# Appropriate Information Processing for Telemonitoring of Manufacturing Processes

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**Abstract –** Importance of telepresence application increases in the field of manufacturing. In production the main activities are divided; the locations of management, design, manufacturing and services are separated sometimes to diverse countries or continents. The development of information technologies and telecommunication made possible the sense of presence from a remote location. In this paper authors introduce a set of information processing methods that was developed to answer the new challenges of telepresence application in manufacturing. Process signals, such as cutting force or acoustic emission, were processed using linear prediction method. Due to this transformation of process signals not only the amount of the relevant information was reduced but we also gain an expressive form to distinguish the deviated states of machining processes. The developed monitoring method was used successfully for experimental monitoring of different machining operation in the case of highly differing signal types. As another type of data processing for telepresence applications, data based visualization method was suggested instead of direct broadcasting video information. The simulated virtual environment, the generated diagrams, the properly selected information may help in telediagnostics of complex manufacturing environment. As an experimental demonstration the monitoring of robotized manufacturing was investigated.

Keywords: Telepresence, Diagnostics, Manufacturing

## 1. INTRODUCTION

The synergetic development of information technology and telecommunication made possible the independent and mobile processing of any information or data. In production systems the different tasks such the management, the design, the quality assurance, the manufacturing were separated, and the quick and mobile information access was essential for keeping the productivity, profitability and competitiveness of companies. The telepresence applications may help in quick decision of the remote management and may separate the expertise and the production process, etc.

There are several fields within a factory environment, where it is essential to involve human experts to observe, to test, to control and to feel the details of the production processes, both in the design and the planning stages, and during the manufacturing, testing and verification processes. As soon as digital technology reaches a complexity within the environment, appropriate digital communication and information processing subsystems can meet the above listed user requirements. These new features raise the quality level, the efficiency, the observability and controllability of the production, but also allow the customer and end-user to actively take part in the processes of manufacturing. Implementing interactive multimedia services for telepresence, advances the technology of the given manufacturing facility into a new, higher level [1].

One of the most general definitions of telepresence was drawn as the ultimate goal of these efforts: to produce a transparent link from human to machine; a user interface through which information is passed so naturally between operator and environment that the user achieves a complete sense of presence within the remote site. Considering the up to date intermediate link, the telepresence is the ability to operate remotely in a computer mediated world. On the other hand a virtual presence can be also defined in the frame of telepresence as experience by a person when sensory information is generated only by and within a computer - compels a feeling of being present in an environment other that the one the person is actually in [2]. However telepresence applications in manufacturing raise new challenges such as

1. the selection of the appropriate information for data transfer,
2. reducing the amount of the data for efficient communication speed,
3. automating as much decision making as possible,
4. recreation of the virtual copy of a real environment in a remote location based on minimal information,
5. quick, safe and reliable communication lines,

In our research we focused on the first 4 questions mentioned before. In order to monitor the manufacturing process appropriate data transformation methods are investigated that are able to reduce the volume of the information but able to keep the essential content of it. Since transmission of the information consumes only limited time and memory (due to the fast progress of telecommunications means), we are able to recreate the original environment in the level of the necessary decision support based on the processed information.

## 2. TELEMONITORING OF MACHINING TOOLS

Determination of the actual state of the cutting tool or prediction of the possible failures of the tool is one of the most important topics of the cutting tool and process monitoring field. Using sensors in the machine results enormous amount of data, but it does not mean valuable information or real knowledge about the process. The role of data processing method is essential in gaining information for monitoring, especially in the case of telemonitoring where the amount of transporting data is critical.

### 2.1. Data processing method
The data processing method combined two mathematical processes. The first step was the widely applied Fourier transformation that converts the signal from the time domain to the frequency domain. The second method is imported from the speech processing, it is the linear prediction.

The first step of compressing data was to create the average power spectrum from the time domain signals. This method was processed as follows:

- One record was cut up to m pieces of 4096 point segments with 50% overlapping.
- Absolute Fast Fourier Transformation (AFFT) was calculated for the m segment of the record with a Kaiser's windowing.
- The resulted AFFTs were averaged respect to frequency domain.

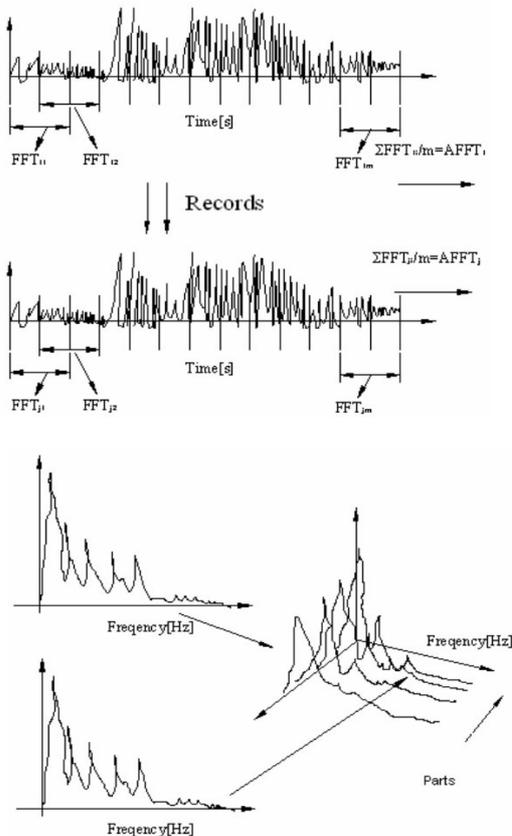Figure 1 gives a schematic demonstration of the method.



Fig. 1. Creation of average FFT from the time signal.(illustration)

### 2.2. The linear prediction
Linear prediction (LP) is a speech–processing method for forecasting elements of a vector with the foregoing ones, on the basis of following mathematical equation. [3] (1)

$$\bar{s}(n) = \sum_{i=1}^{p} \alpha_i s(n-i) \qquad (1)$$

However the experiment expressed by the $\alpha_i$-s does not describe the phenomenon with proper precision. The lack of precision can be outlined by the prediction error as follows (2):

$$e(n) = s(n) - \bar{s}(n) = s(n) - \sum_{i=1}^{p} \alpha_i s(n-i) \qquad (2)$$

Although this method was originally designed to predict, it can also be used to emphasize the essence and to describe the phenomenon very briefly. In that case if the vector is known in advance than we talk about deterministic linear prediction (DLP).[4]
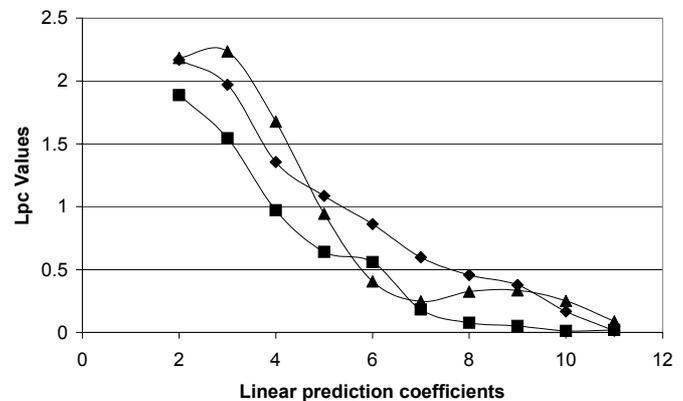


Fig. 2. Illustration of the LPC vectors

In this work the DLP was used as a compressing method. For all rows of the FFT matrix the LPC vectors were calculated. Since one LPC vector describes one row of the FFT matrix (one record in frequency domain) with very few elements, it is much easier to compare the rows in the LP space. If two records of Fourier transformation are same then their LPCs are also the same. If two FFT rows are different, then the corresponding LPCs are also different. Here the LPCs are same from element to element, so we compared every first, every second, and so on (Figure 2.).

In case of tool monitoring instead of knowing the exact frequency and amplitude changes we have to notice the significant change in the tool wear process. On the other hand for the decision making we need only few alternatives, and it is no problem if they have small errors. Thus, if we estimate a phenomenon with small errors, using only few parameters, than we gain a method what gives a significant support for the decision making.

### 2.3. Application of the processing method
In the mass production it is very common, that the process is repeated without relevant change, however the difference in the positions or other non relevant change in the conditions can result distinguishable change in measured signals, especially in the case of extreme circumstances like over-wear or breakage. We used this phenomenon to predict

the tool wear, and throughout the tool wear the possible failures.

In the experiment we examined a normal turning operation. Here we continuously apply permanent machining parameters (f,a,v), the only difference we had was that we moved along parallel with the rotating axis of the workpiece thus we changed the transfer function continuously. We recorded data using three different machining circumstances with one insert and repeated the measurements in three different conditions of tool insert as Table 1 shows.

| Tool insert | 1st | 2nd | 3rd |
|---|---|---|---|
| Record | 1st 2nd 3rd | 4th 5th 6th | 7th 8th 9th |
| Condition of insert | Brand new | Small graduate wear | Over-wear |
| Flankwear in mm | 0 | 0.03 | 1.45 |

Table 1 Condition of wear on the inserts

The measuring set-up was as follows. AE transducers, the so-called water-jet AE sensors were applied, a coolant stream was used as a transmission medium to transfer AE signals generated from the cutting process to the HP spectrum analyser. Since the distance between the cutting zone and transducer element is small, the damping effect is minimised and the signal-to-noise ratio is significantly improved. [5] (Figure 3) The HP 3588A Spectrum analyser gave the SWEPT energy spectrum of the measured signal in the range of 50000–750000Hz. The applied machining parameters are summarized in Table 2.
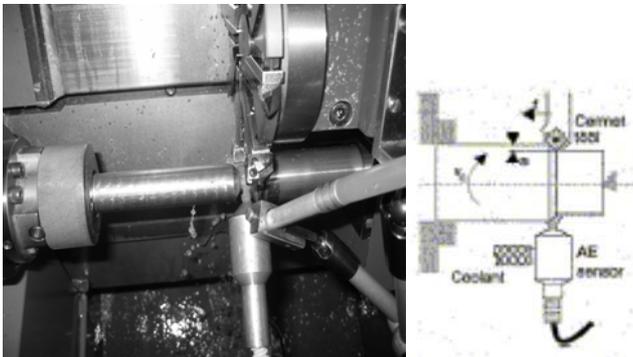


Fig. 3. The experimental environment

| Parameter | Value |
|---|---|
| Workpiece material | Ck45 |
| Feed | 0.2 mm/ rev |
| Depth of cut $a_p$ | 0.5 mm |
| Main cutting speed $v_c$ | 150 m/min |
| Tool | Somitomo    DCMT    07T308 Coated carbide AC 2000 Ndu chip breaker |

Table 2. Machining parameters in the experiments

### 2.4. The comparison of the results

As it is discussed, we generated LP coefficient vectors. In the following figures the values of the LP coefficients were plotted against the sequence numbers of LP coefficients. We applied eleven elements LP vector, in this

case the compressing ratio is high (refer the earlier discussed method) and above the 11th coefficients the coefficients are very small. The first LP coefficient is always one caused by its generating process – so the coefficients are depicted from the 2nd till the 11th.

In case of turning we can divide the diagram into two parts at 7th LP coefficient. From the 2nd till the 6th they are decreasing. From the 7th in case of new tool it is increasing (fig. 4 a ), in the graduate wear condition (fig. 4 b) constant and in case of over-wear condition it is decreasing above the 7th coefficient. (fig. 4 c )
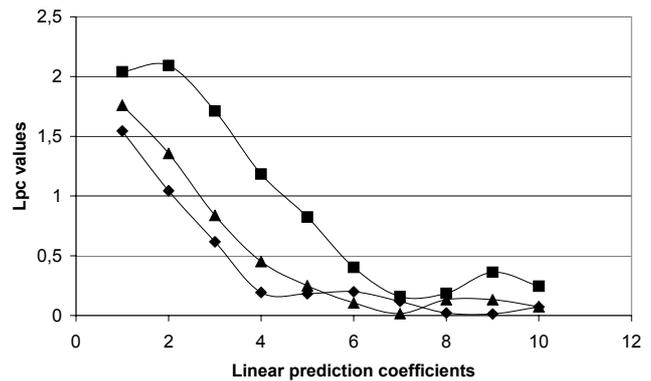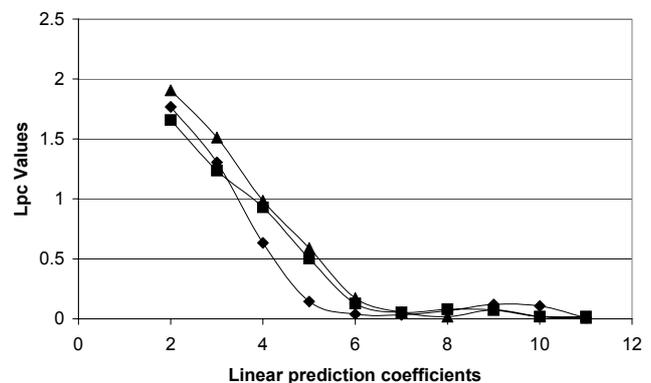


Fig. 4 a   LPC values of the brand new insert



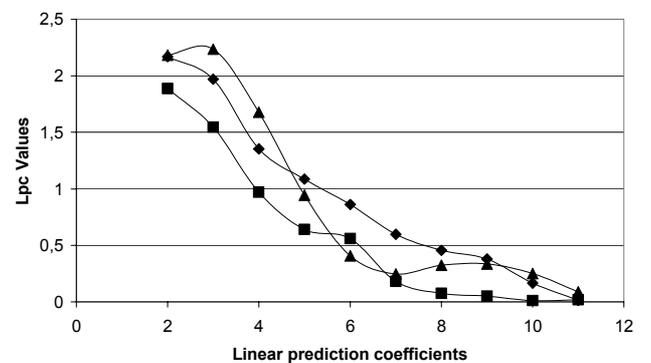Fig. 4 b   *LPC values of the* graduate worn insert



Fig. 4 c   LPC values of the over-worn insert

The other significant issue on the diagram is that in the initial wear condition the difference is great - comparing the curves (see fig. 4 a). In the graduate wear condition this difference is small (fig. 4 b) and it increases again (fig. 4 c) in the case of over-wear condition.

Similar application of this processing method is discussed in [2] and [6] where the tool condition was monitored also in milling operation. There we used a 4 axis Deckel milling machine. A slit was machined in a cylindrical work piece, 3,2mm wide and 9mm deep . This process was repeated 400 times on two workpieces, on both sides. The parameters of the process are shown in Table 3.

| Machining parameter | Value of the parameter |
|---|---|
| Rotations of main spindle | 1250 round/min |
| Feed rate | 1440mm/min |
| Diameter of the tool | 125mm |
| Thickness of the tool | 3,2mm |
| Number of the teeth | 14 |
| Direction of milling | Counter clockwise |
| Number of the work piece | 2 |
| Diameter of the work piece | 18mm |
| Material of the work piece | 34CrNiMo6 |
| Machine | Deckel FP 3A |
| Material of the teeth | WIDIA TPC 25 |
| Cooling | Without cooling lubricant |

Table 3   Machining parameters for milling

The milling process itself was recorded throughout the tool life. The experimental set–up is depicted on Fig. 5 with the simulated different transfer paths. Here we gained the measured data in time domain. For first an average Fast Fourier transformation (FFT) was created, and for this averaged spectrum the LPC was applied.
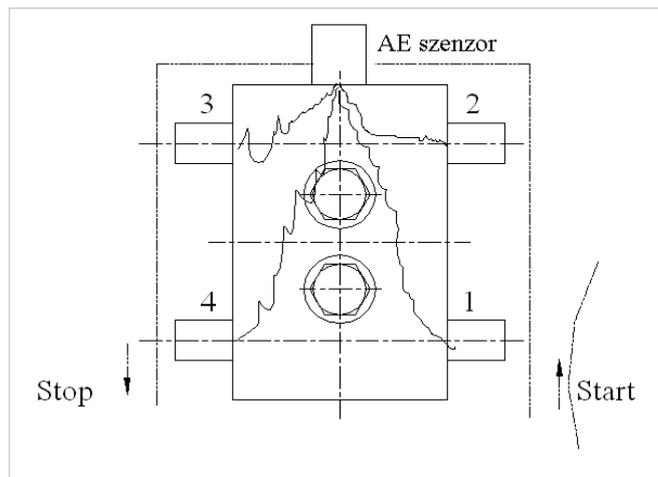


Fig. 5   Milling configuration

In this examination we took four consecutive milling cycles with different transfer functions and we compared the resulted LPCs. This sampling method was repeated four times in different stages of wear process. The sample wear parameters are depicted in table 4.

| The number of four measurements | 1,2,3,4 | 49, 50, 51, 52 | 949,950, 951,952 | 1561,1562, 1563,1564 |
|---|---|---|---|---|
| The wear condition | Brand new | Small graduate wear | Great graduate wear | Over wear |
| Flank wear in mm | 0 | 0.08 | 0.7 | 1.42 |

Tab. 4th the wear parameters

In the case of milling we can find the second LPC as much greater than the others. In initial wear condition (fig. 6 a) the values of the LPCs [$3^{rd}$–$11^{th}$] are small but they are quite chaotic. In the beginning of the graduate wear (fig. 6 b)the $3^{rd}$ the $4^{th}$ and the $6^{th}$ LPC are seriously increased in comparison with their values in the initial wear period. Meanwhile the $5^{th}$ and $7^{th}$ –$11^{th}$ LPC were decreasing. In fig. 6 c in case of great graduate wear condition the features are quite similar, but the $6^{th}$ coefficient is decreased as the $11^{th}$ is increased
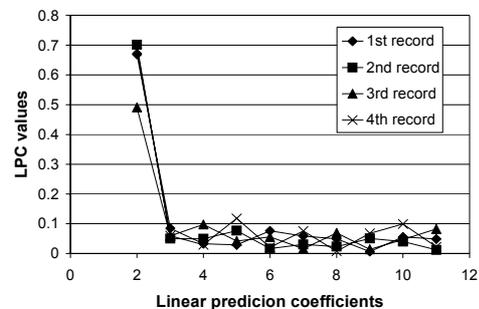


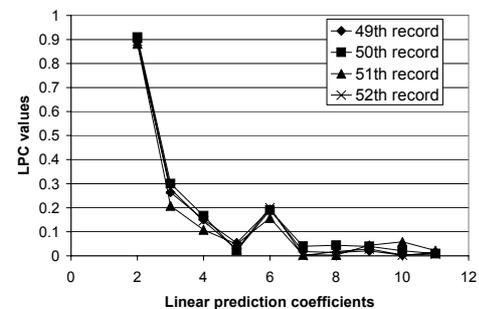Fig. 6 a   LPC valuess of the brand new insert



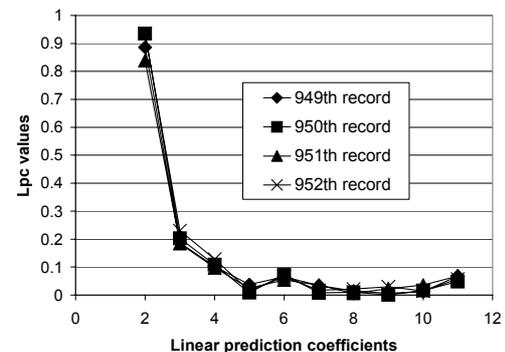Fig. 6 b   LPC values of the small graduate worn insert



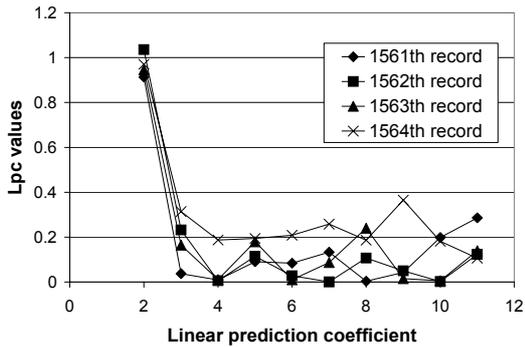Fig. 6 c   LPC values of the great graduate worn insert

Fig. 6 d   LPC values of the over- worn insert

However the most interesting feature in the two graduate wear diagrams (fig. 6 b, c) is that, even if the transfer functions  and the wear conditions (tab $4^{th}$ ) are different the curves within the diagrams and in the two diagrams are very similar.

In fig. 6 d in the case of over-worn tool also a chaotic feature can be found on all curves. On the other hand the values of all coefficients are increased compared to their values in the graduate wear conditions tool.

## 3. REALIZATION OF A TELEMONITORING FRAMEWORK

In manufacturing systems a manufacturing process could be tracked remotely by an expert that is not in front of the system permanently. Instead of it he (or she) is in a remote site and access the system just in case that his (her) advice is required. The communication between the manufacturing system and the expert is through a couple of electronic devices, one of them installed at the manufacturing system's site and the other at the expert's site.

### 3.1. The concept

The manufacturing system's device, (*called: the client monitor)* must be equipped with some sensors in order to get information on some of the most important parameters of the manufacturing system that is being monitored. These sensors could be a temperature sensor, force sensor, pressure sensor, vibration sensor, position sensor, humidity sensor, or any other sensor that the system requires in order to be monitored. The client monitor must be equipped with a screen to display, in real time, the most important parameters of the manufacturing system.

The expert and the operator of the manufacturing system are able to communicate with each other using the monitor device that each one has at their site. The monitor at the expert site, (*called the central monitor or primary monitor)*, is equipped with all necessary devices and display tools for evaluating the manufacturing system performance. All information that is needed by the expert comes from the client's monitor acquisition system. The central monitor must be able to store, retrieve and display data. Based on the remote information that the expert has got from the manufacturing system he (or she) must be able to evaluate the condition and performance of the remote manufacturing system in order to provide the best advice to the operator.

A telemonitoring system must be built base on at least three elements: Concurrent Server, Local Controller and Client (Figure 7). The Concurrent Server stores information of the manufacturing systems being telecontrolled and offers a secure half-duplex communication features with the Client, it is also used as a bridge between the Client and the Local Controller in order to control it. The Local Controller that obtains information from a specific manufacturing system has to pre-process the information and send out, to the Concurrent Server, the current performance of the manufacturing system as well as the information obtained from the sensor system. The Client is the remote unit that displays the incoming information from the concurrent server to the expert's screen, this unit also controls the flow of information from the experts to the local controller through the Concurrent Server. An expert using the Telecontrol unit is able to monitor the manufacturing system and to change remotely the values of parameters [7].
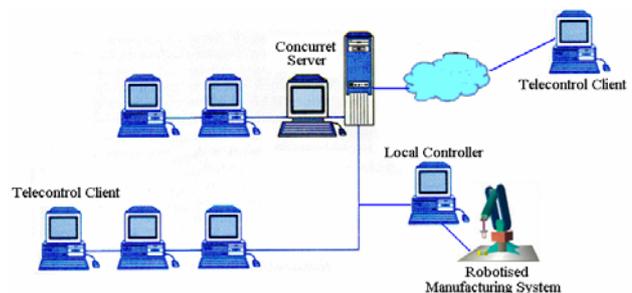


Fig. 7. The conceptual scheme of the telemonitoring system

The system is constructed on the "client - server" technology. Client part users can see in a browser.  This part consists of HTML pages and Java applet. The server part is latent from the eye of the user. Server part consists of ASP(Active Server Pages) and SQL Data Base. For the interface in client-server systems the structured query language (Structured Query Language SQL) will be used. It represents a means of organization, control and information retrieval in database.

### 3.2. Visualization of robot movement in this frame

We have realized the telemonitoring system of one industrial robot (PUMA 560 type). The communication between the concurrent server and the local controller must be reliable, fast  and secure. The SQL sever, that keeps the information about the actual position of the last joint as well as its speed, is able to give us the relevant information of the industrial robot when the connection is through the network. Finally, the visual system was capable to display the movement of the industrial robot in real time based on the information the SQL server provided to the local controller.

DataBase has the table with the information of coordinates and speed of the robot for being used  by the telemonitoring system. Based on the actual position an speed of the robot this table is renovated by LabView controller in Real Time. (Table 4)

| n | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Position | 1.571 | 0 | 1.571 | 0 | 0 | 0 |
| Speed | 0 | 0 | 0 | 0 | 0 | 100 |

Table 4   Table of Robot coordinates and speed

Active Server Pages are components that allow web developers to create server-side scripted templates that generate dynamic, interactive web server applications. By embedding special program codes in standard HTML pages, a user can access data in a database, interact with page objects such as Active-X or Java components, or create other types of dynamic output. The HTML output by an Active Server Page is totally browser independent which means that it can be read equally well by Microsoft Explorer, Netscape Navigator, or most other browsers.

In Active Server the following Java applets were programmed in order to provide the actual position and speed information for the clients:

**Robot_SetFrames.asp** create two frames in one window.

**RobotApplet.asp** displays the Java applet and dispatches to applet necessary parameters.

**Update.asp** is responsible for the operation with the database. For this purpose,  SQL language is used.

Client part can be any network computer connected to the internet and running  Java enabling. browser. The browser can display the running Java applets. The experts or managers can follow the actions of the robot with the help of a simple visualization of its motion (figure 8).
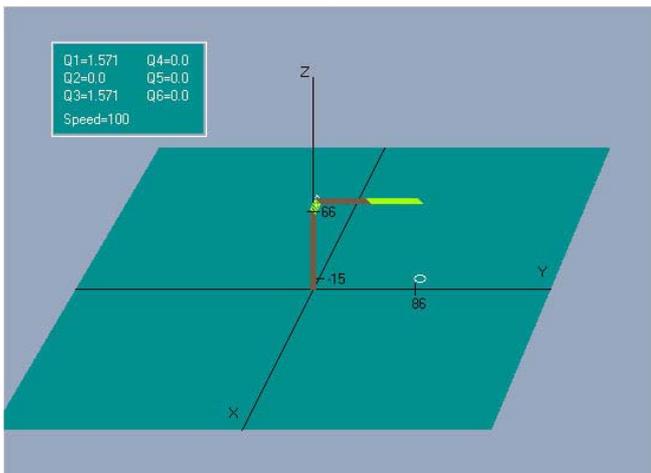


Fig. 8   The visualization for the client part

The system provides the actual position of the robot arms, however the interaction and controlling are not allowed. In order to realize the real time interaction or controlling possibility a low-level operation system must be used such as UNIX. For advancing the sophisticated tasks like controlling, monitoring and network communication the server must handle several clients that can even be direct controllers, supervision modules or simple network computers. Because of the open architecture of the controller and other operating modules the security solutions and access permissions are the most sensitive tasks [8].

## 4. CONCLUSIONS

In  the  field  of  automation,  the  reliable  process  control  is essential for acceptable flexible mass production. To achieve this goal first we need right information about the process and  a  reliable  transfer  media,  and  at  last  but  not  least  we have  to  have  an  automated  ability  to  emphasize  the  essence of  the  sensory  data.  Linear  prediction  method  ensures  that the  information  that  essential  for  monitoring  decision  is saved  while  the  amount  of  the  transported  data  is compressed.  The  server-client  architecture  implemented  as  a tool  for  telemonitoring  of  manufacturing  processes,  proved to  be  a  sound  solution  for  experts.  Further  investigations  are promising  fields  for  targeting  research  and  industrial developments

## 5. ACKNOWLEDGEMENT

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