Laboratory Exercises: The laboratory exercises are to be done in teams of two (or one) outside of class time. Each lab report must be submitted on time to Blackboard according to the schedule shown in the EE/ME 4290/5290 Syllabus. Each laboratory requires a single written technical report, for the team, with a Memo. Each LMP report is worth 10 points.

Each lab should be completed with the same partner all semester, if possible (or solo all semester is fine). If you have a partner, both partners must work and write equally for each LMP report submission (absolutely no alternating assignments with your partner!). Turn in one report with both names for all lab submissions. Normally both partners will earn the same grade.

NO LATE ASSIGNMENTS WILL BE ACCEPTED! NO LMP GRADE WILL BE DROPPED!! Your laboratory reports for all submissions must include plenty of graphics — sketches, photographs, etc., to support your results. Be sure to properly reference any graphics obtained from an outside source.

Safety: Even though these activities are more virtual than physical, for any hardware interaction, safety is of PARAMOUNT IMPORTANCE!! You must have at least one other person in the laboratory with you at all times; use common sense.

Laboratory Mini-Projects Summary

1. Planar and spatial robot mobility (number of degrees-of-freedom, dof)
2. Robot reachable workspaces
3. Adept SCARA Industrial Robot sketches, modeling, DH parameters, joint limits, workspace
4. DARwIn-OP robot sketches, modeling, DH parameters, joint limits, and workspace
5. Industrial kinematically-redundant robot (KRR) report
6. Industrial parallel robot report
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Laboratory Reports Format

Each submitted lab report must be formal and of technical report quality. They needn’t be long but they must be complete. The MUST include plenty of graphics: sketches, diagrams, and digital photos. If a figure comes from another source, you MUST reference that source. Here is the required report format for each EE/ME 4290/5290 lab report:

1. The cover sheet must be the memo, serving as the Executive Summary: abstract and mini-results, mini-discussion, and mini-conclusion.
2. Problem statement
3. Results
4. Discussion
5. Conclusion
6. References
7. Appendices (if necessary)
Laboratory Mini-Project Assignments

Laboratory Mini-Project **LMP 1**

*Calculation of mobility (number of degrees-of-freedom) for various planar and spatial serial and parallel robots*

Use the appropriate mobility equation (planar or spatial) to calculate the number of degrees-of-freedom for each of the following robots:
- The six planar robots and one mechanism on the next page.
- The eight spatial robots on the ensuing two pages.

For **all** cases, ignore the gripper or other end-effector dof (e.g. ignore the fingers in the human arm).

You **must** fill in the tables below:

### Planar Serial Robots

<table>
<thead>
<tr>
<th>Name</th>
<th>( N )</th>
<th>( J_1 )</th>
<th>( J_2 )</th>
<th>( M )</th>
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</thead>
<tbody>
<tr>
<td>2R serial robot</td>
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<tr>
<td>3R serial robot</td>
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<tr>
<td>4R serial robot</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>RRPR serial robot</td>
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</tr>
<tr>
<td>5-bar <strong>RRRRR</strong> parallel robot</td>
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<tr>
<td>3-RRR parallel robot</td>
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<td></td>
</tr>
<tr>
<td>Parallel jaw gripper</td>
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</table>

### Spatial Serial Robots

<table>
<thead>
<tr>
<th>Name</th>
<th>( N )</th>
<th>( J_1 )</th>
<th>( J_2 )</th>
<th>( J_3 )</th>
<th>( M )</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRPR SCARA serial robot</td>
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<tr>
<td>5R Mitsubishi serial robot</td>
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<td>6R PUMA serial robot</td>
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<tr>
<td>7R FTS serial robot</td>
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<tr>
<td>SRS Human arm</td>
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<tr>
<td>8R ARMII serial robot</td>
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</tr>
<tr>
<td>6-UPS Stewart platform</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>3-RUU Delta parallel robot</td>
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</tbody>
</table>

Make your own sketches for each of these devices. Clearly indicate the rotation and other active motion axes. You must also provide discussion for all of your planar and spatial mobility results.
Planar robots:

- 2R serial robot
- 3R serial robot
- 4R serial robot
- RRPR serial robot
- 5-bar _RRRRR_ parallel robot
- 3-RRR parallel robot

Parallel jaw gripper mechanism
Spatial robots:

- RRPR SCARA serial robot
- 5R Mitsubishi serial robot
- 6R PUMA serial robot
- 7R Flight Telerobotic Servicer (FTS) serial robot
- SRRU Human arm (ignore hand freedoms)
- 8R NASA ARMII serial robot
6-UPS Stewart platform parallel robot

3-RUU translational-only Delta parallel robot
Laboratory Mini-Project **LMP 2**

**Reachable workspace of various common robot architectures**

With your partner, draw the reachable (translational) workspaces of the following spatial robot designs, assuming realistic joint limits for each case.

- 3-dof 3P Cartesian serial robot
- 3-dof PRP Cylindrical serial robot
- 3-dof RRP Spherical serial robot
- 3-dof 3-RUU translational-only Delta parallel robot
- 4-dof RRPR SCARA serial robot
- 4-dof 4R Articulated serial robot
- 6-dof 6-UPS Stewart Platform parallel robot
- 8-dof Cartesian Contour Crafting Cable-Suspended parallel robot

Discuss the advantages and disadvantages of the reachable workspaces of each of the above cases, relative to each other, assuming similar sizes.

As usual, include plenty of graphics to demonstrate your discussions.
Laboratory Mini-Project LMP 3

Adept SCARA Industrial Robot sketches, modeling, DH parameters, joint limits, and workspace

For the ADEPT 550 SCARA table-top industrial robot in the Stocker 015B lab:

- What does SCARA stand for?
- Identify all active joints of the Adept 550 SCARA robot; include joint variable names for each.
- Measure all important dimensions for the Adept 550 SCARA robot (units: m and deg)
- Identify the robot power source, actuators, and transmissions.
- Identify the power source and actuation of the gripper.
- Sketch the kinematic diagram
- Attach the coordinate frames
- Derive the Denavit-Hartenberg Parameters
- Determine the joint limits – report in a clear table, using deg units (mm for the prismatic joint)
- Sketch the approximate translational workspace of this robot

This activity should definitely be done in the lab – feel free to use the Adept 550 manual. DO NOT remove this manual from the lab at any time for any reason! You are also free to use any valid Internet resources to answer each part – be sure to reference your sources in a professional manner.

As with all lab reports, include plenty of sketches, diagrams, and photographs for all important items in this assignment.

For your convenience, here is the Adept 550 User Manual:

Laboratory Mini-Project LMP 4

**DARwIn-OP robot sketches, modeling, DH parameters, joint limits, and workspace**
*Note: all graduate students must substitute the Baxter Robot System for DARwIn-OP*

For one of the 20-dof DARwIn-OP autonomous humanoid robots in the Stocker 402A robotics lab, focus on one arm if you are a team of undergraduate students, but focus on one leg if you are a team of graduate students. For a mixed undergrad and grad team, focus on one leg.

- What does DARwIn-OP stand for?
- Sketch the kinematic diagram of your assigned serial chain (you choose left or right, arm for undergrads and leg for grads)
- Attach the coordinate frames
- Derive the Denavit-Hartenberg Parameters
- Determine the joint limits – report in a clear table, using deg units
- Sketch the approximate translational workspace of your assigned serial chain (arm or leg)
- What is the OS and programming environment?
- What is the power source? How long does it last?
- What sensors are used?
- What control methods are used?
- DARwIn was clearly designed to play soccer. List at least three additional tasks/applications that DARwIn could do that do not involve soccer or other sports.

This activity should definitely be done at least partially in the lab, so you can understand the robot motions. Also feel free to use any DARwIn-OP information on-line – be sure to reference all of your sources in a professional manner. The on-line Darwin manual can be found here: [www.ohio.edu/mechanical-faculty/williams/html/PDF/DarwinQuickStart.pdf](http://www.ohio.edu/mechanical-faculty/williams/html/PDF/DarwinQuickStart.pdf)

As with all lab reports, include plenty of sketches, diagrams, and photographs for all important items in this assignment.
Laboratory Mini-Project LMP 5

In-depth study and report on a specific serial industrial kinematically-redundant robot of your choosing

A kinematically-redundant robot (KRR) is one that has more active joints \((n\text{-dof})\) than the required Cartesian motions \((m\text{-dof})\). For example, our 3D world requires 6 Cartesian dof \((x, y, z, \text{ roll, pitch, yaw})\) and so any serial robot with 7 joints or higher is kinematically-redundant. There are many other real-world scenarios (i.e. other \(m\) and \(n\) values) that lead to kinematic redundancy.

With your partner, choose one specific industrial kinematically-redundant robot, preferably one for which a lot of images and technical data are available on the Internet.

- Include a clear photograph
- Sketch the kinematic diagram – show one if that is available but also make your own sketch.
- Demonstrate the motion of each joint.
- Sketch the approximate translational workspace.
- Discuss the range of applications this robot is used for.
- Discuss the power supply and transmission.
- What sensors are used?
- What control method(s) are used?
- Enumerate the technical data: manufacturer, cost, weight, payload-to-weight ratio, repeatability, accuracy, maximum speed and acceleration, etc.
- Discuss the advantages and disadvantages of your chosen serial kinematically-redundant robot compared to a similar non-kinematically-redundant serial robot.

As usual, include plenty of graphics to demonstrate your discussions.
Laboratory Mini-Project LMP 6

In-depth study and report on a specific industrial parallel robot of your choosing

A parallel robot has multiple mechanical linkages connecting the ground link to the end-effector. This is in contrast with standard serial robots that have one cantilevered mechanical path from the ground link to the end-effector.

With your partner, choose one specific industrial parallel robot, preferably one for which a lot of images and technical data are available on the Internet.

- Include a clear photograph
- Sketch the kinematic diagram – show one if that is available but also make your own sketch.
- Demonstrate the motion of each joint.
- Sketch the approximate translational workspace.
- Discuss the range of applications this robot is used for.
- Discuss the power supply and transmission.
- What sensors are used?
- What control method(s) are used?
- Enumerate the technical data: manufacturer, cost, weight, payload-to-weight ratio, repeatability, accuracy, maximum speed and acceleration, etc.
- Discuss the advantages and disadvantages of your chosen parallel robot compared to a similar non-parallel serial robot.

As usual, include plenty of graphics to demonstrate your discussions.