# EGR/CS 434 Green Robotics, Automation, & Machine Intelligence

***Final Exam questions will be selected from the following. The exam will be closed everything.***

*J.T. Wunderlich PhD*

**2017 QUIZZES'** *(some of these exact questions, or slight variations of them, may appear on the Final)***:**

**2017 QUIZ 1**

From required readings:
[44] Wunderlich, J.T. (2013). **Green robotics, automation, and machine intelligence; a new engineering course in sustainable design.** *International Symposium on Green Manufacturing and Applications* (ISGMA 2013), June 25-29, Oahu, Hawaii. (PUBLICATION #2 IN MY PUBLIC FOLDER)
[59] Wunderlich, J.T. (2009), **PhD Course in Advanced Robotics**, visiting Professor of Engineering, University of Trento, Italy.
And reflecting on these class presentations
http://users.etown.edu/w/wunderjt/**Green_Robotics_Hawaii_TALK_5**.pdf (The talk for publication #44 above)
http://users.etown.edu/w/wunderjt/**19YEARS_RMI_PAST_PRESENT_FUTURE**.pdf (Presented in Vienna, Austria in 2017).

- Briefly describe how this course has evolved:

From your required readings (PUBLICATION #3 IN MY PUBLIC FOLDER, and HARDCOPY HANDED OUT IN CLASS)

[61] (2017): **Moving Closer to Reality,** IEEE Spectrum.
[62] (2017): **How Augmented Reality (AR) is changing the way we work,** IEEE Spectrum.
[63] (2017): **Second Life Founders Second Act,** IEEE Spectrum.

- State one **specific** **unique** **new** thing mentioned in each of these papers.

**2017 QUIZ 2**:

From required reading:
[17] Campos, D. and Wunderlich, J. T. (2002). **Development of an interactive simulation with real-time robots for search and rescue.** In *Proceedings of IEEE/ASME International conference on Flexible Automation, Hiroshima, Japan*: (session U-007). ASME Press.

- Describe the function of each of the three vehicles simulated, and physically built for real-time control.

From required reading:
[19] Wunderlich, J.T. (2001). **Simulation vs. real-time control; with applications to robotics and neural networks.** In *Proceedings of 2001 ASEE Annual Conference & Exposition, Albuquerque, NM*: (session 2793), [CD-ROM]. ASEE Publications.

1. Sketch *AND LABEL AS MUCH AS YOU CAN* the **2-2-1 NEURAL NETWORK** in the paper:
2. Describe **in words** what a **Jacobian Matrix** does
3. For a Manipulator, explain the similarities and differences between controlling the motion of a Manipulator's End-effector, and the Path Planning of a Mobile robot

**2017 QUIZ 3**

From required reading:
[37] Bajracharya, M., Maimone, M.W., and Helmick, D. (2008)**. Autonomy for mars rovers: past, present, and future**. In *Computer*: December, 2008. (pp. 44-50). *IEEE Press.*

1. Briefly describe some of the UNIQUE FUNCTIONING of the first NASA Rover on Mars in 1997: "Pathfinder" "Sojourner"
2. Briefly describe some of the UNIQUE FUNCTIONING of the TWO NASA Rovers put on Mars in 2004: "Mars Exploration Rovers" Spirit" and "Opportunity"
3. Briefly describe some of the UNIQUE FUNCTIONING of the NASA Rover initially scheduled to be put on Mars in 2009: "Mars Science Lab"
   NOTE: Launch was actually in 2011, and vehicle was named "Curiosity"

From required reading:
[10] Wunderlich, J.T. (201X). Two single-chip neurocomputer designs; one bottom-up, one top-down. (draft journal paper)
[13] Wunderlich, J.T. (2004). Top-down vs. bottom-up neurocomputer design. In Intelligent Engineering Systems through Artificial Neural Networks, Proceedings of ANNIE 2004 International Conference, St. Louis, MO. H. Dagli (Ed.): Vol. 14. (pp. 855-866). ASME Press. ["Novel Smart Engineering System Design Award, 2nd runner-up best paper" from over 300 submissions],

1. Sketch and completely label the Biological neuron for a bottom-up neurocomputer design.
2. Sketch and completely label the Behavior model for a top-down neurocomputer design.

**2017 QUIZ 4**

From required reading:
[52] Wunderlich, J.T. (1992). **A vector-register neural-network microprocessor with on-chip learning; Appendix A "Machine Intelligence History** (Part of Chapter 1 of a book draft)**"** *Masters Thesis*, Pennsylvania State University

1. Sketch and completely label the Threshold Logic Unit developed by McCulloch and Pitts in 1943. Also, write the simple equations that shows when it's output is either 1 or 0
2. What did K.S. Lashley observe about the functioning of biological brains in 1950 (hint: it's a form of fault-tolerance)
3. What was the main underlying governing principle of biological neural systems noted by S. Grossberg in 1976; And how does this apply to the present information age and all the info we are flooded with every day.
4. Sketch and completely label a 2-2-1 Backpropagation Neural Network (hint: it looks like the one you drew in quiz # 2), and add weighted Bias inputs to the two Neurons in the hidden layer, and one weighted Bias input to the one output neuron.
5. State in words how it learns to do two-input logic functions like and AND or XOR

| X | Y | AND | | X | Y | XOR |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | | 0 | 0 | 0 |
| 0 | 1 | 0 | | 0 | 1 | 1 |
| 1 | 0 | 0 | | 1 | 0 | 1 |
| 1 | 1 | 1 | | 1 | 1 | 0 |

6. Describe **Linear Separability** (in words) and also draw a diagram that shows it for an AND and for an XOR

**2017 QUIZ 5**

From required readings:
[57] Wunderlcih, J.T. (1991), VP Expert Case Study: Doctor's Office Answering Service
[58] Wunderlcih, J.T. (1991), VP Expert Case Study: Selecting a toy for a baby

1. List two of the four different advice given to callers to the doctor's office by the AI Expert System:
2. Name two of the five different situations hopefully prevented by the AI Expert System deciding what to advise callers to a doctor's office:
3. Sketch the AND/OR graph for backward chaining of the AI Expert System execution as it goes from gathering data from a caller to a doctor's office to deciding the advice to give a caller:
4. Name one of the three assumptions made when developing an AI Expert System to select a toy for a child:
5. State something about how confidence values are calculated in choosing a toy in an AI Expert System to select a toy for a child

**2017 QUIZ 6**

From required reading #9 in the reading packet:

[16] Wunderlich, J.T. (2003). **Defining the limits of machine intelligence.** In *Proceedings of IEEE SoutheastCon, Ocho Rios, Jamaica*, [CD-ROM]. IEEE Press.

1. Name any one of the **Basic Animal Abilities** other than the two given below, and then fill in all the boxes to its right, including a narrative **PARAGRAPH of your own** in the "Comments" box.
2. Name any one of the **Complex Abilities** other than the two given below, and then fill in the boxes to its right, including a narrative **PARAGRAPH of your own** in the "Comments" box.

**Mental Ability Matrix**

| | | Can human do? | Can bug do? (spider) | Can Conventional Computer Program do? | Can Symbolic AI Program do? | Can Artificial Neural Network do? | Comments |
|---|---|---|---|---|---|---|---|
| | ***BASIC ANIMAL ABILITIES:*** | | | | | | |
| 1 | Acquire and retain knowledge | yes | yes | yes | yes | yes | Just like SAT's |
| 2 | Solve problems | yes | yes | yes | yes | yes | Just Like SAT's |
| | | | | | | | |
| | ***COMPLEX ABILITIES:*** | | | | | | |
| 21 | Abstraction | yes | unlikely | no | no | somewhat | Conceptual Design |
| 22 | Intuition | yes | unlikely | no | not yet | soon | "Gut" feeling |
| | | | | | | | |

**2017 QUIZ 7**

From required IEEE publications handed out in class (and available in my public folder as file: "IEEE AI summary 2016_17.pdf"):

"The Promise of Artificial Intelligence"

*and*

"Landing a Job in Artificial Intelligence"

1. Name three specific examples given in **"The Promise of Artificial Intelligence"** special IEEE edition (i.e., from either **"Mastering Deep Learning"** or **"AI is All Around Us"**
2. Reflect on the article "Landing a Job in Artificial Intelligence" and state how you believe it could factor into the type of jobs you look for when you graduate

**2017 QUIZ 8**:

From required reading:

[64] Ferrucci, D.A.(2010), ***"Building Watson: An Overview of the DeepQA Project,"*** AI Magazine.

1. Explain how the game of Jeopardy is normally played by humans (2 points)
2. How did the game of Jeopardy need to be modified to accommodate Watson? (1 points)
3. In only the space below, describe the most noteworthy aspects of how Watson works (7 points)

**2017 QUIZ 9**

From required reading:

[33] Painter, J. G., Coleman, D., Crouse, J., Yorgey, C., and Wunderlich, J.T. (2008) **Wunderbot 4 IGVC report**. *Judged and published on-line by IGVC.*

1. Describe the competition
2. Describe the key aspects of the Wunderbot 4 Path Planning
3. Describe the key aspects of the Wunderbot 4 vision system
4. Describe the key aspects of the Wunderbot 4 wireless communication

**2017 QUIZ 10**

From required readings:

#26 "PUBLICATION_MARS_SPIRIT_GLOBAL_PATH_PLANNING_JPL.pdf" and

#27 "PUBLICATION_MARS_SPIRIT_ALL_PATH_PLANNING_JPL.pdf" in reading packet:

[36] Carsen, A., Rankin, J., Fuguson, D., and Stentz, A. (2007). **Global path planning on board the mars exploration rovers.** *In Proceedings of the IEEE Aerospace Conference, 2007. IEEE Press.*

[37] Bajracharya, M., Maimone, M.W., and Helmick, D. (2008). **Autonomy for mars rovers: past, present, and future.** In *Computer*: December, 2008. (pp. 44-50). *IEEE Press.*

1. Describe Local Path Planning including a specific example from these readings
2. Describe Global Path Planning including a specific example from these readings
3. Describe how Local and Global Path Planning can be complimentary when running concurrently (for any application you wish to discuss)

**2017 QUIZ 11**

From required readings: in reading packet:

#16 UBLICATION_Niku_Robotic_Arm_Book_Excerpts.pdf

#17 PUBLICATION_SIM6_046338_Wunderlich_original_PROOF.pdf

#20 PUBLICATION_Wunderlich_1993_TeleRobotic_Rehabilitaion_Robot.pdf

i.e., on syllabus:

[5] S. B. Niku, (2001), ***Introduction to Robotics: Analysis, Systems, Applications***, Prentice Hall (ISBN: 0130613096)

[14] Wunderlich, J.T. (2004). **Simulating a robotic arm in a box: redundant kinematics, path planning, and rapid-prototyping for enclosed spaces.** In *Transactions of the Society for Modeling and Simulation International*: Vol. 80. (pp. 301-316). San Diego, CA: Sage Publications.

[22] Wunderlich, J.T., S. Chen, D. Pino, and T. Rahman (1993). **Software architecture for a kinematically dissimilar master-slave telerobot**. In *Proceedings of SPIE Int'l Conference on Telemanipulator Technology and Space Telerobotics*, Boston, MA: Vol. (2057). (pp. 187-198). SPIE Press.

1. From [5], name one of the robot coordinate systems other than Cartesian
2. From [5], define what an end-effector is.
3. From [14], name two of the parameters being optimized other than speed
4. From (22) describe who this robotic system is designed for
5. From [22] describe how Force-Feedback is used.

**(EXTRA CREDIT):** From [14], describe in words the "Null Space" of the Jacobean Matrix transformation between joint-angle velocity space and Cartesian end-effector velocity space

# *Additional possible FINAL EXAM QUESTIONS:*

# GUEST LECTURES

**IN REFERENCE TO THE FOLLOWING:**

- TALK: ***"Phoenix Contact Industrial Automation"*** (by Dan Fenton)
  - # (X points)**:** What is a **PLC** and how does it differ from a typical PC?
  - # (X points)**:** Describe what you learned about Phoenix contact USA and Phoenix Contact International

**IN REFERENCE TO THE FOLLOWING:**

- TALK: ***"Signal Processing & Digital Design Applications"*** (by David Coleman PhD)
  - # (X points): Describe the what you learned (be specific)

**IN REFERENCE TO THE FOLLOWING:**

- TALK: ***"Career planning"*** (by Jane Nini)
- TALK: ***"Understanding Hate"*** (by Ambassador John Craig)
- TALK: ***"Study Abroad"*** (by Megan Bell)
  - # (X points)**:** An essay question asking you to relate these talks in a specific way that I will ask you for

# MACHINE INTELLIGENCE & LEARNING

FROM:

Reading / Lecture - http://users.etown.edu/w/wunderjt/ITALY_2009/Machine_Intelligence_History.pdf

Lecture - http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_MACHINE_INTELLIGENCE.pdf

Reading / Lecture - http://users.etown.edu/w/wunderjt/ITALY_2009/BIGXORtest.pdf

Reading - *Wunderlich, J.T. (2004).* ***Top-down vs. bottom-up neurocomputer design.*** *In Intelligent Engineering Systems through Artificial Neural Networks, Proceedings of ANNIE 2004 International Conference, St. Louis, MO. H. Dagli (Ed.): Vol. 14. (pp. 855-866). New York, NY: ASME Press*:

Lecture - http://users.etown.edu/w/wunderjt/0%20Calculus%20Review.pdf

Lecture - Wunderlich, J.T. (201X). **Two single-chip neurocomputer designs; one bottom-up, one top-down.** *(draft paper / book chapter)*

#(X points)**:** List the two observations of the **human brain** made by **William James in 1890**

#(X points)**:** Write **Hebb's** 1949 statement on **learning**.

#(X points)**:** In discussing all of the historical developments that eventually led to the 1986 Rumelhart **back-propagation neural network** model in 1968, briefly describe one significant contribution of each of the following individuals:

1) 1943 McCullah and Pitts
2) 1949 Hebb
3) 1960 Rosenblatt
4) 1974 Werbos

# (X points)**:** Draw a picture and explain the functioning (with equations <u>and</u> words) the significant computational **Neural Network architecture** defined by **McCullah and Pitts** in 1943.

# (X points)**:** Compare and contrast (with both sketches and words):

1. Rosenbaltt's 1960 **PERCEPTRON**
2. Rumelhart et al. 's 1986 **BACK-PROPAGATION**

# (X points)**:** Concerning the research of the Physicist J.J. **Hopfield**:

1. How did his 1982 neural network model's learning differ from other models such as backpropagation.
2. What did he contribute in 1984 that significantly changed the functioning of other neural network models to follow. Explain the significance of this contribution.

# (X points)**:** Discuss a type of Neural Network different from backpropagation and discuss how it differs.

# (X points)**:** In 1969, **Minsky and Papert** made a significant observation about neural networks regarding their ability to deal with **linear separability**. Define linear separability and compare using tables and graphs the difference between the binary "AND" function and the binary "XOR" function with regards to Minsky and Papert's observations. What development in neural networks solved this dilemma?

# (X points)**:** Concerning **neurons**,

a. Sketch and label a graph of the action potential of a **biological** neuron
b. Sketch and label a graph of the **hard-limiter transfer-function** used in artificial neural networks.
c. Sketch and label a graph of the **sigmoid transfer-function** used in artificial neural networks
d. Which of (b) or (c) is more like (a) and why.
e. What is it about the sigmoid transfer-function that makes it desirable for **back-propagation learning**

# (X points)**:** Sketch a **2-2-1 back propagation Neural Network** including Biases

# (X points)**:** Write the **Weight Changing Equations** for a back propagation Neural Network -- for both layers, and for the Bias

# (X points)**:** Describe **<u>in words</u>** each step of one **FEED-FORWARD** pass of one **EXEMPLER** in the set (e,g, 00 -> 0 for the XOR example):

# (X points)**:** Describe **<u>in words</u>** each step of one **BACK-PROPAGATION** pass for one **EXEMPLER** in the set (e,g, 00 -> 0 for the XOR example); first talk about the error signal created, then how it used in each layer.

# (X points)**:** In **gradient decent learning**, describe the import concept involved in:

a. Varying the learning rate and how it relates to the topology of the error-surface
b. The importance of using a continuously differentiable neuron transfer function and how the instantaneous-slope of this function can effect learning.

# (X points)**:** Why do you think much higher precision is needed for Neural Network back-propagation computations during learning than after learning completed.

# (X points)**:** Recalling Dr. W.'s **neural network code**:

1. What is the **stopping tolerance** for? (i.e., "STOPtolerance")
2. Why can the **learning rate** can be set so high for simple 2-input examples (i.e. 1 to 5 instead of typically much less than 1 for complex applications)?
3. Why is the learning rate (in this code or any other code) more sensitive for the XOR example than the AND or OR?

# (X points) What is **Proprioception** in humans, and how does this relate to "Pose" in Robot path planning?

# (X points)**:** List ANY FIVE of the 10 parts of the **human brain** identified in lecture and discuss the function of each.

# (X points)**:** List and describe the function of the 3 different **types of neurons**.

# (X points)**:** Describe in your own <u>words and sketches</u> (no equations), the method of **"Least Squares"**

# (X points)**:** Describe in your own <u>words and sketches</u> (no equations), **Gradient Descent learning** (including how the error surface is created)

# (X points)**:** Sketch and label a graph of the typical **sigmoid neural network transfer function**, then sketch and label a graph of it's derivative. Then explain how the magnitude of the derivative effects neural network backpropagation learning.

# (X points)**:** List any five of the 10 parts of the **human brain** identified in lecture and discuss the <u>function</u> of each.

# (X points)**:** What is the function of a **dendrite**.

# (X points)**:** List and describe the function of the 3 different **types of neurons**.

In *Wunderlich, J.T. (2004).* ***Top-down vs. bottom-up neurocomputer design****. In Intelligent Engineering Systems through Artificial Neural Networks, Proceedings of ANNIE 2004 International Conference, St. Louis, MO. H. Dagli (Ed.): Vol. 14. (pp. 855-866). New York, NY: ASME Press*:

# (X points)**:** Briefly describe the conceptual difference between **"Top-down" and "Bottom-up" neurocomputer design**.

# (X points)**:** Describe the importance of maintaining high-precision for the neuron transfer function during learning.

# (X points)**:** Compare and contrast Dr. W's various numerical methods used to approximate the neuron transfer function (just the basic concepts – don't reproduce all equations).

# (X points)**:** Why bother to attempt on-chip learning?

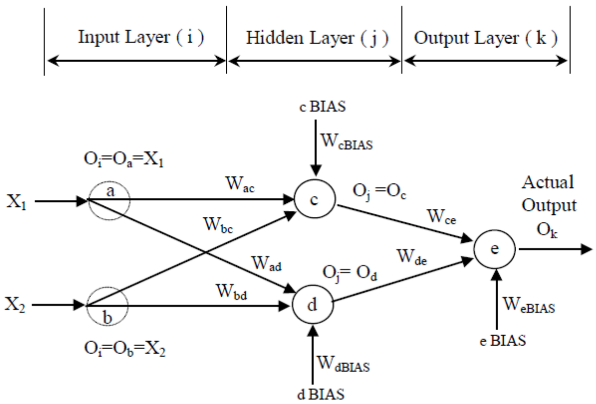
# (X points)**:** Why is a polynomial a good idea for neuron transfer function implementation?

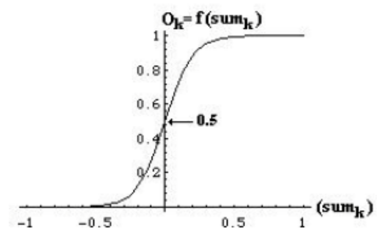
FROM:

Lecture - http://users.etown.edu/w/wunderjt/0%20Calculus%20Review.pdf

Lecture - Wunderlich, J.T. (201X). **Two single-chip neurocomputer designs; one bottom-up, one top-down.** *(book chapter)*

(x points) For a three layered 2-2-1 Neural Network shown, with layers i, j, and k, and the given neuron output Transfer Function,




$$O_k = f(sum_k) = \frac{1}{1+e^{-sum_k}}$$

derive ONLY the following equation for changing the weights between the output layer and the hidden layer~~, and the equation for changing the weight connected to the BIAS for the hidden layer~~.

$$\Delta W_{jk} = \eta * \left[ (d_k - O_k) * O_k * (1 - O_k) \right] * O_j$$

and graph and discuss how understanding the derivative of the transfer function leads to understanding more about the machine learning.

## ANSWER:

We begin with the goal of minimizing the sum-squared errors between desired output $d_k$ coming out of output neuron in output layer k, and the actual output $O_k$

$$E = \frac{1}{2} \sum_k (d_k - O_k)^2$$

In small learning steps $n$ and in the opposite direction as the uphill sloping gradient; therefore:

$$\therefore \Delta(W_{jk}) \, \alpha \, -\left( n \frac{\partial E}{\partial W_{jk}} \right)$$

and then backpropagating the error to the next layer such that:

$$(\Delta W_{ij}) \, \alpha \, \left( -n \frac{dE}{dW_{ij}} \,\&\, \Delta W_{jk}\text{'s} \right)$$

But for this question we are only being asked to derive the equation between the output layer and the hidden layer.
So we begin by using the chain rule to get the neuron Output into the equation:

To get $O_{jk}$ into calculations, we use the chainrule:

$$\Delta W_{jk} = -n \frac{dE}{dO_k} \frac{dO_k}{dsum_k} \frac{dsum_k}{dW_{jk}}$$

Solving each piece of yields:

| $\Delta W_{jk} = -n$ | $* \dfrac{dE}{dO_k}$ | $* \dfrac{dO_k}{dsum_k}$ | $* \dfrac{dsum_k}{dW_{jk}}$ |
|---|---|---|---|
| | $\dfrac{\partial\left[\frac{1}{2}\sum_k (d_k - O_k)^2\right]}{\partial O_k}$ <br> $= \frac{1}{2} * 2(d_k - O_k)(-1)$ <br> $= -(d_k - O_k)$ | $= f'(sum_k)$ | $\dfrac{\partial\left[\sum O_j W_{jk}\right]}{\partial W_{jk}}$ <br> $= \sum_j O_j$ <br> $= O_j$ for a given $\Delta W_{jk}$ |

$$\Delta W_{jk} = -n(-(d_k - O_k))(f' sum_k))(O_j)$$

and using the Quotient Rule to evaluate $(f' sum_k)$ and letting $sum_k$ be ***x***:

$$f'(x) = \frac{v(x)u'(x) - u(x)v'(x)}{(v(x))^2}$$

with $u(x) = 1$ and $v(x) = 1 + e^{-x}$ for our $f(sum_k) = \dfrac{1}{1+e^{-sum_k}} = f(x) = \dfrac{1}{1+e^{-x}}$ :

$$\therefore f'(x) = \frac{(1+e^{-x})(0) - (1)(0 + e^{-x}(-1))}{\left(1+e^{-x}\right)^2}$$

$$= \frac{e^{-x}}{(1+e^{-x})^2}$$

And then we manipulate it to get it in the form of all $O_k = f(x) = \dfrac{1}{1+e^{-x}}$ terms:

$$= \frac{e^{-x} + (1-1)}{(1+e^{-x})^2} = \frac{(e^{-x}+1)-1}{(1+e^{-x})^2} = \frac{(1+e^{-x})}{(1+e^{-x})^2} - \frac{1}{(1+e^{-x})^2} = \frac{1}{(1+e^{-x})} - \frac{1}{(1+e^{-x})^2}$$

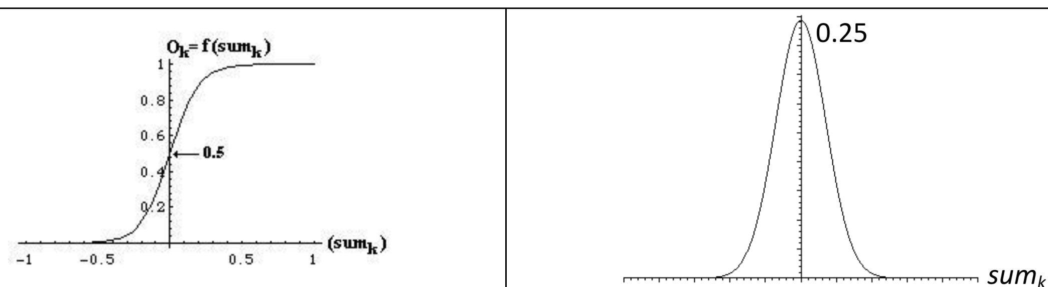
$$= f(x) - f(x)^2$$

$$= f(x)(1 - f(x))$$

$$f' sum_k = f'(x) = O_k(1 - O_k) \qquad (28)$$

To yield our equation 5 when we substitute (28) in (26): $\Delta W_{jk} = \eta * \left[(d_k - O_k) * O_k * (1 - O_k)\right] * O_j$

This has the effect of magnifying the weight changes when the net input to a given neuron is near zero as shown in Figure 17; and results in "*pushing*" neuron outputs towards the asymptotes at 0 and 1.




$$O_k = f(sum_k) = \frac{1}{1+e^{-sum_k}} \qquad O_k' = f'(sum_k) = O_k(1 - O_k)$$

Figure 17: Nonlinear continuously differentiable neuron transfer function and it's derivative which peaks when the net input to a neuron is zero and has dramatically less effect on learning outside of a narrow range of net input.

# (X points): Given the **following neuron transfer functions** with A, B, and C defined on day of test:

$$O_j = \frac{A}{B + e^{\sum_i (-O_i * W_{ij})}} \qquad O_k = \frac{A}{B + e^{\sum_j (-O_j * W_{jk})}}$$

and error (i.e., "cost") function:

$$E = 1/C * \left[ \sum_k (d_k - o_k)^3 \right]$$

derive **using Calculus** (i.e., the **chain rule, partial derivatives, the quotient rule, etc.**) **an equation for changing the weights between the hidden layer and the output layer of a three-layered (i, j, k) back-propagation neural network**. Assume there are no BIAS connections to the neurons. Simplify your final equation as much as possible. **Also, discuss how weight changes are magnified when output neurons are at "sticking points".**

FROM:
Lecture - http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_MACHINE_INTELLIGENCE.pdf
Reading - *Wunderlich, J.T. (2003).* ***Defining the limits of machine intelligence*****.** *In Proceedings of IEEE SoutheastCon, Ocho Rios, Jamaica, [CD-ROM]. IEEE Press.* :

# (X points): **HOW SPECIFICALLY** does **symbolic AI differs from artificial neural networks** for each of the abilities listed here:
Reduced **Mental Ability** Matrix (i.e., reduce from the 42 abilities in paper) – **WRITE A SENTENCE OR TWO ABOUT EACH**

| | | Can human do? | Can bug do? (spider) | Can Conventional Computer Program do? | Can Symbolic AI Program do? | Can Artificial Neural Network do? |
|---|---|---|---|---|---|---|
| | ***BASIC ANIMAL ABILITIES:*** | | | | | |
| 3 | *Learn and adapt* | yes | yes | no | ? | ? |
| 13 | Generalize | yes | somewhat | no | ? | ? |
| 16 | Robust under partial failure | yes | yes | no | ? | ? |
| 19 | Stability, repeatability,predictability | somewhat | somewhat | yes | ? | ? |
| | ***COMPLEX ABILITIES:*** | | | | | |
| 25 | Heuristics | yes | yes | somewhat | ? | ? |
| 26 | Inference | yes | yes | somewhat | ? | ? |
| 27 | Hypothesis testing | yes | somewhat | somewhat | ? | ? |
| 31 | Open to inspection | somewhat | somewhat | yes | ? | ? |

FROM:
Reading – http://users.etown.edu/w/wunderjt/ITALY_2009/Expert_Systems_Book_Exherpts.pdf
Reading – http://users.etown.edu/w/wunderjt/ITALY_2009/Expert_Systems_Book_Exherpts%20PART%202%20.pdf
Lecture - http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_MACHINE_INTELLIGENCE.pdf
Reading -http://users.etown.edu/w/wunderjt/ITALY_2009/Expert_System_Case%20_Study_1_by_Wunderlich%20%282%29.pdf
Reading -http://users.etown.edu/w/wunderjt/ITALY_2009/Expert_System_Case%20_Study_2_by_Wunderlich.pdf

# (X points): Describe what each of the following historic **Expert Systems** does:
1) 1960's DENDRAL
2) 1979 PROSPECTOR
3) 1983 INTERNIST
4) 1984 MYCIN

# (X points): List and describe the three major **deficiencies of symbolic A.I. expert systems**
# (X points): List and describe the four major types of symbolic A.I. expert system problems
# (X points): Describe what each of the following does in a symbolic A.I. expert system:
1) Explanation Subsystem
2) Knowledge Base
3) Knowledge Base Editor
4) Inference Engine

# (X points): Describe "Backward-chaining" in symbolic A.I. expert systems.
# (X points): Recalling Dr. W's symbolic **A.I. expert system "Advise Callers to a Doctor's Office,"** :
1) Describe the important assumptions and possible ethical and legal ramifications of them.
2) Draw the And/Or graph for Dr. W.'s design

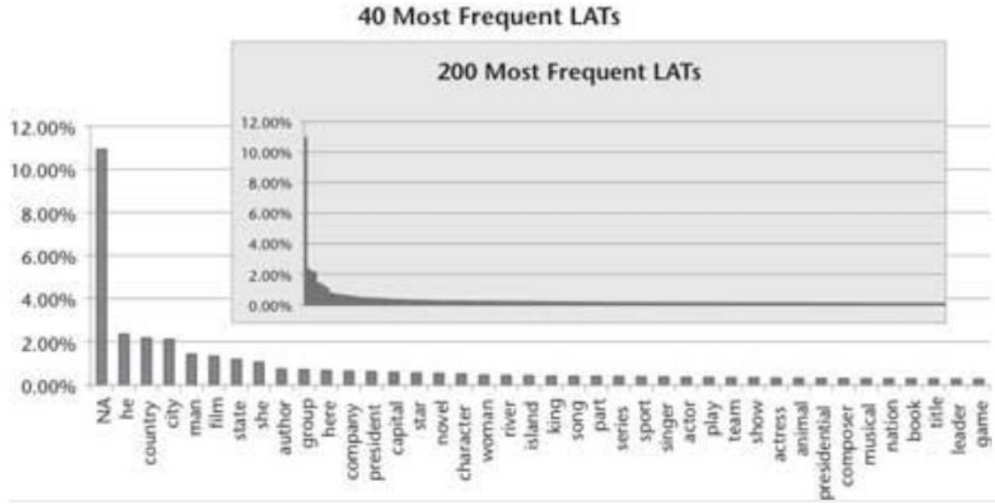
# (X points): Compare in your own words **"Probability Theory" vs. "Uncertainty Theory"** for symbolic A.I. expert systems.
# (X points): Describe the <u>two</u> places **confidence values** are used i**n Expert Systems**
# (X points): Recalling Dr. W's symbolic **A.I. expert system "Selecting a Toy for a Child,"**:
1) Describe the significance of the Confidence values used for both the rules and the user inputs.
2) Draw the And/Or graph

# (X points): Draw a complete **"And/Or graph" for** the following **symbolic A.I. expert** system discussed in lecture defined by the following rules:
1. If engine is getting gas and the engine will turn over, then the problem is spark plugs.
2. If engine is does not turn over and the lights do not come on, then the problem is battery or cable.
3. If engine is does not turn over and the lights do come on, then the problem is starter motor.
4. If there is gas in the fuel tank and gas in the carburetor, then the engine is getting gas.

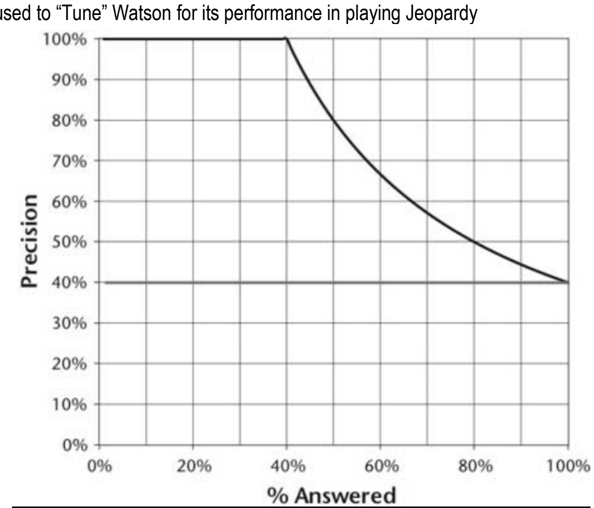
## "IBM WATSON"

In Lecture - http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_MACHINE_INTELLIGENCE.pdf

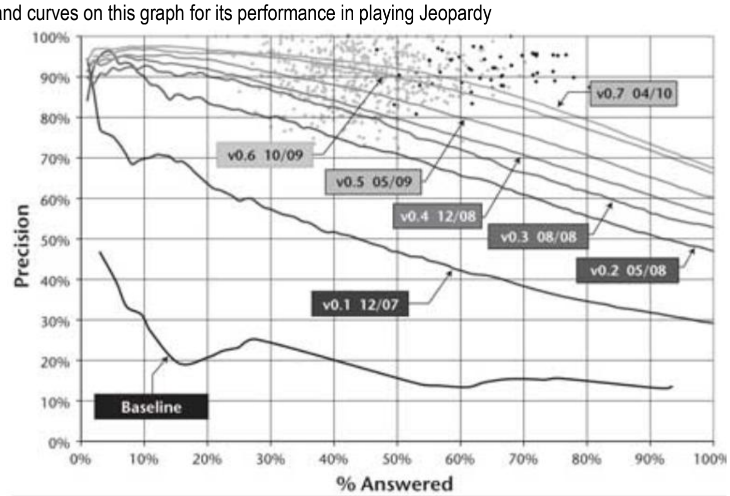
# (X points): Name five different problems encounter over the entire development of Watson
# (X points): Define what a LAT is
# (X points): Discuss how this graph was used to make Watson not so Application Specific




# (X points): Explain how this graph was used to "Tune" Watson for its performance in playing Jeopardy




# (X points): Explain all the dots and curves on this graph for its performance in playing Jeopardy




# (X points): Describe the exceptional characteristics of each of these following aspects of Watson:

a. Creating a "Corpos"
b. "Context" In Natural Language Processing
c. "Intent" In Natural Language Processing
d. "Inference" In Natural Language Processing
e. Probability and Confidence
f. Statistical Analysis of Unstructured Data
g. The use of multiple types of Machine Intelligence

From lecture **"Computer Fundamentals"** http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_COMPUTERS.pdf

(x points) Draw the complete table comparing Simulation to Real-time Control *(in Robotics applications, but applicable to all intelligent systems)*

ANSWER:

| Simulation | Real-Time control |
| --- | --- |
| Using good engineering and physics, create a model of a physical system (i.e., not just a cartoon) | Establish stable closed loop control with a good model ("Plant") that represents physical system being controlled |
| Vary inputs to simulation to better understand model | Fine tune PID control to better manipulation of physical system |
| Use more complex computer hardware to enhance graphics and model complexity | **Intentionally simplify** all hardware to yield fast, compact, fault-tolerant, real-time responses |
| Use more complex computer software to enhance graphics and minimize programming effort | **Intentionally simplify** code to yield fast, compact, fault-tolerant, real-time responses. No operating system or a real-time OS may be best |
| Interact with real-time code to improve physical model and build ENVIRONMENTAL MAPS | Interact with simulation to obtain GLOBAL PATH-PLANNING rather than Local |

# ROBOTICS *(and Intelligent Navigation & Control)*

## ROBOTICS PART-1 Rovers and Humanoids

From lecture **"Sensors and Navigation"**
http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_SENSORS_&_NAVIGATION.pdf

# (X points)**:** Describe how early sailing ships used **Dead Reckoning**
# (X points)**:** Describe how early sailing ships used **Celestial Navigation**
# (X points)**:** List the SEVEN classifications of sensors
# (X points)**:** For the **1971 Lunar rover**, list the FIVE **NASA requirements** for LRV subsystems
# (X points)**:** For the **1996 NASA Pathfinder "Sojourner,"** list the FIVE **Autonomy** features
# (X points)**:** For the **2004 NASA Mars Explorer Rovers "Spirit" and "Opportunity,"** list the SEVEN **Autonomy** features (including the four 2006 upgrades)
# (X points)**:** For the **2011 NASA Mars Science Lab Curiosity,"** list the THREE **Autonomy** features (including the one planned but not implemented)
# (X points)**:** Describe how **"Local Attractors**" could help with the exploration of the subsurface ocean of Europa
# (X points)**:** Reflecting on lectures and readings throughout the semester, discuss with pictures and words **LOCAL vs. GLOBAL path-planning**

From required reading:
Wunderlich, J.T. (2001). **Simulation vs. real-time control; with applications to robotics and neural networks.** In *Proceedings of 2001 ASEE Annual Conference & Exposition*, Albuquerque, NM: (session 2793), [CD-ROM]. ASEE Publications.
http://users.etown.edu/w/wunderjt/ITALY_2009/PUBLICATION14sim_vs_RT.pdf

# (X points)**:** For a Manipulator, explain (in words) the similarities and differences between controlling the motion of a Manipulator's End-effector, and the Path Planning of a Mobile robot
# (X points)**:** Define unit-direction vector (write the equation), and describe in words why it is called a unit vector, and how you use it in Path Planning

From the class lecture on **"Rover Mechanics"**
http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_ROVER_MECHANICS.pdf ,

# (X points)**:** Compare and contrast the most advanced Bipedal robot made by **Boston Dynamics** to **Honda's Asimo**, compare these specifics:
1) Dexterity
2) Dynamic Stability
3) Machine Intelligence
4) Potential applications

# (X points)**:** Regarding the research by the MIT professor on advanced **prosthetics**, discuss each of these specifics:
1) Dexterity achievements
2) Dynamic Stability achievements
3) Interfacing to human central nervous system
4) Two of the specific applications shown in the TED Talk

# (X points)**:** Regarding **Humanoids, name:**
1. FIVE Basic **Human Structural Pieces**
2. FOUR **Alternative Biological Structural Pieces**
3. SEVEN **Alternative Biological Architectures**

In Campos, D. and Wunderlich, J. T. (2002). **Development of an interactive simulation with real-time robots for search and rescue.** In Proceedings of IEEE/ASME International conference on Flexible Automation, Hiroshima, Japan: (session U-007). ASME Press.

# (X points)**:** How are the Real-time robots implemented and how do they communicate with the simulation?

From the lecture on **"UAVS, UUV'S, and Swarms"**
http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_AUVs_UUVs_and_Swarms.pdf

# (X points)**:** Name the Northrup Grumman UAV initially only used for surveillance
# (X points)**:** Name the Raytheon UAV's discussed
# (X points)**:** Sketch the netcentric warfare swarm (ground, air, and space) discussed
# (X points)**:** Sketch the search and rescue peacetime swarm (ground, air, and space) discussed
# (X points)**:** State some details of how Mathematics/Physics of Dr ViJay Kumar's Helicopter swarms operate at the University y of Pennsylvania Grasp Lab
# (X points)**:** State some details of how Mathematics/Physics of Dr ViJay Kumar's Helicopter swarms operate at the University y of Pennsylvania Grasp Lab
# (X points)**:** State some details of how Mathematics/Physics of Dr ViJay Kumar's Helicopters at the University y of Pennsylvania Grasp Lab are used for:
1) Local Path-Planning Real-Time Control in Swarms
2) Global Path planning for building a simulation of an environment

FROM:
Roland Siegwart, Illah R. Nourbakhsh and Davide Scaramuzza, ***"Introduction to Autonomous Mobile Robots, Second Edition (Intelligent Robotics and Autonomous Agents),"*** Massachusetts Institute of Technology, 2nd edition, Mar 31, 2011 in lecture: http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_ROVER_MECHANICS.pdf

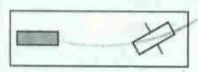
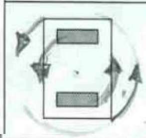
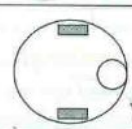
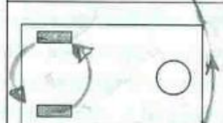
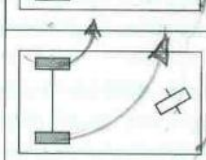
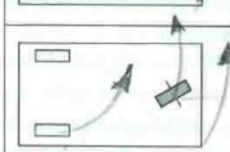
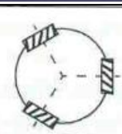
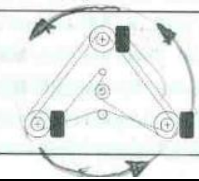
Icons for the each wheel type are as follows:

- unpowered omnidirectional wheel (spherical, castor, Swedish);
- motorized Swedish wheel (Stanford wheel);
- unpowered standard wheel;
- motorized standard wheel;
- motorized and steered castor wheel;
- steered standard wheel;
- connected wheels.

ZTR = ZERO TURNING RADIUS
OD = OMNI DIRECTIONAL
(ZTR) = ZTR IN IT'S GROUND FOOTPRINT



**Table 2.1**
Wheel configurations for rolling vehicles

| Wheel configuration number | # of wheels | Arrangement | Description | Typical examples |
|---|---|---|---|---|
| 1 | 2 |  | One steering wheel in the front, one traction wheel in the rear | Bicycle, motorcycle |
| 2 | ZTR |  | Two-wheel differential drive with the center of mass (COM) below the axle | Cye personal robot |
| 3 | 3 (ZTR) |  | Two-wheel centered differential drive with a third point of contact | Nomad Scout, smartRob EPFL |
| 4 | ~ZTR |  | Two independently driven wheels in the rear/front, 1 unpowered omnidirectional wheel in the front/rear | Many indoor robots, including the EPFL robots Pygmalion and Alice |
| 5 | ~ZTR |  | Two connected traction wheels (differential) in rear, 1 steered free wheel in front | Piaggio minitrucks |
| 6 | ~ZTR |  | Two free wheels in rear, 1 steered traction wheel in front | Neptune (Carnegie Mellon University), Hero-1 |
| 7 | (ZTR) OD |  | Three motorized Swedish or spherical wheels arranged in a triangle; omnidirectional movement is possible | Stanford wheel Tribolo EPFL, Palm Pilot Robot Kit (CMU) |
| 8 | ZTR OD |  | Three synchronously motorized and steered wheels; the orientation is not controllable | "Synchro drive" Denning MRV-2, Georgia Institute of Technology, I-Robot B24, Nomad 200 |

| Wheel configuration number | # of wheels | Arrangement | Description | Typical examples |
|---|---|---|---|---|
| 9 | 4 | | Two motorized wheels in the rear, 2 steered wheels in the front; steering has to be different for the 2 wheels to avoid slipping/skidding. | Car with rear-wheel drive |
| 10 | | | Two motorized and steered wheels in the front, 2 free wheels in the rear; steering has to be different for the 2 wheels to avoid slipping/skidding. | Car with front-wheel drive |
| 11 | | | Four steered and motorized wheels | Four-wheel drive, four-wheel steering Hyperion (CMU) |
| 12 | | ~ZTR | Two traction wheels (differential) in rear/front, 2 omnidirectional wheels in the front/rear | Charlie (DMT-EPFL)<br>WUNDERBOTS |
| 13 | | ZTR OD | Four omnidirectional wheels | Carnegie Mellon Uranus |
| 14 | | ZTR | Two-wheel differential drive with 2 additional points of contact | EPFL Khepera, Hyperbot Chip |
| 15 | | ZTR OD | Four motorized and steered castor wheels | Nomad XR4000 |
| 16 | 6 | ZTR OD | Two motorized and steered wheels aligned in center, 1 omnidirectional wheel at each corner | First |
| 17 | | ZTR | Two traction wheels (differential) in center, 1 omnidirectional wheel at each corner<br>~ TANK | Terregator (Carnegie Me lon University) |

| Type of motion | Resistance to motion | Basic kinematics of motion |
|---|---|---|
| Flow in a Channel | Hydrodynamic forces | Eddies |
| Crawl | Friction forces | Longitudinal vibration |
| Sliding | Friction forces | Transverse vibration |
| Running | Loss of kinetic energy | Oscillatory movement of a multi-link pendulum |
| Jumping | Loss of kinetic energy | Oscillatory movement of a multi-link pendulum |
| Walking | Gravitational forces | Rolling of a polygon (see figure 2.2) |

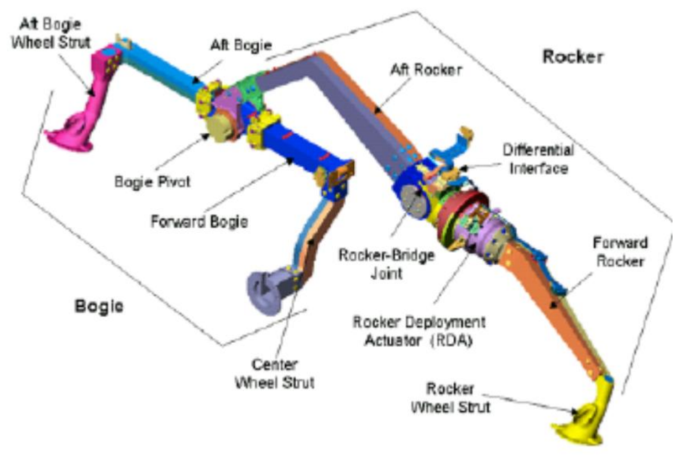



Figure 2. Left-side of Rover Rocker Bogie Assembly

# (X points)**:** Which of the following is closest to that of the **1970's NASA Lunar Roving Vehicle (LRV)**
1. Wheel configuration number (___)
2. Wheel configuration number (___)
3. Wheel configuration number (___)
4. Wheel configuration number (___)
5. "Rocker-Bogie" shown in Figure 2

# (X points)**:** Which of the following is closest to that of the **NASA Mar's Pathfinder "Sojourner" (1996), NASA Mars "Spirit" and "Opportunity" (2004), and NASA Mars Science Lab "Curiosity" (2012).**
1. Wheel configuration number (___)
2. Wheel configuration number (___)
3. Wheel configuration number (___)
4. Wheel configuration number (___)
5. "Rocker-Bogie" shown in Figure 2

# (X points)**:** Which of the following is the most **Statically and Dynamically Stable**
1. Wheel configuration number (___)
2. Wheel configuration number (___)
3. Wheel configuration number (___)
4. Wheel configuration number (___)
5. None of these are Stable

# (X points)**:** Which of the following is the most **Maneuverable**
1. Wheel configuration number (___)
2. Wheel configuration number (___)
3. Wheel configuration number (___)
4. Wheel configuration number (___)
5. None of these are Maneuverable

# (X points)**:** Which of the following is the most **Controllable**
1. Wheel configuration number (___)
2. Wheel configuration number (___)
3. Wheel configuration number (___)
4. "Rocker-Bogie" shown in Figure
5. None of these are Controllable

# (X points)**:** Using the four main criteria that we used in the "Rover Mechanics" lectures in class (i.e., **MANEUVERABILITY, CONTROLLABILITY, STATIC STABILITY,** and **DYNAMIC STABILITY**, compare the *"Wheel"* Configurations of a **BICYCLE vs. a TANK.** Do this by:
1. Sketch the wheel Configuration "Arrangements" as shown in the text, including identifying the drive wheel(s) and steering wheels
2. Make a table with assessment scores of these two *"Wheel"* Configurations (i.e., four columns of assessment, Pugh Diagram style)

From lecture:
http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_ROVER_MECHANICS.pdf

# (X points)**:** Describe in words the **running** versus **railed-vehicle** shown in the following graph, PLUS add narrative on the startup of running vs. railed vehicle not shown on graph

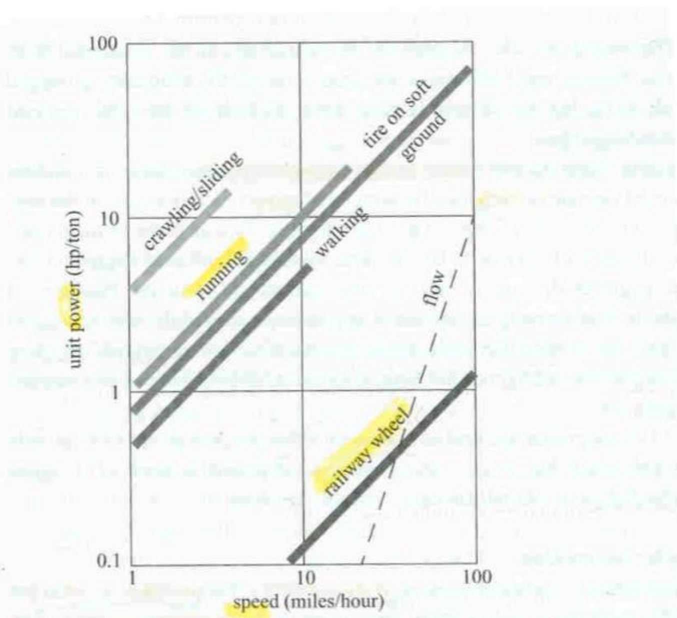



**Figure 2.3**
Specific power versus attainable speed of various locomotion mechanisms [33].

From Roland Siegwart, Illah R. Nourbakhsh and Davide Scaramuzza, ***"Introduction to Autonomous Mobile Robots, Second Edition (Intelligent Robotics and Autonomous Agents),"*** Massachusetts Institute of Technology, 2nd edition, Mar 31, 2011

(**EXTRA CREDIT**)**:** In reference to:
Roland Siegwart, Illah R. Nourbakhsh and Davide Scaramuzza, ***"Introduction to Autonomous Mobile Robots, Second Edition (Intelligent Robotics and Autonomous Agents),"*** Massachusetts Institute of Technology, 2nd edition, Mar 31, 2011,
in our lecture http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_SENSORS_&_NAVIGATION.pdf

Describe in words, mathematics, and vector diagrams the relationship between a humanoid robot watching out the window his master's back yard which includes a mobile robot mowing the lawn using dead-reckoning and random paths while avoiding a bunny who is chasing a butterfly. The humanoid robot must awaken his master if the lawn is done, if the mobile robot accidentally traps the bunny, or if the bunny catches the butterfly; And then the humanoid robot tells the master with a hand-drawing the exact location of the bunny, butterfly, and the mobile robot. Clearly identifying all local-to-global and global-to-local mappings. Clearly identify all simulations vs. real-time control activities (both artificial and biological).

## **ROBOTICS PART-2** Robotic Arms *(i.e., Manipulators)*

FROM:

Reading - S.B. Niku, (2001), ***Introduction to Robotics: Analysis, Systems, Applications***, Prentice Hall (ISBN: 0130613096)

Reading - Wunderlich, J.T. (2004). **Simulating a robotic arm in a box: redundant kinematics, path planning, and rapid-prototyping for enclosed spaces.** In *Transactions of the Society for Modeling and Simulation International*: Vol. 80. (pp. 301-316). San Diego, CA: Sage Publications.

Reading - Wunderlich, J.T., S. Chen, D. Pino, and T. Rahman (1993). **Software architecture for a kinematically dissimilar master-slave telerobot**. In *Proceedings of SPIE Int'l Conference on Telemanipulator Technology and Space Telerobotics*, Boston, MA: Vol. (2057). (pp. 187-198). SPIE Press.

Lecture - **Robotic Arm Design"** http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_ARM_DESIGN.pdf

# (X points)**:** Concerning Robotic Manipulator **DEGREES OF FREEDOM (DOF)**:

- How many Degrees Of Freedom (DOF) do you need to position the end of a manipulator anywhere in 3D space ANSWER: **3**
- How many Degrees Of Freedom (DOF) do you need to position <u>and orient</u> an end-effector anywhere in 3D space ANSWER: **6**
- How many Degrees Of Freedom (DOF) does the human arm have. ANSWER: **7**

# (X points)**:** Describe with both pictures and words, three different types of **coordinate systems** used for manipulators

# (X points)**:** Describe with both pictures and words, two different types of **reference frames** used for manipulators.

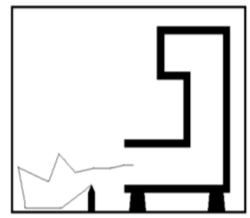
# (X points)**:** What is a Teach Pendant, and how is it used in path=planning of industrial manipulators.

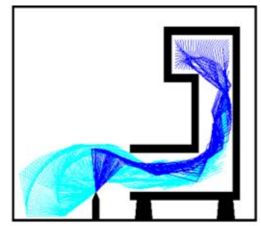
.

From Reading:

Wunderlich, J.T. (2004). **Simulating a robotic arm in a box: redundant kinematics, path planning, and rapid-prototyping for enclosed spaces.** In *Transactions of the Society for Modeling and Simulation International*: Vol. 80. (pp. 301-316). San Diego, CA: Sage Publications.

http://users.etown.edu/w/wunderjt/ITALY_2009/PUBLICATION_SIM6_046338_Wunderlich_original_PROOF.pdf





) # (X points)**:** what is the main objective of the research

# (X points)**:** Describe in words what a **Jacobian Matrix** does

# (X points)**:** Describe the **Rapid Prototyping** process

# (X points)**:** Describe the **obstacle avoidance method** used

# (X points)**:** Describe how **"Local Attractors"**are used

# (X points)**:** List the five parameters in the **performance equation** used to evaluate test-trajectories of candidate designs;

# (X points)**:** Define in words a **Hyper-redundant manipulator**

FROM:

Lecture - **"Robotic Arm Design"** http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_ARM_DESIGN.pdf

Reading - Wunderlich, J.T., S. Chen, D. Pino, and T. Rahman (1993). **Software architecture for a kinematically dissimilar master-slave telerobot**. In *Proceedings of SPIE Int'l Conference on Telemanipulator Technology and Space Telerobotics*, Boston, MA: Vol. (2057). (pp. 187-198). SPIE Press.

(http://users.etown.edu/w/wunderjt/ITALY_2009/PUBLICATION_Wunderlich_1993_TeleRobotic_Rehabilitaion_Robot.pdf )

# (X points)**:** Describe the application of this technology (i.e., who it is for),

# (X points)**:** Sketch the setup of the technology as shown in the PPT slides and publication

(**EXTRA CREDIT**)**:** Using **partial derivatives** and your knowledge of trigonometry, derive the **Jacobian Matrix** for a 2-DOF 2D Robotic Arm as shown in http://users.etown.edu/w/wunderjt/ITALY_2009/TALK_ARM_DESIGN.pdf

## **ROBOTICS PART-3** Automation

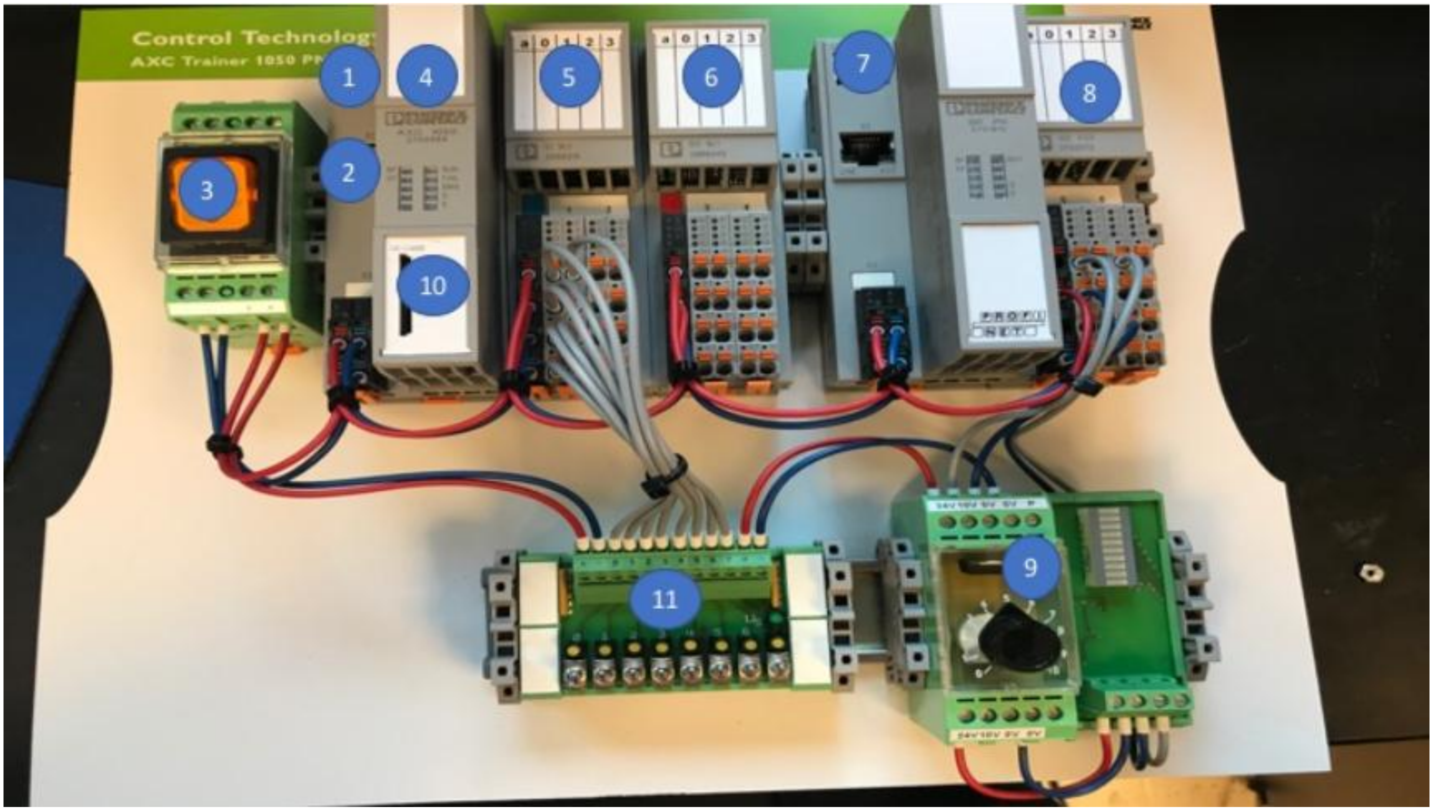
# **SEMESTER PROJECT**

# (X points)**:** Questions about your specific contributions to the team project of **AUTOMATED AGRICULTURE OVER THE INTERNET** including:

1) Working implementations of **Real-Time Control** and **Simulation**
2) Correlation to **weather data**
3) **Sustainable Grow-Tent** in the Lab – with working automated control of lighting and watering that will function over the entire winter break *(i.e., to keep plants alive)*
4) Weekly conference calls to our **real-world clients in France**

# Advance Phoenix Contact Programmable Logic Controllers

(x points) Name each of the 11 parts labeled on the photo of our AXC/AXL PLC's.




## Answer:

1. Ethernet Port to Computer
2. Ethernet Port to AXL
3. Power Switch
4. AXC
5. Digital Input
6. Digital Output
7. Ethernet Port to AXC
8. Analog Input/Output
9. Potentiometer
10. Run/Stop Switch
11. Input Switches

(X points) During the AXC/AXL Lab Exercises we discovered that we can use logic gates to create code for the Axiocontrollers. Give a detailed example of a design experiment, of your own making, using the Axiocontroller. Describe each step from drag and dropping the right gates, connecting them and listing each variable and its type, to the possible outputs of the exercise. Draw the gates and list the variable types. Extra points for difficulty and Creativity.