COMUPTER AIDED REMOTE CONTROL FOR A MANIPULATOR SYSTEM TO REPAIR SEWERS

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SUMMARY

Remote controlled operation requires a lot of information about the working environment. Cameras and proximity sensors can not give all the information being considered as necessary for working in a narrow and hardly observable environment. If the environment is geometrically more or less defined, computer support can give the missing information.

The handling task in this case is the cutting of the old mortar in brick sewers and the replacing of a new one.

The sewers have an elliptic cross-section which is exactly mathematically described. Therefore, the handling task can be preplanned by a computer algorithm. During the cutting operation the operator has the possibility to correct the cutter path with a joystick which works in a coordinate frame fitting to the sewer surface.

In the first working step the longitudinal gaps are cut and the end points of the transverse gaps are taught.

In this way we get a number of path points which have to be combined by a special computer algorithm to an extended gap-program.

The operator has the ability to change the path velocity between 0% and 100%; therefore, it can react on unpredictable events.

In case of emergency, like breaking of a cutter, the operator can start a interruption routine. After repairing of the damaged part the automatic program can be restarted at the beginning of a gap.

The real manipulator movement will be shown on three video terminals. Additionally, a synthetical two-dimensional representation on a personal computer is available which does not only show the manipulator in the sewers but also the working process and the state of the machine.

1. INTRODUCTION

The public sewer system with a length of 285.000 km in Germany is an important instrument for the protection of nature. It is only able to fulfill its shelter function if it is absolutely watertight. In this paper we want to present a control system for the remote controlled renewing of brick lined sewers.

Up to now the worker has to work under extremely dangerous and unhealthy conditions. This project is aiming the development of a machine enabling the operator to carry out his work outside of the sewer at a save and comfortable working place.

The main component of the renewing system is a hydraulic driven manipulator with five degrees of freedom for the automatically cutting and filling of brick sewers. Together with the company HOCHTIEF the Fraunhofer-Institute for Manufacturing Engineering and

Automation has developed this machine in nearly two years. The operator is informed about the redevelopment process by three CCD-cameras. Two cameras are integrated in the wrist axes and are facing the tool. The third camera is mounted on the vehicle. This camera can be swung by the operator in any direction so that the robot itself as well as the sewer can be inspected.

The operator defines via the TV-image the edge points of the bricks which the robot has to redevelop. At first, the gaps are cut free by a finger milling cutter with a width of 15 mm and a depth of 20 mm. Simultaneously, the gap is cleaned by blowing or suctioning.

In the next operation the mortar is pressed into the gap and smoothed in an automatic mode.

For the movement within the sewer the robot is mounted on a walking gear. It is conformed to the elliptic cross-section of the sewers whereas strong deformation does not limit the movability.

For the replacement of single bricks a working place for manual tasks has been integrated in the robot vehicle.

Control instruments and monitors in a container outside of the sewer are informing the operator about the state of the machine and the state of the working process.

2. PROBLEM

Remote controlled manipulations in a geometrical exactly defined surrounding that is only partly detectable with cameras and proximity sensors demands the support of a computer. The aim is to give the operator as much information as it requires to carry out its operating task but with as little sensors as possible. The support itself is separated in the synthetic representation of the working area and in the precalculation of the robot motion.

In "Advanced handling-systems with enhanced performance flexibility" a controller principle is presented closing the gap between manually controlled tele-operation and automatically controlled robots.

In this controller principle the operator has been integrated in the supervisor and control system. Therefore, a control system is necessary which is not common in ordinary robot systems.

We have three different operation levels:

- Supervisor level
  The operator monitors all movements and interrupts the auto matic mode only in case of emergency.

- Motion / Path-level
  The operator moves the manipulator in a special frame for the fitting of precalculated programs to the real structure.

- Drive level
  The operator moves directly each joint. This should be done as rarely as possible because it reduces the working speed of the machine considerably.

The aim of this level construction is to pull the operator step by step out of the motion control process and to increase the automatic level in such a way.

Therefore, the operator should be able to influence or to interrupt running programs.

This leads to the following special features:

- Abortion of running programs at once or after execution of the actual command.

- Interruption of the program for manual operations and afterwards resuming of the program.

- Continually manual correction of a program or shift of single points or paths.

3. EXAMPLE OPERATION

3.1 PHILOSOPHY OF THE CONTROL SYSTEM

As we can see in Figure 2 the sewers are constructed by circles with different radius and different center points. In this way we get a sewer with an elliptic intersection.

For such a sewer it is possible to calulate the location of longitudinal joints as the used bricks have a constant width and the number of the brick layers is constant too.

Therefore, we have a clear relation between robotmotion and brick pattern. So we can calculate a motionprogram which moves the robot along the longitudinal joints of the sewer. This maeanderprogram bases on the fact that the joint pattern does not follow only a theoretical scheme but it is also given with the real sewers.

The sewers were built on stencils so that we have only a small deflection from the desired cross section. The deflection lays in the range of one joint width (10 - 15 mm). The location of transversal joints and of crevices cannot be precalculated as there do not exist constant conditions.

The endpoints of these joints are taught during the cutting of the longitudinal joints. While on the robot controller the motion program is running on the PC a program for the teaching of the endpoints is running.

The operator supervises via two cameras the motion of the cutter and presses a key on the PC when it passes the endpoint of these endpoints. After the transversal they are combined cutting to a new motion program.

3.2 FIRST WORKING STEP: CALIBRATION

The renewing of the sewer is done in sections with a length of 500 mm. After that the robot has to walk 500 mm. The deflection between sewer main frame and robot has to be measured. Therefore, an automatic program has to be started with 8 path points that are placed on the side, on the top and on the bottom of the sewer. The precalculated points have a predefined distance to the sewer surface. If the robot has reached the calculated point the operator can move the robot tool to the surface in small steps. When the surface is contacted the point is registered. So we get 8 points on the sewer surface for the calculation of the realtiv position and orientation of the robot within the sewer.

The two points at the bottom have to be in a longitudinal joint. This is the reference joint for the already mentioned maeander program. Whereas the other 6 points can be anywhere on the sewer surface.

The third task of the calibration step is the detection of the connection to the previous section. The refilling of the joints has to be done without any gap. So we have to find the end of the previous reflected joint by a camera as well.

3.3 SECOND WORKING STEP: CUTTING AND TEACHING

With the previous detected deflection of the robot frame and with the reference joint the maeander program for the longitudinal joints can be calculated. For each joint 6 path points have to be well defined at the end and at the beginning of the three points. One with a fixed distance to the sewer surface. It is necessary for the change of one joint to the other one. One point on the surface and one with the cutting depth within the joint. Additionally, the sewer normal for each longitudinal is calculated.

As it is quite unrealistic to think that the calculated paths hit the longitudinal joints exactly the operator can influence the calculated path tangential to the sewer surface. When the cutter moves along the longitudinal joint the operator teaches the end points of transversal joints and of crevices.

3.4 THIRD WORKING STEP: CUTTING OF TRANSVERSAL JOINTS

The end points taught in step 2 are sorted and the points which belong to one joint are combined to a new motion program which is build up similar to the program of step 2.

The result of the teaching (step 2) and the result of the sorting algorithms is shown on the PC-Display. So the operator is always informed about the actual state of the renewing process as the following working steps are also showing.

3.5 FORTH WORKING STEP: REFILLIING

With the path data of step 2 and step 3 the path program for refilling of the joints can be calculated. It is built up nearly identically to the other programs but it takes into consideration the correction of the operator during the longitudinal movement and the different distance of the tool to the surface. The refilling is done nearly fully automatically. The mortar pump is started by the robot controller at the starting point of the joint and stopped at the end. The operator can influence the path velocity to guarantee a correct refilling of the cutting joints.

3.6 FIFTH WORKING STEP: WALKING

The robot itself has a range of 500 mm so it has to move after each section. Therefore, the robot is mounted on a walking gear. Two pillars are connected with a telescope. The first pillar is released and the telescope is pulled out. Then the first pillar is locked, the second pillar is released and the telescope is pulled in. In the new position the second pillar is locked. The two locked pillars lock the robot un-moveable within the sewer which is very important for the automatic cutting and refilling of the joints.

3.7 INTERACTION BETWEEN ROBOT CONTROLLER AND OPERATION CONTROLLER

There is a clear separation between motion control and path planing. The above mentioned working steps are defined on a PC which works as an operation controller. Whereas the path movement is controlled and supervised by the robot controller.

On both controllers endless programs are running communica-ting by semaphores. The PC-controller takes one coordinate of the path file, sends it to the robot controller and sends an additional start signal. When the robot has arrived at this new coordinate the robot controller sends the signal to send a new coordinate to the operation controller.

4. CONCLUSION

The list of the presented controller concept shows that the computer support is an essential tool for remote handling tasks. Especially when the working environment is very complex and without direct observation possibilities. The controller system is suited to the described handling task but it can also be fitted to similar ones.

The generalized idea is to reduce the direct interaction between manipulator and operator and to increase step by step the computer support.

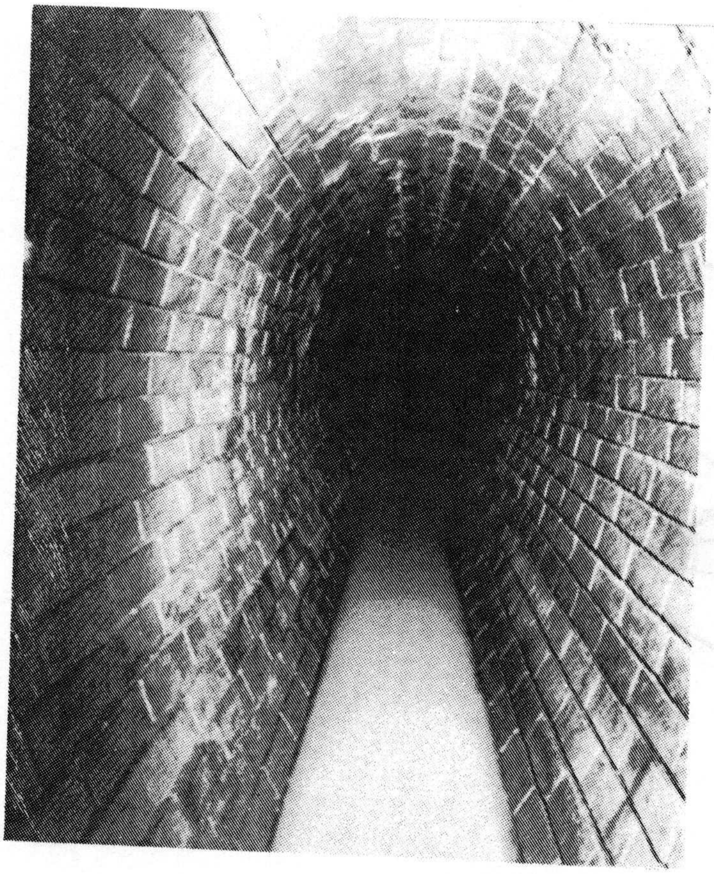

Figure 1: Typical German Sewer

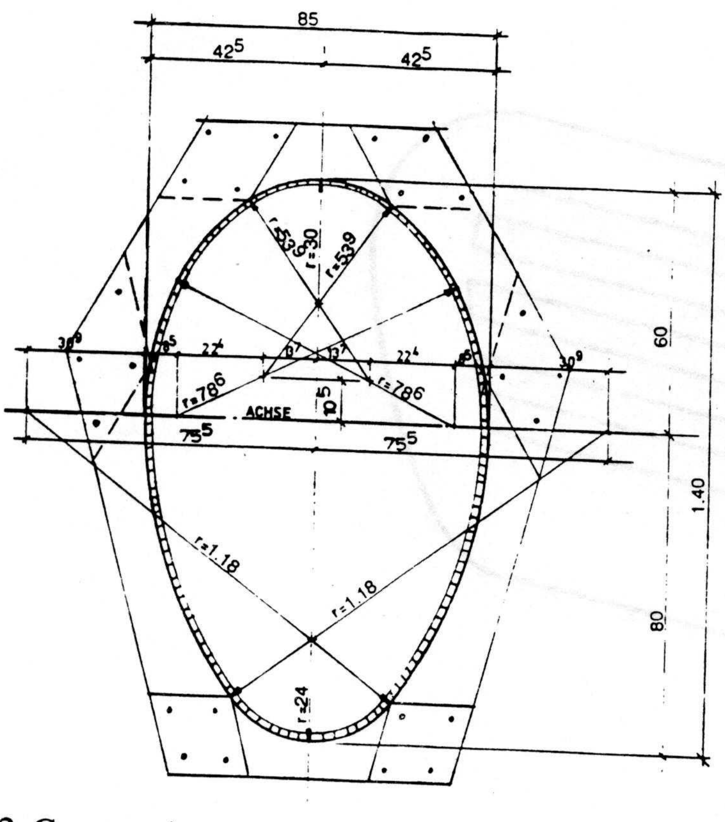

Figure 2: Construction of a sewer by circles

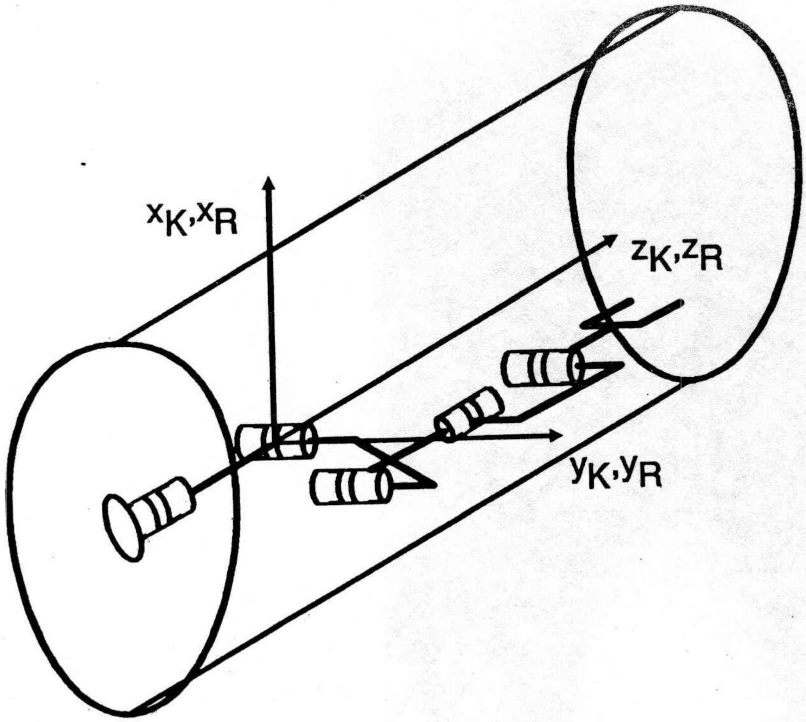

Figure 3: Robot and Sewer Frame

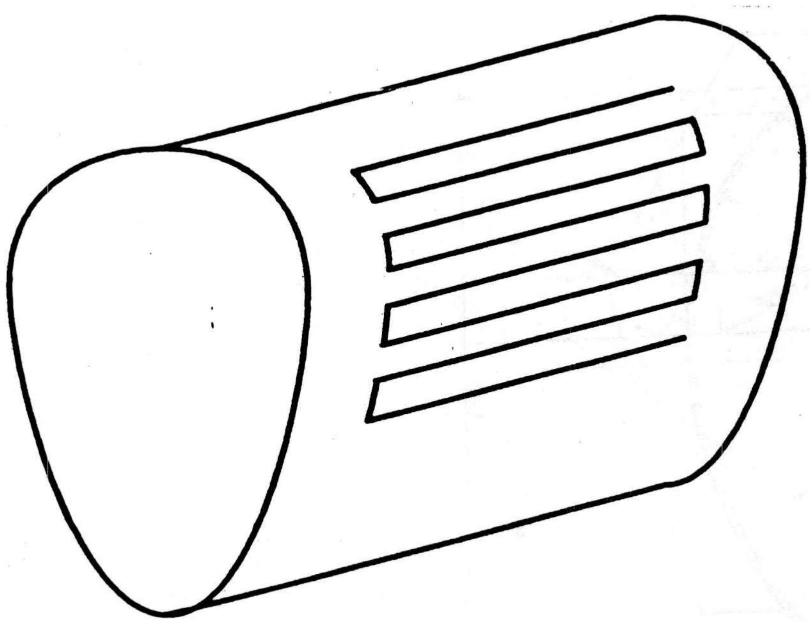

Figure 4 Precalculated robotpath