6D seam tracking

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Introduction

By means of laser technology many production tasks are solved more intelligently and more precisely than is possible using conventional methods. The SCOUT joint tracking system has been developed for this range of applications, has been on the market since 1990 and fully fulfils the requirement profile.

SCOUT positions robots or portals with a precision of ± 0.05 mm in three dimensions along a joint, while keeping the orientation of the tool with respect to the work piece surface constant with the pre-set value.

The time-consuming teaching process for the definition of the robot path before processing and before every modification to the workpiece becomes unnecessary and is reduced to the definition of a few points on the path. These are at least at the start of the track where the sensor with its search area (typically 20 x 80 mm) has to be positioned and possibly the separation points for several path segments.

Fast image processing (50 Hz) permits tracking speeds of more than 20 m/min and allows the automatisation of the "rapid" processes during gluing and sealing by precisely following the three-dimensional path of the joint.

The SCOUT system can adapt the maximum possible tracking speed to the dynamics of the system, because, for example, small bends in the path would result in high transversal acceleration.

SCOUT: The system and its components

SCOUT is designed for three-dimensional joint tracking, i.e. for high precision and high speeds during laser welding. However, any other type of processing following the sensor is also possible.

The system components of the SCOUT are the sensor head and the sensor computer, an industrial PC designed for rapid and precise 6D-joint tracking during series production.
The system can be networked and are connected to the user interface by means of Ethernet.

The sensor head is connected to the portal or robot so that it is leading ahead of the tool, and it generates video sequences of the joint or edge which can be evaluated by the SCOUT sensor computer using the light section procedure or using the patented light section / grey image combination method.

After mounting the sensor onto the processing head and the calibration, SCOUT will guide the robot in real time without a teach in, only the start of the joint and the search direction must be entered.

The SCOUT system hardware is characterised as:

- Specially designed PC hardware for the requirements of a production line
- Use of Compact Flash memory instead of hard disk
- Available in three basic models for production line, small number production applications and training.
- Sensor functions are monitored by microcontroller, connected via CAN-Bus
- Can be extended for new production tasks by software upgrade
- Reference path and safety tube functionality available
- Interface to the commonly used machine control types available for the two different interface methods: master and correction

Characteristic values

- Data rate 250 points/sec.
  Five points on the joint are captured in a single video image. This high measuring point density ensures a large signal-to-background ratio and the precise recognition of the beginning and the end of the joint.
- The maximum speed is limited by the density of known pointsand tried and tested up to 8 m/min.
- The minimum path radius corresponds to the sensor lead distance (20-60 mm).

All standardised interface types are supported by both systems. For examples it is possible during laser beam welding to control the operating laser via an analogue or digital interface. This allows the laser to be switched off precisely at the end of the joint or for it to be turned to full power at the start of the beam.

The decisive advantage of the SCOUT results from the intelligent integration of the measured data into the robot or portal control. The communication between the sensor computer and the commercially available controls can also to a large degree be adapted to an existing system. This is how a superior complete system is constructed.

The joint tracking for one-dimensional applications by means of a separate linear or swivelling axis has been tried. The side deviation of the joint position is directly transmitted to the amplification servo mechanism constructed as a combination of motor, gears, encoder and tachometer generator as a scaleable ± 10 V control voltage. It is also possible to activate a servo-motor control for the drive of this axis directly from SCOUT via a serial RS-232 or RS-422 interface. Various DC motors and axes with sensors or rotary transmitters are available on the market and can be combined for the specific application.

This simple joint tracking method (e.g. Y or Z) can sensibly be used where no robotic device is available or where the available control is not accessible.

The measuring principle

For the light section procedure measuring principle, a pattern consisting of 5 lines is projected onto the workpiece at an angle and this pattern is observed vertically with a CCD camera. The video image is evaluated in the sensor computer and each point where the five light beams are offset is defined as a point on the joint.

The advantage of the redundant method is that no moving parts are required in the sensor head and that 5 points on the edge are evaluated simultaneously in a single video image.

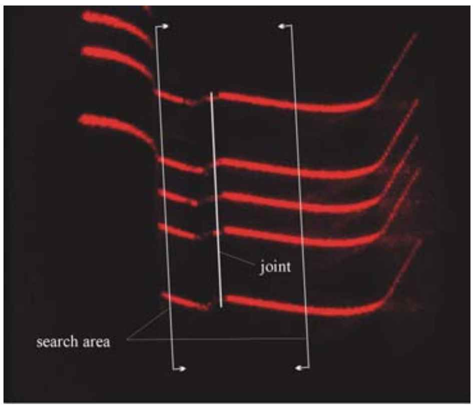


Figure 1 shows a plate profile and sensor image of a complex joint on two overlapping plates (fillet weld) deep inside a channel in a passenger vehicle roof.

Here the search area is marked by two vertical lines, which are ended by two arrows pointing inwards. The joint position is indicated by a line.

Before activation of the SCOUT joint type, tool properties, path description etc are defined. The options for this example of a joint definition are illustrated in figure 1, for example with the term "**search area**". In this way it can be ensured that the opto-electronic sensor tracks the desired joint and the second joint also appears within view. Further selectable joint parameters are e.g. the plate thickness or the gap between the plates. Should, during active guidance by sensor during laser welding, one of the parameters (e.g. the air gap) leave the tolerance field, SCOUT will stop the processing and switch off the laser before the workpiece becomes damaged. This allows the operator of the production plant to correct the cause of the fault and usually to continue the processing.

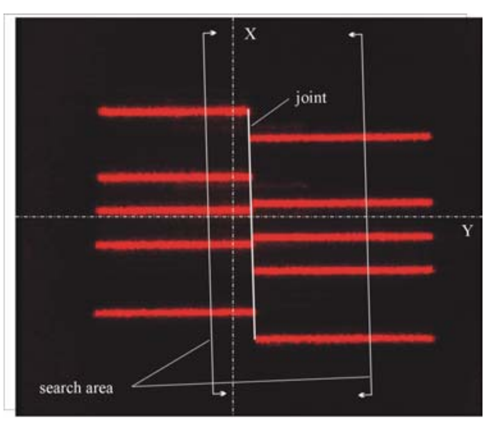
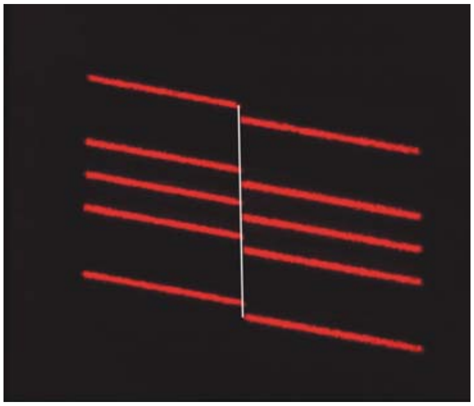


Figure 2 allows us to see the 5 measuring points on the joint directly. The position of the joint is not in the geometric centre of the sensor's field of view. The information about the z-axis (distance) is contained in the position of the line pattern above and below the calibrated target position.



In Figure 3 an angle of approx. 15° is set transversally to the joint direction between the planar workpiece surface and the sensor head.

If the sensor is tilted in the direction of the joint (dragging) the distance between the line is reduced, if the sensor is tilted to the front, the distance between the lines is increased. In this example the length of the lines remains constant.

If the sensor distance above the workpiece is modified, the line pattern is shifted "to the top " (increasing distance) or "to the bottom" and the length of the lines and the relative line spacing also change.

Every 20 ms the position co-ordinates x and y of a maximum of five points on the joint are calculated from the video image, the height Z and the two angles of the plane orientation are also determined by the image evaluation.

This ensures, even with unfavourable measuring conditions, that every 20 ms several (maximum five and minimum three) measuring points define the location of the edge or the start/end of the joint precisely.

Even the complete failure of individual video images does not affect the system precision. With 250 points per second, the redundant procedure produces a very high number of measuring points along the joint. Only with a tracking speed over 40 m/min, do consecutive video images no longer overlap. In addition, the limited exposure/shutter time of the CCD camera in the sensor head reduces the absolute measuring precision of the SCOUT because of the unavoidable image blurring.

The measuring precision of the sensor head at rest with standard optics is up to ± 0.005 mm, the actual tracking precision depends on the control and the quality of the robotic system.
± 0.05 mm is realistic.
The angle of the normal to the plane and the tipping angle are available with a precision of 0.5° .

The offset data dx, dy and dz, with respect to the B coordinate system (TCP coordinates) and the tool orientation are made available in the integration of the "portal control“.

When the SCOUT is provided with the actual position of the TCP, the measuring data can be transferred by forward and backward transformation into the coordinate system of the robotic system and the target position of the TCP, and the tool orientation can be transmitted.

In this case the SCOUT fully controls the movements of the robotic system in space. This is required for making the 6D joint tracking (X, Y, Z with orientation A, B, C) possible.

With a measuring procedure where purely the grey image contrast is evaluated, the joint path of a butt joint or of a scribed line is recognised (X and Y). However, no information about the height of the sensor above the workpiece or the orientation of the plane can be gained.

The combination of both procedures, light section and grey image, is used for the patented butt joint sensor. The overall position in space of the joint (X, Y and Z) and the orientation of the plane are determined by measurement using this procedure. Using this sensor a butt joint or even a line scribed onto the plate can be tracked on a complex 3D surface.

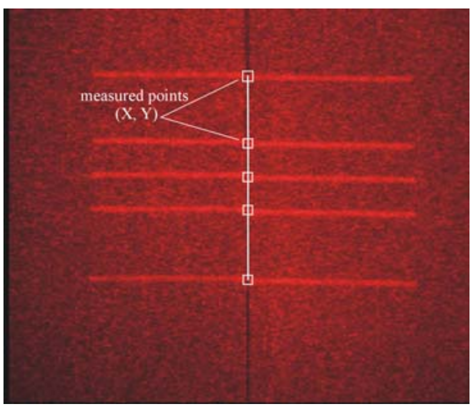
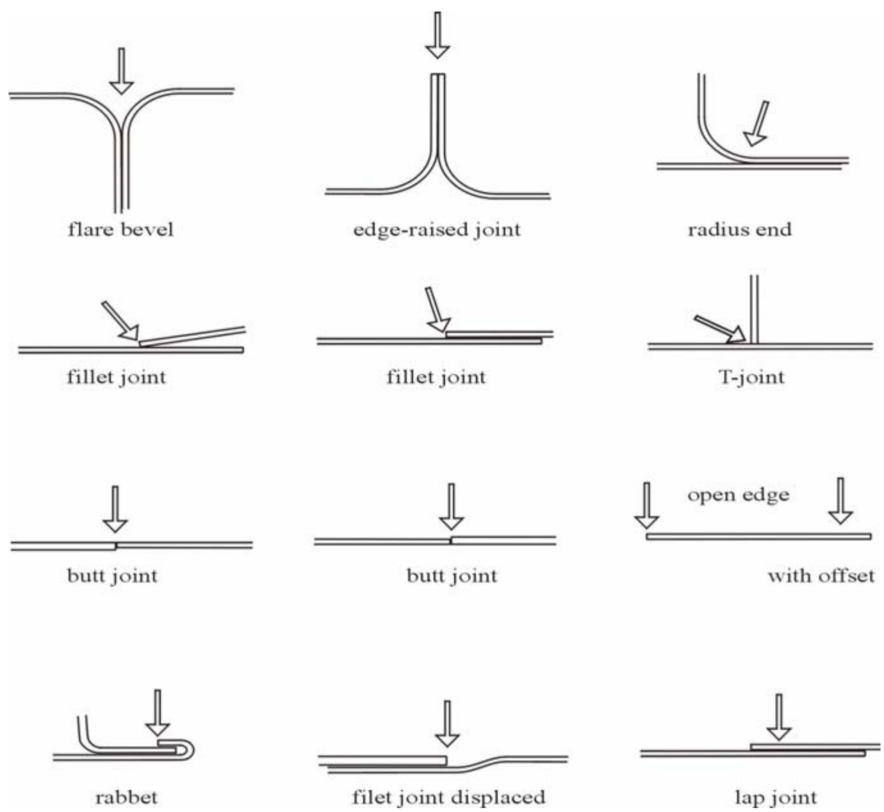


Figure 4 shows the joint recognition for the butt type joint. The tracking of scribed lines or even pencil lines is also possible with these settings.

Available joint types

The system supports all available joint types:

- fillet joint left /right/neutral
- tee-joint left /right
- open edge left /right
- lap joint left/right
- V-joint
- butt joint
- edge-raised joint
- radius end at the fold



Additional functions for flexibly capturing optical measured data

- "MEASURING"

The relevant data about workpiece geometry, trajectory of the joint and distance between sensor and workpiece and the orientation angles A, B and C with respect to the workpiece surface are recorded.

The measured data generated are the geometry data of the surface visible "from the outside", for example the distance of the sensor head from the surface, orientation with respect to the surface, permissible gap dimensions, permissible height offset between the two sides of the joint, radii of the two halves of a raised-edge joint, radius of a pipe, etc. and the provision of the measured data in the "world coordinate system".

During the dynamic measuring procedure by robot, the geometrical data of car shell parts, for example at the clearance between door and frame, are transmitted into a process computer (including e.g. a PC or notebook) and there they are finally compared with the target data (CAD) and statistically evaluated.

- "REFERENCE PATH"

The feature REFERENCE PATH is primary set to stabilize seam tracking during production, even under poor seam detection, e.g. sputter or blinding. Basis is the fixed robot and workpiece position, so that the trajectory is fixed in space and “only” the tolerances are left.

Generation of a REFERENCE PATH take place during normal seam tracking but with reduced velocity. The data are stored automatically under the same label, density of the data are 1/10th of a mm.

Now if during the production process the seam recognition gets lost, data from the REFERENCE PATH are used instead and a possible offset between last measurement and reference data is considered.

For safety reasons seam detection during the first segment is mandatory.

With the new REFERENCE PATH function, seam tracking can be repeated again as often as desired by the robotic system (robot) by using the stored data, without new joint tracking. In this context, all operations offered in the SCOUT path program can make use of the path data.

It is, for example, possible to follow a trajectory which has been recorded using a low speed at a high speed, recorded paths can be repeated backwards, different exit points can be entered for selected path points, the orientation of the workpiece can be chosen without limitation, and the trajectory can be rotated or shifted in space.

Interfaces to machine control systems

It will not be contested that the introduction of a sensor with a high measuring point density at higher tracking speeds will overtax, in same cases by several hundred percent the usual types of sensor in currently available robot controls. This applies both to the physical connection to the relevant control systems and to the speed at which the sensor signals can be introduced into the existing path planning.

The following system integration between SCOUT and machine control has already been realised and tested:

Path Correction Concept (NEW):

- ABB
- Fanuc
- KUKA KR C2
- Motoman

The correction principle is applied to the teached path of a robot movement by using the measuring data of the sensor. The data must be interpreted by the robot controller.

Additionally all geometric data from the seam are available and can be used to optimize the welding process.

3D integration:

- COMAU C3G 900plus with Tricept robot
- KUKA KR C1, VK RC1
- Power Automation PA 8000
- SEF SR1 control with 6-axis SR25/A1 robot
- SIEMENS RCM 3C control with 6-axis KUKA industrial robot (IR361/8, IR161/24),
- SIEMENS RCM 3C control with 6-axis MANUTEC robot,
- SIEMENS 840D
- STÄUBLI Adept CS7 with 6-axis SX series robot,
- VW VRS1 control with 6-axis IR361/8, VK120 and VW 5-axis portal

2D integration (only for special applications):

- IBH Macro 8000 control with 5-axis portal (Arnold, Trumpf)

1D integration (measured value output as control voltage for linear axes)

- ± 10 V to servo amplifier
- 4 – 20 mA to servo amplifier

Special solutions (in preparation)

- Output of correction values for the programmed path for all usual robot control systems possible: Cloos, Motoman, Reis
  and SPS: SIEMENS S5 / S7

List of the SCOUT users	Application
Aerospatiale Avions, St. Nazaire - F	Laser
Airbus GmbH, Nordenham	Laser
Alenia Aeronautica SpA, Turin – I	Laser
Algo Systems S.A., Athen – GR	Laser
Audi AG, Ingolstadt	Laser, MAG
Audi AG, Neckarsulm	Laser
Blohm & Voss, Hamburg	Laser
Burtscher AG, Freidorf - CH	WIG
BMW AG, FIZ München	Laser
CLFA, Arcueil – F	Laser
Daalderop BV, Tiel - NL	WIG
DaimlerChrysler AG, Sindelfingen	Laser, Laser-Hybrid
DaimlerChrysler AG, Untertürkheim	Laser
DaimlerChrysler AG, Mettingen	Laser-Hybrid, MIG
DaimlerChrysler AG, Düsseldorf	Laser
EDAG, Eisenach	Laser
FhG-ILT, Aachen	Laser
FhG-IWS, Dresden,	Laser
FIAT, Neapel - I	Laser
Fuhrmann Fahrzeuge GmbH, Steinebrunn – A	Laser
HOLVRIEKA, Emmen - NL	Laser
ISE, Bergneustadt	Laser
IWB, Garching / München	Laser
KWD Automobiltechnik GmbH, Wolfsburg	Laser
LTKK, Lappeenranta – FIN	Laser
Photon AG, Berlin	Laser
PML, Singen (Alusingen)	Laser-Hybrid
Dr.-Ing.h.c. F. Porsche AG, Weissach	Laser
P.S.A., Paris - F	Laser
Renault, Guyancourt - F	Laser
Serra Soldarura S.A., Barcelona – E	Laser
Solblank S.A., Castellbisbal – E	Laser
TMS Produktionssysteme GmbH & Co., Linz – A	Laser
Volkswagen AG, Werk Anchieta - Brasilien	Laser
Volkswagen AG, Werk Bangkok - Thailand	Laser
Volkswagen AG, Werk Bratislava - Slovakia	Laser
Volkswagen AG, Werk Brüssel - Belgien	Laser
Volkswagen AG, Werk Emden	Laser, MAG
Volkswagen AG, FAW-Volkswagen, Changchun - China	Laser
Volkswagen AG, Werk Hannover	Laser
Volkswagen AG, Werk Kassel	Laser
Volkswagen Sachsen GmbH, Werk Mosel	Laser
Volkswagen AG, Werk Pamplona - Spanien	Laser
Volkswagen AG, Werk Puebla - Mexico	Laser
Volkswagen AG, Shanghai-Volkswagen, Shanghai - China	Laser
Volkswagen AG, Werk Uitenhage - Südafrika	Laser
Volkswagen AG, Werk Wolfsburg	Laser
Volvo Cars, Gent - Belgien	Laser

SCOUT system components

PCI bus standard version

consisting of:

- Sensor head incl. software module (light section procedure)
- Sensor computer (IPC housing, 19“)
- Ethernet, TCP/IP communication interfaces
- User interface on PC (Java application)
- 9“ TV monitor
- Connection cable to the sensor head, 25 m
- Integrated self-testing equipment

Options Prices on request

- Sensor head and software module for butt joints
- Water cooling
- Data interface for measured data (parallel / serial)
- Connection board for the machine control (Profibus, Interbus-S)
- Connection for a further control (software)
- Analogue data interface
- Serial data interface
- Introduction to the system and training
- Software update service

Technical data

Sensor head (available optics)

Sensor type	B	D	F	E	H	C	G
Distance to workpiece [mm]	**100**	120	100	100	100	100	100
Visual field [mm] (w x l)	**16 x 9**	5 x 3	9 x 5	29 x 6	11 x 6	36 x 20	20 x 10
Depth of field [± mm]	**12**	3	7	25	9	25	15
Measuring precision [± µm]	50	20	35	50	44	140	80

Measuring range	corresponds to visual field and depth of field
Gap width	0 mm - 10 mm (butt joint)
Lead distance	> 25 mm
Wave length	690 nm (visible)
Eye safety	Mk I sensor laser class 1, Mk II sensor class 3b
Calibration	self-calibration by means for reference plate
Dimensions	50 mm x 70 mm x 94 mm
Weight	400 g
Surround for industrial applications	replaceable welding protection glass

Sensor computer (PCI bus)

Image processing	20 ms for every TV image, 50 Hz real time
Density of measuring points	4 ms - 5 ms, max. 250 measuring points / sec.
Maximum tracking speed	>8 m/min, limited by the movement system
Memory for path parameters	4 GByte
Housing (IPC, 19")	490 mm (B) x 220 mm (H) x 500 mm (T)
Power consumption	400 W
Weight	10 kg

Marketing and Service Cooperation

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