I confirm that I shall be pleased to deliver a paper on:

Robotic Arm Simulation (RAS) in 3d Factory Environment

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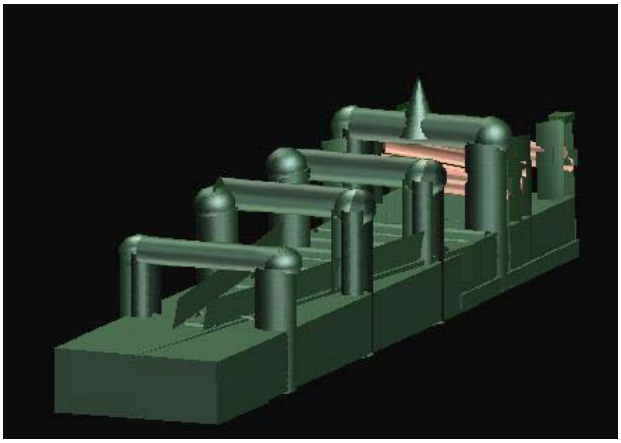
Abstract :
The paper gives a brief description of detailed modeling and **simulation** study in industry which uses Robot arms. It presents formulation and application of a strategy for control of Eight robot arms .The system is a projected assembly line for Pipe manufacturing.
The major issue is using discrete event **simulation** of a robot's Inverse Kinematics working in a Pipe manufacturing Factory, combined with high GUI.
Apart from the pure industrial motives, objectives are to "**image**" the assembly line and robot arm into a 3D graphic **simulation** model, to produce knowledge about Inverse Kinematics of Robot and industrial production capacity.
The Tools used for creating the simulation factory environment are:

- 3d Max 5.0
- 3D Exploration 1.81
- and OpenGL (GLUT) Library
- MFC 6.0 with C++ language.

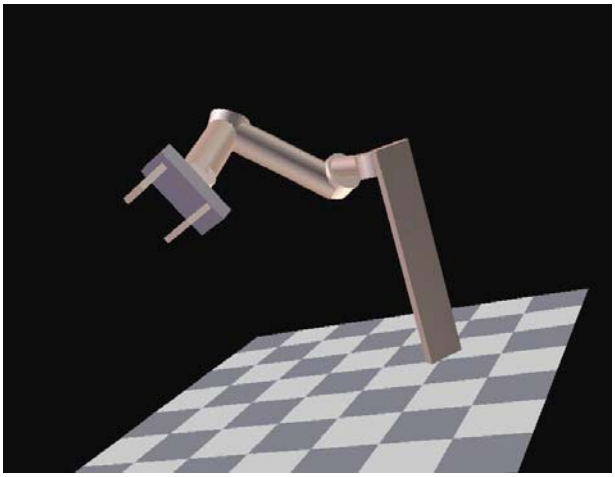
1. Introduction:

It is believed that model complexity should not be extended beyond the necessity of practical application and insight. One strives for simplicity and a minimum description of system behaviour. On the other hand there is strong desire for a high degree of visualization. Today, there is a growing interest for integrating visualisation and virtual reality techniques into the modelling and **simulation** process. The strong graphical user interface could also lead us to believe that the over all **simulation** user interface has decreased. To take full advantage of the graphical user interface, it is often necessary to build very detailed models. Modelling and **simulation** can be very resource demanding activities. Increasing the level of detail means putting even more resources into it, and to find an appropriate level can be a tough decision to make.

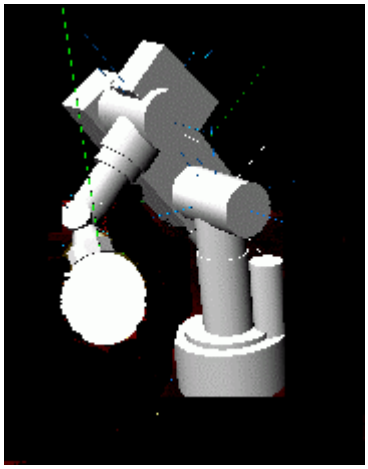
This paper presents the detailed modeling and **simulation** study. The system is an projected assembly line for pipe manufacturing by using robot arms. The Inverse kinematics of robotic arms are simulated in 3d factory environment. In the study, we focus on visual and logical aspects, in order to maximize both. It is important to keep in mind that the over all questions in this study, generally would allow a much higher level of model abstraction.



The visual model of the planned assembly line is shown in the illustration above



The visual model of the planned robotic arm use for carrying strips and pipes.



The visual model of the planned robotic arm use for molding the strips.

2 The tool environment:

In the present study three simulation tools are used:

- **<u>3d Max 5.0 :</u>**
  It is used for the 3d modeling of the assembly line and the robot arms.

- **<u>3D Exploration 1.81 :</u>**
  It is used for conversting the max file into obj and mtl files .

- **<u>and OpenGL (GLUT) Library :</u>**
  It is used to implement graphics theory just like camera movements and lights effect to produce real visualization.

- **<u>MFC 6.0 with C++ language :</u>**

Creating user Interface by using MFC and C++ used for reading the obj and mtl file of the models.

And combined form of C++ and OpenGL (glut) library used for establishing the Simulation.

Concept of Discreate Event Simulation and Inverse Kinematics of robot arms:
The reason for which I prefer to to show Discrete Event Simulation rather than the continous simulation of robot arms kinematics .

Because virtual robot arm' motion in factory is not continous in constant time rate but it is event based .

Discrete Event Simualtion of the system is defined in terms of discrete events.
In this study , asynchronous simulations a type of Discrete Event Simulation is used means the system is only updated at the time of the next relevant event.

4. **Description of the process:**

Commanly many labours are used to lift the heavy strips and cut the measured strips from the big coils of the strips and then placed in the strip molder machine . Traditionally many huge machine with complex functionality is used . And when strip molded and pipes are formed as by-product , then this huge and heavy pipes are carried by many labours . These pipes are very hot and very hard to carry by human beings.

These things gives the idea to use few robotics arms instead of many labours. Robots can do many works more efficiently and no fear of injuries as labour can have(pertain). Robots can mold the strips more accurately so no fear of lost of the strips..Robots can grip the pipes more vigourously than human , so no fear of damages in the pipe.
These measurements will highly increase our production capacity.

5. OBJECTIVES

The objectives of the study can be divided into

1) First of all , "**image**" the assembly line from a technical 3d drawing and control mechanisms into a logical 3D graphic **simulation** model.

2) Second task is to model the virtual robotic arms who have different degree of freedoms as mentioned below.

Two robot arms which are used to lift (carry) the strips and placed at the strip molding machine having these details.

- Gripper having two fingers, possesses 6 degrees of freedom
- Wrist possesses two degrees of freedom.
- Elbow possesses 3 degrees of freedom.
- (forearm)Sholder possesses 6 degrees of freedom.

Another Four (4) robot arms which work like hammer to mold the strips and it is attached with the molding machine possessing these details.

- (Wrist)End of this robot arm is round and it has only no degree of freedom.
- Elbow has one degree of freedom.

Two robot arms which are used to lift (carry) the pipes and placed these pipes in compound where welding will be done, possesses these details.

- Gripper having two fingers.
- Wrist possesses one degrees of freedom.
- Elbow possesses 4 degrees of freedom.
- (forearm)Sholder possesses 6 degrees of freedom

3. To verify the technical concept of industrial production capacity in terms of manufacturing facilities through modeling and **simulation**.

4. To see the impact of integrated **simulation** and visualization on the modeling phase.

Extremely challenging are the difficult conditions resulting from the process. The different size strips to be placed to manufacture the pipes of different diameters. The cycle time for one complete pipe manufacturing should be less than 2 hr. We map the time in that way .

Real time	**Virtual time**
10 min	1sec.
10 min * 6 i ,e 60 min	1sec*6 i.e 6 sec
2hr i.e 120 min	12 sec

This paper will concentrate on the movement of the joints of arm. And also take care if any collision is taken place .

6.**Detail Description of work :**

A definition of the model was made based on system engineering principles including system boundaries and interfaces, functional, operational, physical especially Kinematics

6.1. Modeling of Robot arms and Its kinematics :

The state of the robot is defined in **joint space** by the set of values representing each joint position.

It is more convenient for the user to specify positions in natural coordinate systems such as **world coordinates** fixed with respect to the ground, or **tool coordinates** datumed to the gripper flange. In a Cartesian system, 3 translations specify the gripper position and also 3 rotations are needed to describe the gripper orientation, making 6 degrees of freedom in all.

More may be needed to specify the state of the gripper itself. Fewer d.o.f. are possible when some motions are excluded.
Other standard names for frames include the base frame, station frame, wrist frame, tool frame and goal frame.
The geometrical relationships between these frames are a matter of **kinematics**, based on rigid links and close fitting joints

6.1.1 Specifying position and orientation

The *position* of a point (or the origin of one frame relative to another) is given by a vector.

p=px , py , pz

The *orientation* of a body or a frame can be defined by 3 angles, or rather by a *sequence* of 3 rotations.
Using axes fixed in space we can define **roll**, **pitch** and **yaw** angles about x,y and z respectively. Alternatively we can use **Euler angles** (,,) which are referred to body axes (z,y,x) rather than world axes.
First rotate by angle about axis z, then about the new *rotated* y axis and finally about the yet-again rotated x axis.

A **rotation matrix** can be formed from the unit vectors in the transformed frame corresponding to the unit vectors in the original frame.
Eg: To allow for 3 rotations we form (say) **B** = Bz . By . Bz

Then a vector **q**1 in frame 1 can be transformed to frame 0 by **q**0 = B**q**1 + **p ,** where B gives the rotation and **p** gives the translation of the origin, i.e. **p** gives the origin of frame 1 as measured in frame 0.

6.1.2Homogeneous Coordinates

To write this transformation in the manner of a matrix multiplication, the vectors and matrices are padded with zeros and ones is called the homogeneous transformation matrix.
Using matrix methods, a frame is assigned to each link of the manipulator, so each frame translates and rotates with its link. Then a sequence of transformations can give the coordinates of any point on any link relative to (say) the base frame.

Assigning Link Parameters

<u>A single link</u>

link length, Li = length of mutual perpendicular to axes i and i-1.
link twist, i = angle turned from axis i to axis i+1 projected in the plane normal to Li.

<u>A pair of links</u>

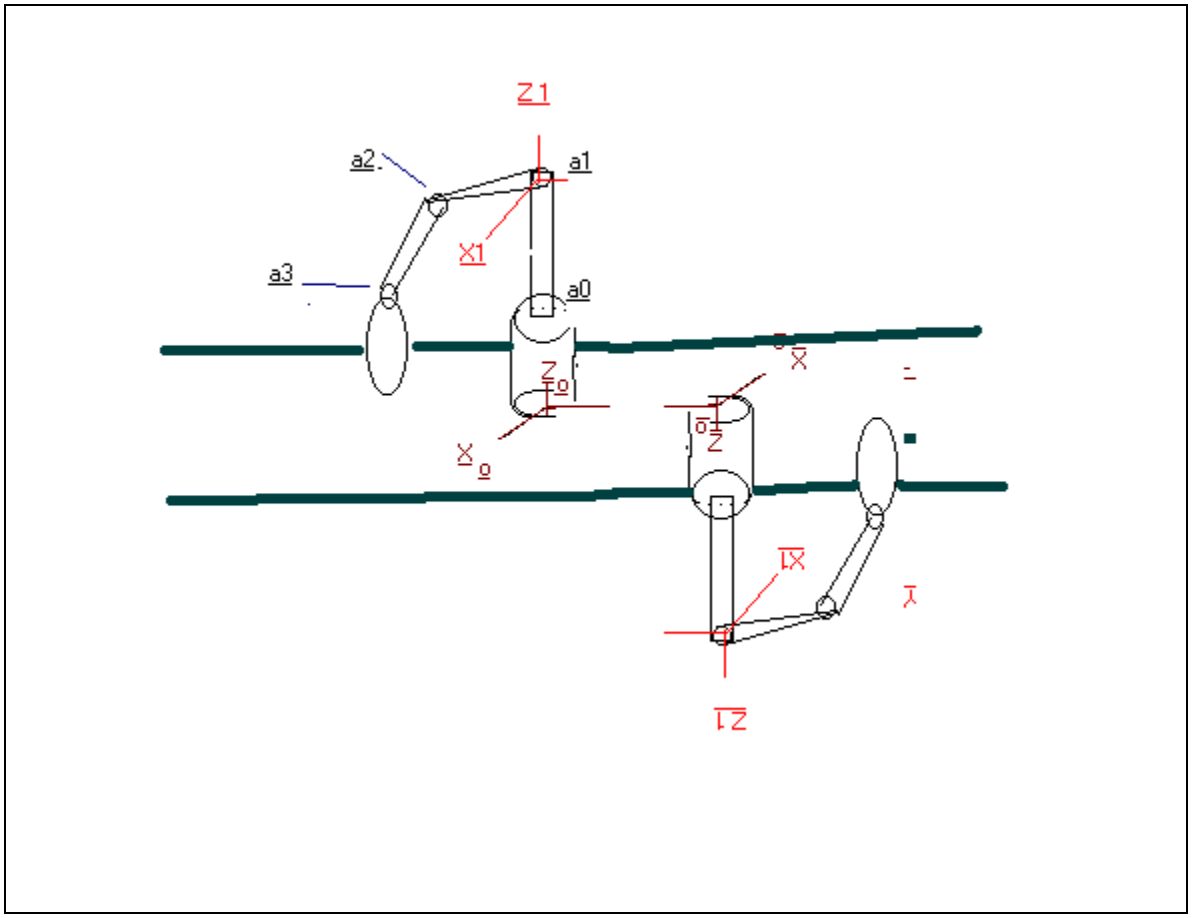
link offset, Di = distance along axis i from its intersection with Li-1 to its intersection with Li. Variable if the joint is prismatic.
joint angle, i = angle between Li-1 and Li about axis i. Variable if the joint is revolute.
Place frame i at end of link i, with Zi axis aligned with joint direction i+1. Note joint i connects link i to link i1.

The Denavit-Hartenberg Matrix

Any two neighboring frames can be brought into coincidence by a prescribed sequence of two rotations and two translations:

1. Rotate frame **i-1** through positive $_{\mathbf{i}}$ around the $\mathbf{z_{i-1}}$ axis to align the x axis.
2. Translate along $\mathbf{z_{i-1}}$ by distance $\mathbf{D_i}$
3. Translate along x_i by distance $\mathbf{L_i}$
4. Rotate through positive $_{\mathbf{i}}$ around the $\mathbf{x_i}$ axis to align the z axes.

6.2 **Simulation results:**



The response variables and controllable factors use in modeling and simulation.

Number of different sizes of strips passing on assembly Line.

Cut the strips in specific sizes which are used to manufucature the pipe of different diameters.

Degree of Freedom (DOF) of robot arm.

Different degree of freedom of different robotics arms are used in this project .
The paper above discuss all these DOF.

Drawing of pipes though a Robot arm's Fingers.

Set the orientation and control the proper robotics inverse kinematics and lift the pipe from the molding machine and then place this on the welding compound.

Temperature at molding

Set the specific temperature and see the result at which the proper molding of strips taken place.

Welding Control

Control the high frequency electricity for welding .

7**. Conclusions**:

The study gave the industrial engineers , labors important insight into possible problem areas. The quantitative results from the **simulation** runs gave strong confidence in their own former estimates. And Top level management can understand the difficulties what the engineer may face during building the real factory environment.

Through the approach, we experienced extensive need for the following skills or disciplines.

- Computer programming
- Systems engineering
- Production engineering and automation
- Production control
- Logistics
- CAD

There were however different stages in the modelling and **simulation** process, where different skills were required.
Most of all, it was a time consuming activity to hardcode the more extensive logic. Approximately 60% of the time, was spent on programming. Since this was a new **simulation** tool , it was also very time consuming to comprehend the simulator software's way of generating and sequencing jobs.
During the modelling phase, it is easy to trapped by the boundaries of the design and layout draft. This truly put a wet blanket on the abstractive capabilities, and probably made the modelling phase more time consuming than with former icon-based **simulation** tools.
The most important experience was that during this detailed modelling phase, we were continuously challenged by apparently minor questions that sooner or later had to be dealt with. The questions were of such character that the consequences of neglecting them at an

early stage would later strike back in a more extensive way. In our study, the issues included both man and machine controlled mechanisms.

The lifelike Graphical model was a great encouragement for further work. The Graphical event based Robots and industrial presentation was given to both people with and without thorough knowledge in modelling or **simulation**. The essential experience was that through visualisation and animation, operators and engineers immediately recognized the manufacturing environment and started to point out .They can easily find the production capaicaity trough it .
Engineers are to assecc the required quantity of raw material for the required quantitiy of production of a particular size or a finished product.

8. **References :**

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http://www.robotic.dlr.de/STUDENTS/Martin.Rohrmeier/**robot**/**robot**.html
A Java 3.D **robot simulation** from MIT:

http://lorca.umh.es/isa/es/asignaturas/crss/practica%20easy.pdf.
A Visaul C based robot simulation software.