DESIGN OF A MANIPULATOR WITH VERY LARGE REACH FOR APPLICATIONS IN CIVIL ENGINEERING

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Abstract

This paper gives an overview of the current state of the art of manipulators with a very large reach in civil engineering. An example for a specific application is presented. Areas for further improvements are investigated and the topics for the research work related to the components are described.

1. State of the art

Manipulators with a very large reach have a wide range of applications in civil engineering:

- Positioning of process equipment (concrete spraying, concrete pumping, sandblasting e.g.)
- Positioning of platforms for machines and workers in order to perform inspection and repair work
- Handling of heavy workpieces

In general those machines are mobile, for some applications fixed installations are used /1/. Now a few comments to limiting factors of existing systems:
In view of the size and task of those systems safety is of paramount importance. A lot of safety measures are included in those systems, so they can be considered as very safe. However the system can not perform the task better than the human operator.
Within the road regulations and the related restictions as far as the overall size of the system is concerned an increasing reach can only be realized with an increasing number of axis. A human operator can only control a limited number of axis simultaneously, so the real ability of the system can only be used on an very limiting scale.
In most cases in civil engineering manipulators are working in a highliy unstructured environment with a lot of possibilities to hit objects. This situation is worsening with an increasing number of axis. In difficult situation several operators are needed.
Even with those limitations described above manipulators with a very large reach are quite popular in civil engineering in the USA and Germany. An example of the already existing capabilities of ratio controlled concrete booms were given in connection with the reactor accident in the USSR last year.

2. Specific application

In order to protect the damaged reactor block 4 as fast as possible several concrete booms were ordered in Germany. Putzmeister-Thomsen recieved the lion's share of the order- among others seven 52 m booms /2/. Special features of these units are:

- 52 m reach with 5 arms, 200 cubic yards per hour capacity and 360 HP engine
- lead lined cap to protect the driver
- installation of two cameras. One lead lined camera at the fifth section surveys the concrete distribution. The second lead lined camera automatically extends when the outriggers swing out to survey the hopper function.
- video monitoring in the drivers cab. Parallel the same installation was positioned 2000 ft away in a protected control center for all pumps.
- radio remote control for all functions. In addition to this a cable remote control was installed as an alternative in order to increase redundancy.

The first 52 m boom delivered from Putzmeister-Thomsen pumped 100 000 cubic yards concrete in three month trouble free, according to Russian sources. This machine is shown in Figure 1. A total of approx. 400 000 cubic yards were pumped altogether in order to protect the reactor. Figure 2 shows the situation in October 86 - the world wide biggest concrete pumping installation with four Putzmeister M52, one Putzmeister M22 and one Schwing M52. Now after the job is finished these machines will be used to upkeep other powerplants in the USSR.

3. Areas for further improvements

The limiting factors described in chapter 1, the obvious experience in the application mentioned above and a study of the market for advanced robotic systems carried out by IPA and KfK was leading to a project for further improvements of those systems with Putzmeister. Some of the aims are described below:

3.1 Controller

- Coordination of the movements from the rotatory arm system in the x,y,z-system for computer controlled movements and compensation of the static and dynamic deflection (see Figure 3).
- Macros for typical movements should be introduced
- Calculation of the stability of the overall system. Introduction of diagnostics for maintainance.

3.2 Operation system

The system should work with options like cable remote control, radio remote control or a system working on the 'follow me' principle. The solution of the operation system is depending on the task.

3.3 Systems for collision avoidance

Teach-In of local restictions is one obvious solution. In this case strategies for local collision avoidance can be introduced into the arm equations (see Figure 4).
Another option is the method for an operator controlled modelling of the environment. Here the subsystems are rangefinders and a seperate PC for modelling the measured data and path planning. Such a system is under development at the KfK.
The most comfortable method is of course an automatic laser rangefinder system with associated software and hardware for solid modelling.

3.4 Mechanical system

As far as the hydraulic system is concerned we can start with already available designs. For the mechanical arm structure a complete redesign is needed. This includes devices to reduce backlash in axis 1, new type of roller bearings and stiffening of the overall arm structure only to mention some of the topics.

4. Outlook

A new generation of manipulators with a very large reach can be expected for the future. Although most of the hardware including controller and sensors are already available or within the current state of the art, considerable risks including high investments and a lot of experience will be needed to achieve a product acceptable for the demanding market of civil engineering machinery.

References

/1/ Leaflet PM 891-1 from Putzmeister-Werk GmbH, Aichtal, West Germany

/2/ Leaflet BP 1133 GB from Putzmeister THOMSEN div., Gardena, California, USA

/3/ M.C. Wanner et al: Hochflexible Handhabungssysteme Robotersysteme 2, Heft 4 (1986), page 217-224

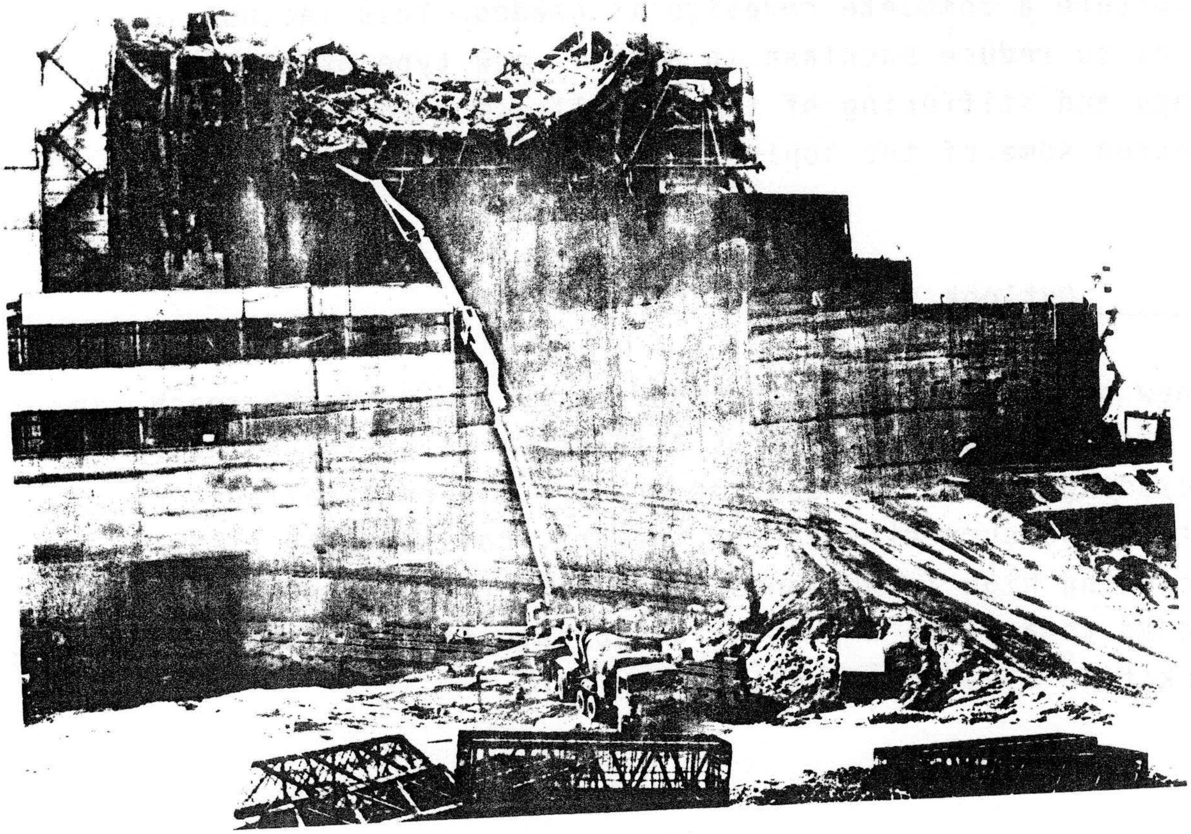

Figure 1:
The M 52 boom from Putzmeister filling the middle step of the pyramid entombment.
Photo: TASS

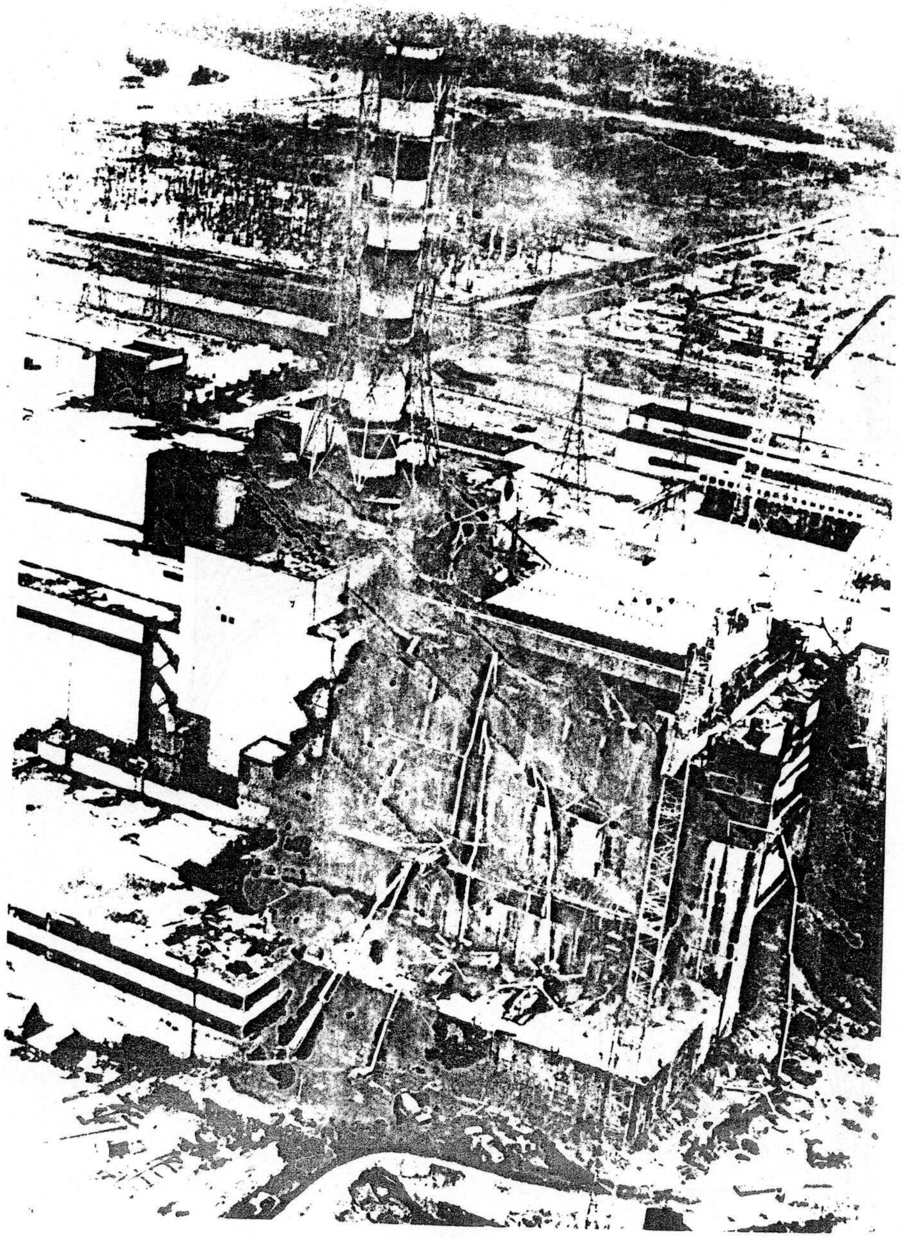

Figure 2:
The situation in October 1986.
One Putzmeister M 52 positioned on the middle step of the concrete pyramid walls is supplied by a Schwing M 52.
The booms on the lower pyramid steps are supplied from trucks and trailer pumps from the ground.
Photo: TASS

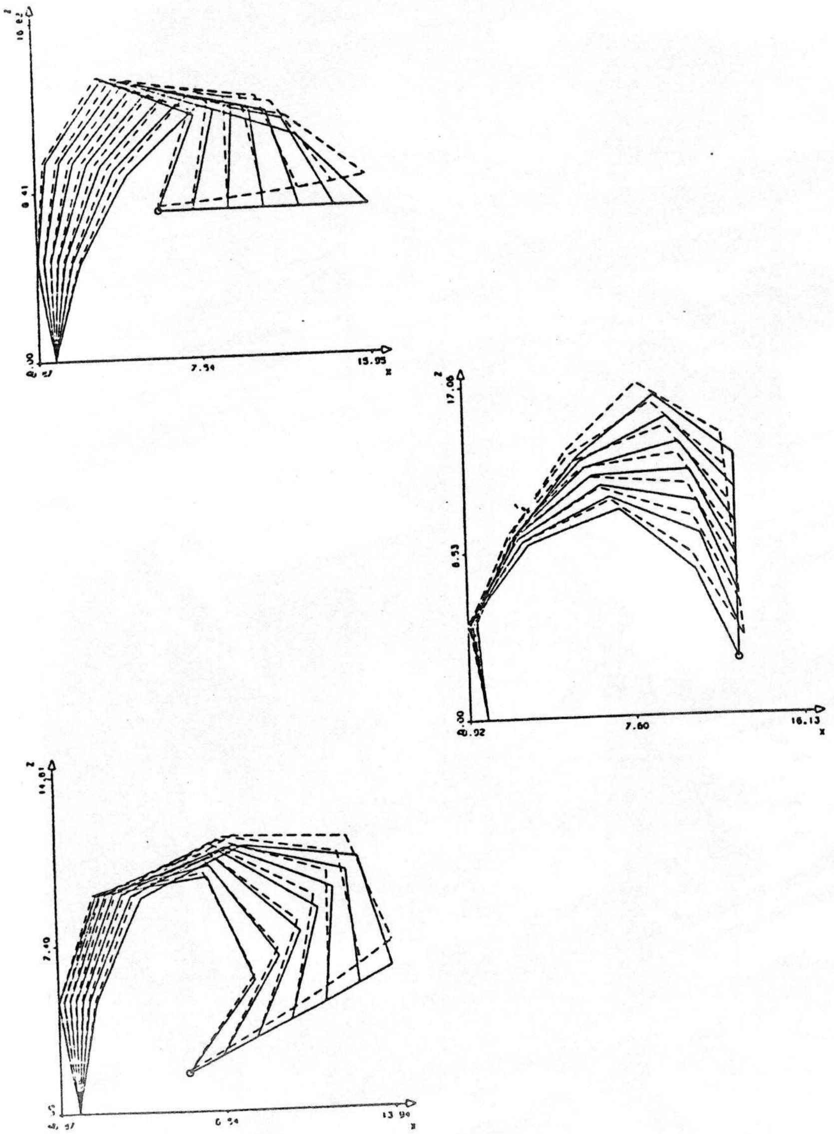

Figure 3:
Integration of the inverse kinematic solution (three redundant axis) with the compensation for static deflection
Photo: IPA

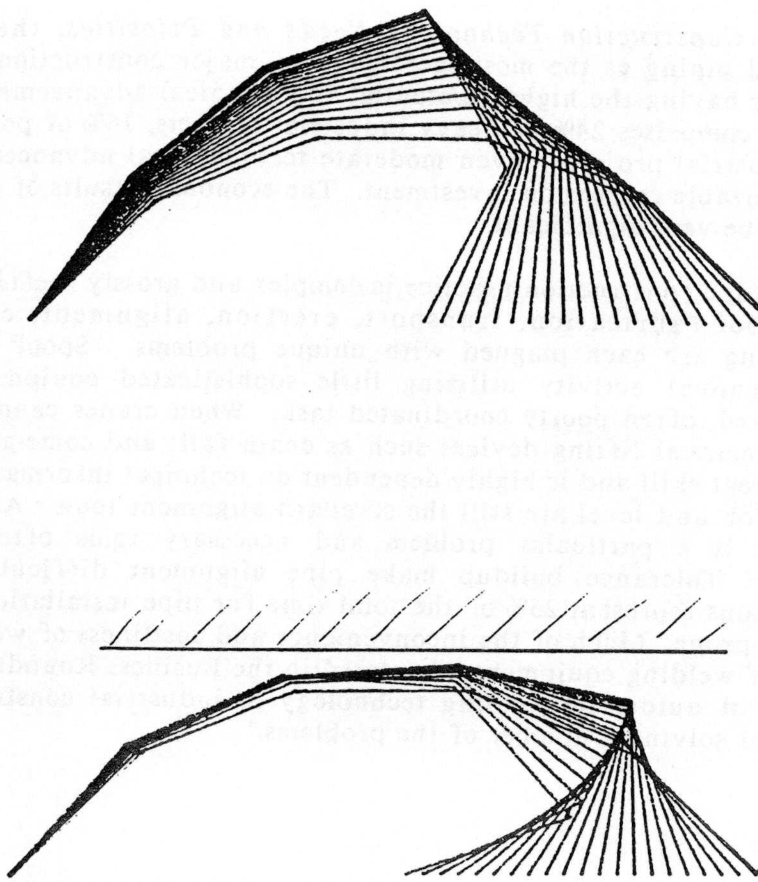

Figure 4:

Local collision avoidance strategies introduced to the basic algorithms of the inverse kinematic solution.
Photo: IPA