Getting Started with Robotics

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Güdel Inc
Getting Started with Bob

• Sales
• Housekeeping
• Keys
• Questions
• Videos
Getting Started with Robotics

• The Business Case for Robotics and Automation Dollars
• The Robotics Market and Industry
• Robot Technology
• System Technology
• Applications
Getting Started with Robotics

• The Business Case for Robotics and Automation Dollars
• The Robotics Market and Industry
• Robot Technology
• System Technology
• Applications
Robotics = Flexible Automation

- **Hard Automation**
  - High Volume
  - Requires Set-up time
  - More maintenance
  - Air Cylinders / actuators
  - Rigid conveyors / fixtures

- **Manual**
  - Fast product change
  - Breaks
  - Monotonous tasks
  - Health Claims
  - Labor Issues
  - Training

- **Flexible Automation**
  - Quick product change
  - Programmable
  - Repeatable
  - Changeable Cell configuration
  - Responds to Part Changes
Robot Definitions

• Dictionary
  • “An automatic apparatus or device that performs functions normally ascribed to a human or a machine in the form of a human.”

• Industrial robot as defined by ISO 8373:
  • An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications.

• Robota
  • Czech word for “forced labor” or “serf”
Why Automate?
Why Automate?

• Need to reduce direct labor
• Can’t get people to do the job
• Need to increase quality
• Difficult to do the job manually
• Need to increase production
• Difficult to meet specifications consistently
• Need to provide flexibility in processes
• Hazardous to personnel
What Do We Automate?

• Repetitious tasks
• Heavy tasks
• Dangerous tasks
• High speed moves
Buy a Robot and Save America

• Average wage for an unskilled worker is $15 - $20 per hour plus benefits
• Average UAW wage for unskilled trades is $30 - $35 per hour plus benefits
• Average wage for similar labor in China is $3 per hour plus benefits

Offshore Manufacturing Risks and Issues
• Higher transportation costs and more problems
• Longer delivery times
• Quality problems
• International concerns like terrorism
• Loss of real-time control of manufacturing
• Loss of ability to make quick product or process changes
• Loss of closeness to your market and your end customers

• A robot works 24/7/365 without breaks, benefits and legacy costs etc……
Buy a Robot and Save America

• 2 shifts per day material handling for 20 years (80,000 hours)
  • 30 Kg Size – 5.4 kVA rating
    • Electric rates 0.11 KwH = 0.594 cents per hour

• Maintenance Costs for 80,000 hours
  • 10,000 hour Lubrication – Lube 8 times
    • About $500 in lubrication costs = $4,000
  • 8 – 10 Years expect some form of unscheduled maintenance
    • $5,000 from typical Service Life Cycle Costs
    • 3 Times in 20 years = $15,000

• Well after 10 years refurbishment may be required
  • Typical cost for full refurbishment - $10,000
Do The Math

• 2 shifts / day for 20 Years
  • Rebuild once in 20 years………..$10,000
  • Maintenance for 20 years………..$19,000
    • Lubrication……………………$4,000
    • Unscheduled repairs…..$15,000
  • Power 0.59 x 80,000 hours………..$47,200
  • Total .................................. $76,200

• OR do it Manually.
  • 80,000 hours x $30.00………… $2,400,000

• Savings.................................. $2,323,800
Buy a Robot and Save America

• Back to the article in Forbes Magazine “Buy a Robot and Save America”
  • Average wage for an unskilled worker is $15 - $20 per hour plus benefits
  • Average UAW wage for unskilled trades is $30 - $35 per hour plus benefits
  • Average wage for similar labor in China is $3 per hour plus benefits(?).
  • Average wage for a robot is around $1 per hour with no benefits.

THIS IS THE BUSINESS CASE FOR ROBOTICS!
Total Value

- Assume a system cost of $250,000 for our application.
  - $250,000 / (80 hours X 52 weeks X 20 years) = $250,000 / 83,200 hours = $3.00 / hour

- Add the maintenance and operating costs over same period from the last slide to calculate the total cost to operate the robot system.
  - $76,200 / 83,200 = 0.92
  - Total = $3.00 + $0.92 = $3.92 / hour.

- Direct labor savings are often the only justification because they are easy to quantify

Very competitive with current labor costs!
More Than Just Labor Savings

- **Harder to Quantify benefits**
  - Increase in productivity
  - Improved quality
  - Material savings
  - Reduced scrap and rework
  - Improved flexibility
  - Reduced WIP
  - Reduced floor space

- **Additional Costs for manual labor**
  - Lunch and breaks = lost production time
  - Vacations = no production
  - Lost time due to injuries = no production
  - Employee turnover, training and retraining
  - Protective clothing and safety devices
  - Locker rooms, lunch rooms and supplies
  - Parking lot
  - Insurance
  - Pensions
  - Workers compensation
  - Cost of inconsistent unpredictable production

Justification should be STRATEGIC decision made by informed management that balances the short-term goal of SURVIVAL with the longer-term goal of GROWTH to posture company to have competitive advantage. It should not be an accounting function.
Justification Calculations

• Inputs
  • Financial inputs
    • System and startup costs, tax rates, payback period standards, cost of money, training costs
  • Labor
    • Current and future.
    • Operational / maintenance / management
  • Operational Items
    • Production increase, scrap reduction, consistency
    • Miscellaneous costs or savings

• Calculations
  • Savings, Investment, ROI Summary, Cash Flow Analysis
Justification On-Line
The Green Sand Casting

- **Create the mold**
  - mixture of sand, clay and moisture
  - simple materials
  - materials can be reused or recycled
  - low cost materials

- **Pour molten metal into the molds**

- **Remove the parts**

- **Machining or clean up is required**
  - Requires surface finish
Robotic Pouring

- Customer’s Results
  - Four times the manual capacity
    - Impeded by peripheral equipment
    - One part every 30 seconds
  - Reduced labor by three per shift
  - Energy reduction
    - Automatic furnace lid closure provides insulation
  - Operator Safety is vastly improved
  - Reduced material use
    - Same material quantity for every part
  - Parts consistency is 100% reliable
    - Repeatable process
  - Increased Parts Quality
    - Metal heat more consistent
    - Pour efficiency
Typical Performance

- **2 – 10 Kg Robots in Material Handling Application**
  - First Installed in 1991
    - Ran 5 second cycle time 3 shifts / day until 2003
  - Re Installed in 2005 (75% capacity)
    - Ran 10 second cycle time 3 shifts / day
  - Both retired in 2008 due to line reconfiguration

- **2 - 10 Kg Robots in Material Handling Application**
  - First installed in 1992
    - Ran 5 second cycle time 3 shifts / day until 2005
  - Reinstalled in late 2005 (75% capacity)
    - Ran 10 second cycle time 3 shifts / day
  - One retired late 2008 due to wiring harness failure
  - Second one is retired 2009

- **Replaced by 3 - 10 Kg Robots**
  - First Installed in 2008
  - Run a 4 second cycle time
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North American Economy

Why do people think the US isn't the leader anymore?
Employees in millions per industry

<table>
<thead>
<tr>
<th>Industry</th>
<th>Millions of Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health care and Social Assistance</td>
<td>18.6</td>
</tr>
<tr>
<td>Retail Trade</td>
<td>12.4</td>
</tr>
<tr>
<td>Accommodation and food services</td>
<td>11.3</td>
</tr>
<tr>
<td>Administrative/support and waste management</td>
<td>10.2</td>
</tr>
<tr>
<td>Professional, scientific, and technical</td>
<td>6.1</td>
</tr>
<tr>
<td>Finance and insurance</td>
<td>6.1</td>
</tr>
<tr>
<td>Wholesale trade</td>
<td>6.0</td>
</tr>
<tr>
<td>Construction</td>
<td>5.2</td>
</tr>
<tr>
<td>Other services (except public administration)</td>
<td>4.2</td>
</tr>
<tr>
<td>Transportation and warehousing</td>
<td>4.0</td>
</tr>
<tr>
<td>Educational Services</td>
<td>3.6</td>
</tr>
<tr>
<td>Information</td>
<td>3.3</td>
</tr>
<tr>
<td>Management of companies and enterprises</td>
<td>3.1</td>
</tr>
<tr>
<td>Arts, entertainment, and recreation</td>
<td>2.1</td>
</tr>
<tr>
<td>Real estate and rental and leasing</td>
<td>2.0</td>
</tr>
<tr>
<td>Mining, quarrying, and oil and gas extraction</td>
<td>0.7</td>
</tr>
<tr>
<td>Utilities</td>
<td>0.6</td>
</tr>
<tr>
<td>Agriculture, forestry, fishing and hunting</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Source: Census Bureau 2013 County Business Patterns

Facts Contrary to Popular Belief

Manufacturing and related industries still provide the 4th largest chance for employment in the USA
AND
Manufacturing related jobs are some of the best average paying jobs
Robots and Jobs

Robots Create Jobs.
Bill Gates’ and Mark Cuban’s idea to tax robots aims to solve a problem that does not exist.

Empirical analysis of economic data shows that automation and the use of robots creates new jobs by increasing productivity. This is in line with the historical experience of technological revolutions, last seen when computers and software automated the business world. According to the McKinsey Global Institute, more than 90 percent of jobs will not be fully automatable in the future. Instead, robots and humans will work together. The positive impact that the increased productivity of robots has on employment can already be seen in the most advanced industrial nations. The US automotive industry, for instance, installed more than 60,000 industrial robots between 2010 and 2015. During this same period, the number of employees in the US automotive sector increased by 230,000. Recent research by the OECD on the future of productivity shows that companies that employ technological innovation effectively are up to 10 times more productive than those that do not.
Industrial Robots History

- **1956**
  - George Devol & Joseph Engleberger met
  - First Working Model late 1959

- **1961**
  - Patented / first mass produced
  - First Installation
    - GM casting plant in Trenton, NJ
    - Die Cast Part Extractor

- **Unimate Robot**
  - First Industrial Robot
  - Weighed 4000 pounds
  - 500 Pound payload
  - Hydraulically Actuated
  - Step by Step Commands stored on a magnetic drum
  - Hydraulic Actuators
  - $100,000 Plus Price

- **Original Model**
  - In Smithsonian Institute
  - Many are still in operation today
Industrial Robot Market

• **Globally 2016**
  - 253,748 units sold
  - 10% Increase over 2015
  - China – 16% increase
  - Europe 9% Increase

• **North America 2016**
  - Revenue $1.9B
  - 34,606 Units
  - 10% growth over 2015
  - Distribution
    - 82% US
    - 7% Canada
    - 11% Mexico

• **Largest increase from 2015**
  - Automotive & Suppliers 25% Increase
  - Food and Consumer Goods 32% Increase

Only about 10% of the companies that could benefit from robots have installed any so far.
“Automation is a central competitive factor for traditional manufacturing groups, but is also becoming increasingly important for small and medium-sized enterprises around the world”, says Joe Gemma, President of the International Federation.
Robot Manufacturers Today

Robot manufacturers and Integrators are at the Automate Show
How We Work in Industrial Robotics

• **Robot Manufacturers**
  - Manufactures the robot
  - Provides robot training, maintenance and service

• **System Integrator [System Builder]**
  - Integrate the robot into a system to perform a specified task
    - Independent business, industry specific, allegiance to robot manufacturer
    - Has knowledge of End User’s business
  - Provides system components, installation, training, service and support
    - Design and build the robot based system
    - Purchases robot and all peripheral equipment
    - Designs and builds systems, writes and maintains programs
    - Trained on entire cell / provides training on system

• **End Users**
  - Uses the robotic based system in production or processing
  - Knows what is required to accomplish tasks
  - Ultimate user - needs training, service, maintenance, spare parts

Our most successful projects are when all three work together
Traditional Applications

- Spot Welding
- Arc Welding
- Coating & Dispensing
  - Less than 10 pounds
  - Greater than 10 pounds
- Assembly
  - Less than 10 pounds
  - Greater than 10 pounds
- Material Handling
  - Packaging / Palletizing
  - Machine Tending
  - Body Shop
  - Other Material Handling
- Material Removal
- Inspection
New Applications and Markets

- **Service Industry**
  - Food Service – RoboBar
  - Care for the Elderly
  - Emergency Service – Humanoids
  - TV / Movie cameras

- **Medical and Pharmaceutical Industries**
  - Prescription Dispensers
  - Hair Restoration
  - Surgery System or Doctor Guidance
  - Prosthetics Research and Design

- **Food and Beverage**
  - Processing
  - Agricultural

- **Warehousing**
  - ASRS Systems

New markets and applications are identified every day.
Beyond Industrial Robots
General Terminology

• **Work Envelope, Work Space or Reach**
  • Range of Motion (mm)
  • The set of points representing the maximum extent or reach of the robot hand or working tool in all directions. Also referred to as the working envelope or robot operating envelope.

• **Payload**
  • Weight carrying capacity (Kg)
  • The maximum total weight that can be applied to the end of the robot arm without a sacrifice of any of the applicable published specifications of the robot.

• **Cycle Time or Speed**
  • Execution time for one task

• **Inertia / Torque**
The Axes – Degrees of Freedom

• **Degrees of Freedom - Axes**
  - Direction or number of ways to specify robot motion in a linear or rotary mode.

• Joint 1 - Base Rotation
• Joint 2 - Rotation of the lower arm
• Joint 3 - Rotation the upper arm
• Joint 4 - Swivel of the upper arm
• Joint 5 - Bend of the wrist
• Joint 6 - Rotation of tool mounting plate

• Joint 7 - ??? – External Axes

• Tool Center Point

Example is a 6 axis articulated robot
External Axes / Cooperative Motion

Axis 1 to 6
Robot

Axis 8 and 9
Sky Hooks

Axis 10 and 11
Part Spinners

Axis 7
Turntable
Axis Speeds

- Rotational axes rated in degrees per second (°/s)
- Linear axes rated in millimeters per second (mm/s)
- Generally rated at full speed, full payload, full range of motion
  - Or defined at a particular CG, listed as Nominal and Max or a caveat is given

How does this relate to your needs?

- Parts per minute
- Parts per hour
- Tact time / Cycles

Industry Standard “Adept” Cycle

300 mm

25 mm
Repeatability

- Repeatability
  - Ability of the robot to return to a preprogrammed position.
  - Closeness of agreement of repeated position movements under the same conditions to the same location.

The Robot can stop anywhere within the 0.008” diameter circle and still fall within the repeatability specification.

Assume repeatability to be +/- 0.004”
Typical Specifications

Reach
Speed
Payload
Inertia
Repeatability

Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>M-7101C/50H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Articulated Type</td>
</tr>
<tr>
<td>Controlled axes</td>
<td>5 axes (J1, J2, J3, J5, J6)</td>
</tr>
<tr>
<td>Speed</td>
<td>6.39 m/min (12.50 mm/min)</td>
</tr>
<tr>
<td>Installation</td>
<td>Floor type</td>
</tr>
<tr>
<td>Motion range</td>
<td>Minimum speed (Note 1)</td>
</tr>
<tr>
<td>J1 axis rotation</td>
<td>6.39 m/min (12.50 mm/min)</td>
</tr>
<tr>
<td>J2 axis rotation</td>
<td>6.39 m/min (12.50 mm/min)</td>
</tr>
<tr>
<td>J3 axis rotation</td>
<td>6.39 m/min (12.50 mm/min)</td>
</tr>
<tr>
<td>J4 axis rotation</td>
<td>6.39 m/min (12.50 mm/min)</td>
</tr>
<tr>
<td>J5 axis rotation</td>
<td>6.39 m/min (12.50 mm/min)</td>
</tr>
<tr>
<td>J6 axis rotation</td>
<td>6.39 m/min (12.50 mm/min)</td>
</tr>
<tr>
<td>Payload</td>
<td>540 kg</td>
</tr>
<tr>
<td>Mass, basic (USB)</td>
<td>540 kg</td>
</tr>
<tr>
<td>Installation environment</td>
<td>Ambient temperature: -40°C to 60°C</td>
</tr>
<tr>
<td>Note 1</td>
<td>During short distance motions, the axis speed may not reach the maximum value stated in Note 2.</td>
</tr>
<tr>
<td>Note 2</td>
<td>The maximum speed at J3 axis is limited by payload at wrist.</td>
</tr>
<tr>
<td>Note 3</td>
<td>Without controller.</td>
</tr>
</tbody>
</table>
Common Industrial Robots

- Cartesian / Gantry
- SCARA
- Telescopic
- Delta Class
- Fast Picker
- Snakes
- Paint
- Articulated
- AGV
- Modular
Cartesian / Gantry Robots

• Four Plus Axes
• Simple Motions
  • Linear X, Y, Z
  • Tool Rotation / Wrist
• Components
  • Structure
  • Carriage
  • Beams
  • Telescope
  • Controls

Palletizing, Logistics
Material Handling
Large / Heavy payload
SCARA Robots

- **Four Degrees of Freedom**
  - One Linear Axis and three Rotary Axes

- **Motions**
  - Rotational
  - Linear Z Axis

- **Highly Accurate**
  - $\pm 0.01$ mm

- **Low payloads**

- **Fast and Vibration Free**
  - Adept Cycle: 0.30 – 0.35 seconds

Packaging
Pick and place
Sorting and Orienting
Assembly
Telescopic Robots

- 3, 4 and 5 Axis designs
- Clean Room Requirements
- Application Specific
  - Wafer handling
  - Larger ones for Flat
“Delta” Class Robots

• 3 Axes – Tripod
  • 4th is optional spin or wrist

• Sorting and Picking
  • Higher level vision required
  • Conveyor Tracking function

• Low Payload

Packaging
Pick and Place
Sorting and Orienting
Fast Picker

• **High Speed Pick and Place**
  • 200 Picks per minute
  • Highly Accurate
  • Very rigid
  • Clean Design

• **Sorting and Picking**
  • Vision typically required
  • Conveyor Tracking function

• **Payload**
  • 1 Kg or less
‘Snake’ Robots

- Multiple Axes
- Stack of Servo Motors
- Slim Shape
- Advanced Movements
- Use in Hard to Reach Applications
- Typically just in Automotive

Part Transfer
Pick and Place
Dispensing
Articulated Robots

- 4, 5 or 6 Axis Designs
  - Rotational Motion
- 3 Kg to 1000 Kg Payload

Welding – Resistance / MIG / TIG
Pick and Place
Material Handling
Palletizing
Dispensing
Sorting
Packaging
Many, many others …………

Most Common / Most Flexible
Paint Robots

- 6 Axis Articulated
  - Designed for Intrinsically Safe Environment
  - Solvent / Hazardous Duty Areas

- Different Wrists

- Different Motion and Movement

- Specific for Paint
High Payload / Heavy Lifters

- **Up to 2.5 Ton Payload**
- **Applications**
  - Automotive Body Shop
  - Railroad Parts
  - Tooling changes (?)
  - Set Castings onto Machines
  - Sand Casting Mold Coating
Assembly Robots

- Machine emulating Man
- Dual Arms

Targeted at the huge Electronic Manufacturing Systems Industry
Modular Robots

- System with a combination of robot types
- Multiple Axes
Specialty Industrial Robots

- Clean Room
- Machining
- Food Grade
- Wash Down
- Sterile
- Stainless Steel
- Hazardous Duty
AGV’s

• Automated Guided Vehicle
  • Floor Markers
  • Vision or Lasers

• Material Movement
Collaborative Robots

• Robots working with Humans
  • Low Payloads
  • Slow Speed
  • Manually Programmed
  • Designed to work without standard safety fence
    • Requires Safety Risk Assessment

• Stop when a hazard is physically encountered
Collaborative Industrial Robots

• Intended to work safely with humans

• Industrial Requirements
  • Higher speed, heavier payload, repeatable processes
  • Stalling or sensing impact when it encounters an obstruction may not always work
    • Cycle time, Payload, Tooling issues
  • Needs to slow or cycle stop when a hazard approaches
  • Must be aware of all obstructions
    • Humans, tooling and others
  • Requires Safety Rated Devices
  • Last 15 – 20 years

• Robot manufacturers offer
  • Speed and Separation Monitoring
  • Safety Rated Monitored Stop
  • Power and Force Limiting Systems
  • Hand Guided Programming

End User must perform the Risk Assessment
Collaborative Industrial Robots

- **Safe Stop**
  - Allows the arm to be safely stopped without disabling its power

- **Safe Speed**
  - Allows dynamic velocity adjustment based on external sensors

- **Safe Zone**
  - Allows definition of a zone that the robot is prohibited from entering

- **Safe Tool**
  - Allows definition of a virtual zone around the tool to prevent it from entering a prohibited area.
Notching Door Sweeps

- Manually
  - Very Slow
  - Only task the human can do
  - Mistakes create scrap
- Collaboratively with a Robot
  - Robot consistency eliminated scrap
  - Robot allows the human time to do other tasks
  - Robotic process eliminated another operation

The plant was considering moving this process offshore
Customer Benefits

System is in the center of the production area so the employees see it

- **Employees witness the robot:**
  - Protecting production by eliminating rework,
  - Protecting the company’s investment by being aware of the tooling, the base, the parts and by not damaging them in operation
  - Saving the company money
  - Seeing it is safe for their coworkers to operate.

- It has eliminated the fear of automation and robotics in this plant
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Robot Components

Arm and Controller

Generally one robot arm per controller
Robot Arm or Manipulator

- Wrist
- Tool Mounting
- Arms
- Base
- Joints 4, 5 & 6 Motors
- Counter Balance
- Joints 1, 2 & 3 Motors
- Floor Anchors
Drive System

- **Design**
  - Belt or Direct Drive

- **Components**
  - Brushless AC Servomotors
  - Absolute Encoders / Resolvers
  - Gears
  - Couplings
  - Timing Belts
  - Drives
  - Castings

- **Maintenance**
  - None
  - Lubrication

15 Minute Mean Time to Repair
Robot Installation and Mounting

• **Installation**
  - Floor - 4” Thick Concrete
  - Ceiling or Wall – structurally capable
  - Direct to the Floor or on a Riser
  - Common Base for Systems

• **Proper floor fasteners- No Casters**

• **Tracks**
  - Floor or Overhead
  - Extends the reach of the robot
Robot Environment

• **Typical Environmental Specifications**
  - IP54 / 65 / 67 Standard
  - Ambient Temperature: 0 – 52°C
  - Relative Humidity: 35% - 85% Non Condensing
  - Vibration: less than 0.5 G

• **Outside the Robot’s specs?**
  - Use a robot specific to the environment

• **Covers**
  - Basic drapes for dirt protection
  - Water resistant
  - Cooled or Heated
  - Acid Resistant
  - Air Purged

• **Other Protection**
  - Heat Shields
  - Water Cooling
  - Air Purged
  - Corrosion protection
Robot Control

- **Components**
  - Controller
  - Teach Pendant
  - Cables
  - Software
• **Design**
  - Houses Servo Amplifiers
  - Houses Signal Amplifiers
  - Houses Power Blocks
  - Houses Programmable Controller
  - Teach Pendant connects to the Controller

• **Functions**
  - Robot Motion - Drives motors
    - Coordinates all axes to control the Tool Center Point
  - Controls I/O
    - Digital
    - Analog in / out
  - Communicates with production system
  - Modifies tasks per input or instruction
  - Networks
  - Collects Data
  - Maintenance Monitoring
Controller Components

- Teach Pendant
- Disconnect
- Memory / AC Power
- Motor Control Center
- Transformer
- Operator Panel
- PC Board Rack
- Power Block for Additional Axes
- Power Block for Axes 1 thru 6

15 Minute Mean Time to Repair
The Operator’s Panel

- **The Operator’s Panel**
  - Apply motor power
  - Cycle start programs
  - Hold or stop programs
  - Select modes of operation
  - Reset errors
  - Determine motor power status
  - Determine error status
  - E – Stop

- **Working Mode Box**
  - Provides functions when the controller is rack mounted

Break release switches are used to manually release the axes brakes with motor power OFF.
Teach Pendant

- **Design**
  - Hand Held
  - LCD Display
  - Hard keys for Functions / Keyboard

- **Functions**
  - Communicates with Controller
  - Dead man Switches
  - E - Stop
  - User’s Interface to the Controller
    - Monitor
    - Teaching / Programming
  - Operator’s System Interface Possibility
  - On the floor program access and touch up
Cable Management

- **Robot Cables**
  - Between the Arm and the Controller
  - Teach Pendant
  - Power drop
  - Signals
Software

- **Position Based**
  - Motion Commands
  - Coded Commands
  - Intended to be Autonomous
  - Different for different manufacturers

```plaintext
begin
movej(p1,tGripper,mNomSpeed)
movesj(appro(p3,trAppro),tGripper,mNomSpeed)
movel(p3,tGripper,mNomSpeed)
close(tGripper)
movesj(appro(p5,trAppro),tGripper,mNomSpeed)
movel(p5,tGripper,mNomSpeed)
on(eGripper)
movesj(p1,tGripper,mNomSpeed)
end
```

- Move to P1 (a general safe position)
- Move to P2 (an approach to P3)
- Move to P3 (a position to pick the object)
- Close the gripper
- Move to P4 (an approach to P5)
- On (tGripper)
Programming vs Teaching

• **Teaching**
  - To move a robot through a series of points to be stored in memory for the robot to perform its intended task.
  - Teaching is typically performed on-line by means of a teach pendant.
  - Can move some robots manually and record points

• **Programming**
  - Developing the set of instructions that causes the robot to execute a specific task.
  - Can be performed on-line or off-line
Simulation & Off Line Programming

• **Build the system in 3D software**
  - Tool for system design
  - Watch and check system operation
  - Verify robot size
  - Verify no crash conditions exist
  - Virtually program the robots

• **Off Line Programming**
  - Program is written remotely
  - Higher level language is used
  - Loaded into Robot Controller
  - Teach pendant touch up is required
Basic Motion Commands

- **Motion Instruction**
  - Defines a target position

- **Interpolation Instruction**
  - Defines how to get to the position
  - **Joint Move** - Robot articulates any axis to accomplish the move
  - **Linear Move** - Maintains the tool in the orientation specified
  - **Circular Move** - Three points and a radius to scribe a circle

- **Speed**
  - Expressed in percent of full speed or a software set maximum speed

- **Termination Instruction**
  - Expressed as a number [1 - 9] most to least accurate.
  - Defines approach to the target position

- **Additional Programming Activities**
  - Actions to be complete before moving to the next target position
    - I / O switching
    - Data acquisition
Software Packages

- Simulation and Off Line
- Graphical / GUI Overlay
- Soft Absorber
- Conveyor Tracking
- Cooperative Motion
- Application Specific
  - Plastic IMM Specific
  - Palletizing
  - Welding
  - Dispensing
  - Tending
  - Paint
  - User Defined
- Operator Interface
- Maintenance Log
- Help Function or Users Manuals
  - Customizable
- Line Management or Load Balance
Getting Started with Robotics

• The Business Case for Robotics and Automation Dollars
• The Robotics Market and Industry
• Robot Technology
• System Technology
• Applications
General System Thoughts

- **Users require a system**
- **Robots are a Mature Product**
  - Pre-engineered / production devices
    - Various models to choose from
  - Very little customization at the robot level
  - Repeatable
    - Must have methods to deal with random events
  - Programmability provides the flexibility
- **Systems**
  - Some are Mature Products
  - Building blocks for designs
  - Many are Custom Designs

Users need a system. Not just a robot
Industrial Robot Systems

- **System Components**
  - Robot and Controller
  - Arm Dressing and Risers
  - Operator Interface
  - End of Arm Tooling
  - Parts Fixtures or Locators
  - Interfaces
  - Pneumatics
  - Sensors
  - Electrical Components
  - Cables
  - Peripheral Equipment
    - Varies by application
  - Controls
  - Communication
  - Safety Components
    - Fence, Gates, Interlocks, Light Curtains, Barriers, Awareness Beacons, Risk Assessment
    - POC, Design, program, build, project management, set up for run off, testing and training
    - Shipping, Site preparation, Installation, Run Off and commissioning

The robot arm is only part of your robot system
Robot System Components

- Arm Dressing
- Robot
- Tooling
- Robot Riser
- System Controller
- Robot Controller
- Safety Fence

A technician working in the control box is not a system requirement
System Development Process

- **Recognize the Need**
  - Determine if Robotics are an Applicable Solution

- **Identify the System Specifications**
  - What do you want to do?
    - Existing Process, Reach, Payload, Speed, Operator Involvement, QC Issues, Interface with Production System, Technological Capability of User
  - Who is going to Integrate the system?
  - Future Needs

- **System Design and Build**
  - Preliminary Layouts and Design Proposal
    - Space Required, Parts Movement, Tooling, Safety Concerns, I/O, Interfaces and Communication, Operator Involvement
    - Simulations / Cycle Time Study / Verification Tests
  - Build and test the system prior to shipment
  - Installation site prep

- **System Start Up and Commissioning**
  - Install, Start-up and Customer Acceptance
  - Continuous Improvement

Involves all parties that will interface the system in the development to assure acceptance when the system is installed
Selecting a Systems Integrator

- **Determine if the Integrator has experience in your industry**
  - Transferable knowledge

- **Evaluate the Integrator’s background and capabilities**
  - Full Service
  - Commercial Issues

- **Check references**
  - The Integrator’s
  - Robot Manufacturers

- **Prepare for disaster**
  - What happens?

- **After sale maintenance**
  - Integrator
  - Robot manufacturer

- **Cost**
  - Is the lowest bid the best?
**Tooling / End Effectors / E.O.A.T**

- The tool attached to the robot arm that actually performs the work.
  - Vacuum Cups
  - Grippers
  - Spatulas / Fingers
  - Spray Nozzles
  - Dispensers
  - Buffing Wheels
  - Machine Tools
  - Water Jets
  - Welding Torches
  - Resistance Welding Guns
  - Saws
  - Laser Cutters
  - Ladles
  - Surgery Implements

Adds to the envelope, payload, torque and inertia.
Tooling Considerations

- **Tooling Vendors**
  - Purchased Component
  - Or custom made per application

- **Design Considerations**
  - Product Considerations
  - “Building Blocks”
  - Repeatable and Positive
  - Include Sensors
    - Part locators / verification of action / QC
  - Environmental Considerations

- **Tool Changers**
  - Manual
  - Quick change
  - Automatic
Arm Dressing

- **Arm Dressing**
  - Services mounted on the arm
    - Cables, air lines, others
    - Internal wiring and pneumatic lines offered
    - Need to secure and account for motion
- **Internal wiring and pneumatic lines are provided**
  - Hollow arms or wrists
  - Holes for cable guides
- **External may be necessary**
  - Vendors or custom
Part Fixture Considerations

- **Tooling Vendors**
  - Purchased Components
  - Custom made per application

- **Design Considerations**
  - Product Considerations
  - Repeatable and Positive
  - Sensors
    - Part locators / verification of action / QC
  - Environmental Considerations

- **No Parts Fixture?**
  - Can Locate – sensors or vision
  - Fixture less system design
  - Cooperative motion
Vision System Applications
Vision Systems

- **Peripheral Equipment**
  - Camera
  - Camera Controller
  - Light Source
  - Calibration Check Means

- **Robot Components**
  - Robot and Controller
  - Interface to Camera Controller
  - Software

- **Applications**
  - Part Location
  - Robot Guidance
  - Inspection
  - Real Time Feedback
Line Balance

- **Method one - Traditional**
  - Handle the maximum amount of parts possible with the first robot
  - Robots used at the highest speed and acceleration
  - Each robot will pass the parts that it cannot handle to the next robot downstream
  - Priority is given to the parts with the greatest advancement in the working area.
  - Out feed conveyor speed is not controlled by the process

- **Method Two – New technology**
  - Robot speed and conveyor speed(s) are controlled
  - Parts and trajectories are assigned to each robot in the stream
  - Parallel or Counter flow configurations are possible
  - Priority is given to either pick all the incoming parts, fill all the out going spaces or both

Software provides part traceability through the system
System Safety Responsibilities

- **Robot Manufacturer**
  - All E-stops are hard wired
  - Mushroom Button E-Stops
  - "Dead-man" Switch
  - Robot velocities are constantly monitored
  - Teach and Check velocities are severely limited
  - Joints equipped with Hard Stops
  - Joints equipped with over-travel limit switches
  - All robot axes have software limits for work space
  - Velocity and deviation errors are constantly monitored
  - All axes equipped with electromechanical brakes
  - Crash software
  - Error messages
  - Training
  - Risk Assessment

- **System Integrator**
  - Personnel barrier
  - Interlocked safety gates / light curtains
  - E-Stop switches strategically placed
  - Awareness barrier
  - Status beacon or signal
  - Maximum envelope marking
  - Behavior management
  - Training
  - Risk Assessment

- **End User**
  - Behavior Management
    - Personnel training
    - No tolerance on misbehavior
  - Maintain safety equipment
  - Risk Assessment

Contact Carole Franklin at the RIA
Resources in Robot Safety

• RIA
  • National Robot Safety Conference
  • Standards meetings
  • Offers Safety Training classes

• RIA Safety Resources
  • Robot Safety Standards
    • RIA/ANSI R15.06:2012
    • RIA/ANSI/ISO 10218-1:201
  • ANSI Technical Reports
    • The 306 – Guides for Risk Assessment
    • The 406 – Use of Safeguarding devices
    • The 506 – describes applying the 2012 standard to older systems
  • ISO/TS-15066:2016, Collaborative Robots

• Participate in a Committee

Get involved. Great networking opportunity
Basic System Process Control

• **Process Control**
  • Communication to external equipment and production system
  • Operator Control of entire system
    • Philosophy with robot controller
  • Define where event is to occur in robot path – at end of move?
  • What action is to occur when the event happens
  • Program / Product Selection
  • Auto Start of entire line

• **Process Monitoring**
  • Data Collection
  • Diagnostics
  • Maintenance
  • Quality Control
  • Process Flow
System Control Philosophy

• **Philosophy 1**
  • Robot Controller does all
    • System I/O, Tooling Control, Motion Control, Operator Interface

• **Philosophy 2**
  • Robot Controller
    • Tooling Control, Motion Control
  • PLC or PC
    • System I/O, Operator Interface

• **Philosophy 3**
  • Robot Controller
    • Motion Control only
  • PLC or PC
    • System I/O, Tooling Control, Operator Interface

• **Philosophy 4**
  • Robot Controller
    • Robot Drives only
  • PLC or PC
    • System I/O, Tooling Control, Operator Interface
    • System Controller has kinematics for the arm
Crashes

- **Crash Avoidance**
  - Software Limits / Zones
  - Hard stops
  - Programming
  - Speed reduction in teach and check
  - Priority in Multiple robot cells
  - Master / Slave

- **Crash Detection**
  - Feedback
  - Mechanical Means
  - Crash Detection Software
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10+ Mistakes in System Integration

- Underestimating Payload, Torque and Inertia.
- Expecting the robot to do too much.
- Overlooking the need for options or peripheral equipment.
- Underestimating Cable Management Issues.
- Not considering all current and future application needs.
- Misunderstanding accuracy and repeatability.
- Not fully utilizing the capabilities of a robot.
- Choosing a robot or system solution solely on price.
- Failure to consider using robotic technology.
- Thinking that robots are too complicated.
- Focusing on the robot alone.
- Not planning for disaster.
- Not selecting the “easy” application first.
Applications Per RIA Classification

- **Spot Welding** - Car Bodies
- **Arc Welding** - Ship Building
- **Coating & Dispensing**
  - Less than 10 pounds – Oven Enameling
  - Greater than 10 pounds – Car bodies, Facias
- **Assembly**
  - Less than 10 pounds – Sutures
  - Greater than 10 pounds – Wiring Light Fixtures
- **Material Handling**
  - Castings, Chickens
  - Packaging – Cookies, Bread Loaves
  - Palletizing – Bags
  - Logistics – ASRS, Shipping Containers
  - Machine Tending – Forging, Power Train Machining
  - Body Shop – Press Tending
- **Material Removal** – Grinding
- **Inspection**
- **Undefined** – Machining, De-boning, Bowling
Spot Welding

- **Product**
  - Body in White
  - Ergonomic
    - Bulky and heavy Welding Gun
  - Labor Savings - significant
  - Consistency in weld process
  - Numerous Welds per station shortens production line
Paint

• **Product**
  • Car Bodies
  • Bumper Facias
  • Ergonomic Issues
  • Person is not in the breathing apparatus
  • Person is not in Explosion Proof area
  • Large Labor Savings
  • Consistent finish
  • Material Savings
Coating and Dispensing

- **Product**
  - Oven Enameling
  - Ergonomic Issues
  - Person is not in the breathing apparatus
  - Large Labor Savings
  - Consistent finish
  - Material Savings
Assembly

**Product**
- Wiring Fluorescent Light Fixtures
- Assembling Sutures
- Removed Ergonomic Issues
- Labor Savings
  - Eliminate manual operation
- Improve quality of wiring
- Reduce wire use
- Reduced pre-wiring operations
- Standardized assembly
Material Handling

• Product
  • Castings
  • Chickens
  • Ergonomic Issue
    • Repetitive motion
  • Labor Reduction
  • Difficult to get people to do this task
  • Quality Improvement
  • Cost reduction
  • Reduced Contamination
Material Handling - Packaging

- **Product**
  - Sausages
  - Bread Loaves
  - Ergonomic issues
    - Speed of motion
    - Repetitive motion
  - Quality of Package
  - Reduced potential for contamination
Material Handling - Palletizing

• **Product**
  - Bags and bales
  - Pallet layers
  - Ergonomic issues eliminated
    - Back Strain from Lifting
    - Repetitive motion
  - Labor Savings - numerous people per line
  - Difficult to get people to do this task
  - Quality of stack / Package
  - Cost reduction
Material Handling - Logistics

- **Product – ASRS Systems**
  - Boxes
  - Pallet layers
  - Ergonomic issues
    - Heavy / bulky product
  - Labor Reduction
    - 2+ people per container
  - Enclosed environment eliminated
  - Stack Consistency
  - Very repetitive and boring work
Machine Tending

- **Product**
  - Forging Press
  - Power Train machining

- WIP is eliminated
- Ergonomic issues eliminated in this task
  - Handling hot parts
  - Repetitive Motion
- Difficult to get people to do this task
- Speed of Operation is greatly increased
- Cost reduction
Press Tending
Material Removal
Machining

- 3/8 router
- Feed rate = 1500 mm/min
- Rotational speed = 20,000 rpm
De-boning

**Product**
- Hams
  - 500 hams per hour
  - Eliminates risk of contamination
  - Removes people from wet area
    - 20+ People
  - Eliminates possibility of cuts
  - Increases yield
  - Huge cost savings
Robotic Bowling

- **Product**
  - Bowling against a Robot

- **Motivation**
  - No Ergonomic Issues
  - No Labor Savings
  - Wins every game
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