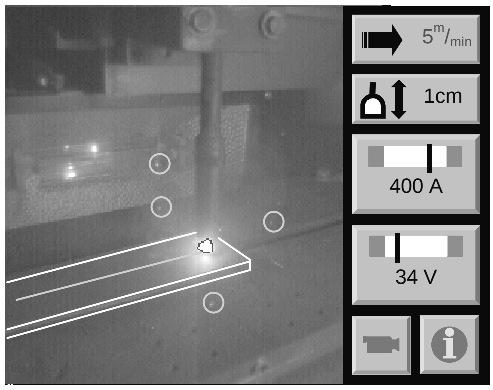


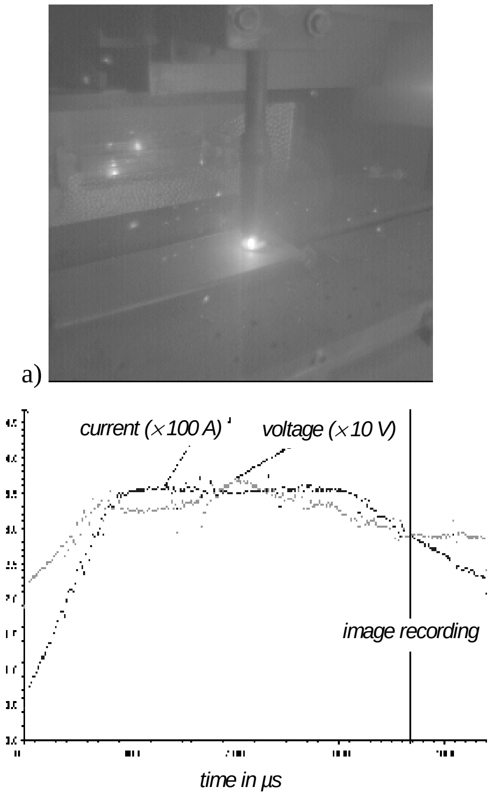
Fig. 8. Possible insertions: work piece geometry, welding seam, splashes, wire feed, height of the arc, welding current and welding voltage

4.3 Quality Control

The system can also be used for quality control. At present this is done via radiometric examination after the welding process, which is very complex and expensive. Additionally this method does not allow any conclusions on occurrences during the welding process.

With the new system during safety-relevant welds the images can be stored together with relevant welding parameters, which can be easily assigned to each individual picture (Nordbruch, Tschirner, Gräser, 2000a), (Nordbruch, Tschirner, Gräser, 2000b). The example (figure 9) shows splashes caused by a to high welding current.

a)



b)

Fig. 9. (a) Image of the welding process;
(b). Synchronized and simultaneously measured electrical welding parameters current and voltage including the time of the image recording

4.4 Education

A further possible application is the use in education of welders. By using of a second head-mounted display, teacher and trainee can observe the same welding process. The influence of changing welding parameters on the weld quality can be directly examined.

5. SUMMARY

The system described in this paper combines a conventional welding helmet with a head-mounted display and two HDRC cameras. The welding scene is observed with the cameras. A portable computer provides further enhancement of the image quality and displays the images in real time in the head-mounted display. The welder has a detailed view on the welding pool, welding seam and his environment. By methods of virtual and augmented reality additional information (e.g. welding parameters or constructional details) can be inserted depending upon the application. The system can be used for getting information about the welding task before the beginning of the welding process, for the observation of the welding process including online quality control, for quality control after the welding process and for education.

6. CONCLUSION

By the visual observation of the welding process in combination with the representation of relevant welding parameters the welder receives a completely new status of information and is able to do his work much more precisely. Thus the simplification of manual welding and an improvement of the welding result are achieved, leading to a better and more constant quality and therefore to a reduction of the inspection expenditure in quality control.

7. ACKNOWLEDGEMENT

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- a manufacturer of welding supplies and devices: EWM HIGHTEC Welding GmbH, Mündersbach, Germany
- a manufacturer of autodarkening welding masks: Optrel AG, Wattwil, Switzerland

8. REFERENCES

Neycenssac, F. (1993). Contrast Enhancement Using the Laplacian-of-a-Gaussian-Filter. In: *Computer Vision, Graphics and Image Processing*, No. 55, pp. 447-463.

Nordbruch, S., Tschirner, P. and Gräser, A. (2000a). *Visual Online Monitoring of PGMAW without a Lightning Unit,* International Sheet Metal Welding Conference IX, 18.-20. October 2000, Detroit, Michigan, USA. Paper Nr. 4-4.

Nordbruch, S., Tschirner, P. and Gräser, A. (2000b). *Visual OnlineOptimization of Pulse Gas Metal Arc Welding with a HDRC-Camera without a Lightning Unit,* UKACC International Conference Control 2000. 4.-7. September 2000, University of Cambridge, UK. Paper Nr. 190

Tschirner, P. (1999). *Visuelle Analyse von HDRC-Kamerabildern des Werkstoffübergangs des MSG-Schweißprozesses,* Diploma Theses, Institute of Automation, University of Bremen, Germany.