Introduction to Informatics

Lecture 28: Review
Readings until now

Lecture notes

- Posted online
  - [http://informatics.indiana.edu/rocha/i101](http://informatics.indiana.edu/rocha/i101)
    - *The Nature of Information*
    - *Technology*
    - *Modeling the World*

- @ infoport
  - [http://infoport.blogspot.com](http://infoport.blogspot.com)

From course package

  - Chapters 1, 4 (pages 1-12)
  - Chapter 10 (pages 13-17)

- From Andy Clark’s book *Natural-Born Cyborgs*
  - Chapters 2 and 6 (pages 19 - 67)

- From Irv Englander’s book *The Architecture of Computer Hardware and Systems Software*
  - Chapter 3: Data Formats (pp. 70-86)

  - Chapter 2: Classical Logic (pp. 87-97)
  - Chapter 3: Classical Set Theory (pp. 98-103)

  - Chapters 1-3 (pages 105-129)
  - OPTIONAL: Chapter 4 (pages 131-136)
  - Chapter 13 (pages 147-155)
  - Chapter 5 (pages 141-144)

- Igor Aleksander, "Understanding Information Bit by Bit"
  - Pages 157-166

- Ellen Ullman, "Dining with Robots"
  - Pages 167-172
Assignment Situation

- **Labs**
  - **Past**
    - Lab 1: Blogs
      - Closed (Friday, January 19): Grades Posted
    - Lab 2: Basic HTML
      - Closed (Wednesday, January 31): Grades Posted
    - Lab 3: Advanced HTML: Cascading Style Sheets
      - Closed (Friday, February 2): Grades Posted
    - Lab 4: More HTML and CSS
      - Closed (Friday, February 9): Grades Posted
    - Lab 5: Introduction to Operating Systems: Unix
      - Closed (Friday, February 16): Grades Posted
    - Lab 6: More Unix and FTP
      - Closed (Friday, February 23): Grades Posted
    - Lab 7: Logic Gates
      - Closed (Friday, March 9): Grades Posted
    - Lab 8: Intro to Statistical Analysis using Excel
      - Closed (Friday, March 30): Grades Posted
    - Lab 9: Data analysis with Excel (linear regression)
      - Closed (Friday, April 6): Grades Posted
    - Lab 10: Simple programming in Excel and Measuring Uncertainty
      - April 12 and 13, Due April 20

- **Assignments**
  - **Individual**
    - First installment
      - Closed: February 9: Grades Posted
    - Second installment
      - Past: March 2: Grades Posted
    - Third installment
      - Past: Grades Posted
    - Fourth installment
      - Presented April 10\textsuperscript{th}, Due April 20\textsuperscript{th}
  - **Group**
    - First Installment
      - Past: March 9\textsuperscript{th}, graded
    - Second Installment
      - Past: April 6\textsuperscript{th} Graded
    - Third Installment
      - Presented Thursday, April 12; Due Friday, April 27
Exam Schedule

- 11595
  - Midterm
    - March 1\textsuperscript{st} (Thursday)
    - Regular Class time
  - Final Exam
    - May 3\textsuperscript{rd} (Thursday)
    - 7:15-9:15 p.m.
The Nature of Information

Symbols and Information Quantity
Information is a Relation!

- The central structure of information is a *relation* among *signs*, *objects* or *things*, and *agents* capable of understanding (or decoding) the signs.

- *Agents* are informed by a *Sign* about some *Thing*.
Semiotics and Informatics

- **Semantics**
  - the content or **meaning** of the *Sign* of a *Thing* for an *Agent*
  - Relations between signs and objects for an agent
  - the study of meaning.

- **Syntax** → **Information Technology**
  - the characteristics of *signs* and symbols devoid of meaning
  - Relations among signs such as their rules of operation, production, storage, and manipulation.

- **Pragmatics**
  - the context of signs and repercussions of sign-systems in an environment
  - it studies how context influences the interpretation of signs and how well a signs-system represents some aspect of the environment.
(Peirce’s) Typology of Signs

- **Icons** are direct representations of objects.
  - Similar to the thing they represent.
  - Pictorial road signs, scale models, computer icons.
    - A footprint on the sand is an icon of a foot.

- **Indices** are indirect representations of objects, but necessarily related.
  - Smoke is an index of fire, the bell is an index of the tolling stroke
    - A footprint is an index of a person.

- **Symbols** are arbitrary representations of objects
  - Require exclusively a social convention to be understood
    - Convention establishes a code, agreed by a group of agents, for understanding (decoding) the information contained in symbols.
    - Smoke is an index of fire, but if we agree on an appropriate code (e.g. Morse code) we can use smoke signals to communicate symbolically.
The Bit

- Shannon used the binary system because it is the most economical
  - Uses less memory
  - Information quantity depends on the number of alternative choices of messages encoded in the binary system
- Bit (short for binary digit) is the most elementary choice one can make
  - Between two items: “0’ and “1”, “heads” or “tails”, “true” or “false”, etc.
  - Bit is equivalent to the choice between two equally likely choices
    - Example, if we know that a coin is to be tossed, but are unable to see it as it falls, a message telling whether the coin came up heads or tails gives us one bit of information.
**Digital versus Analog**

- Digital is used to convey the notion of discrete objects/values
  - Things we can count
  - The word digit comes from the Latin word for finger (digitus)
  - Digital information is equivalent to symbolic information
    - Any symbol system requires a set of discrete symbols for setting up an arbitrary semantic relation

**Analog (or Analogue)**

- Information transmission via electrical, mechanical, hydraulic, and sound signals
  - Continuously varying signals which are not countable
  - What was used up until Shannon
  - Instead of messages being arbitrarily encoded, analog signals rely on some physical property of the medium
  - It implies an analogy between cause and effect, input and output
    - Voltage as an “analogy” to sound in analog synthesizer
    - But it cannot encode any sound whatsoever!
    - Sounds depend on the physical properties of electricity, the transducer and equipment used
Questions

- What is informatics?
- What is the difference between an “index” and an “symbol”? 
- Examples of Analogue vs. Digital Information?
- How does Information Technology relate to semiotics?
Technology

Tools, Cyborgs and History of IT
Transparent Technology

- So well fitted to, and integrated with, our own lives, biological capacities, and projects as to become almost invisible in use (Andy Clark)
- Glasses, wrist-watches, driving cars, mobile phones, pens, sports and musical equipment: human-centered
  - Not the same as easy to understand

Opaque Technology

- Highly visible in use: technology-centered
  - Computers, industrial machines
- Opaque technology can become transparent with practice
  - But it works better when biologically suited
    - Natural fit, ergonomics

http://www.baddesigns.com/examples.html
http://www.jnd.org/

(Donald Norman)
Humans more than using, incorporate technology

- We know we “know” the time, simply because we are equipped with a watch
- As more portable computing devices become available, will we incorporate easily accessible collective knowledge as our own?

- Transparent knowledge technology
  - Example: Google SMS
  - Adaptive Knowledge Technology (Clark, Chapter 6)

http://www.google.com/sms/howtouse.html#top
Charles Babbage (1791 – 1871)

- **Analytical Engine**
  - Working with Ada Lovelace (daughter of Lord Byron) designed what was to have been a general-purpose mechanical digital computer.
    - With a memory store and a central processing unit (or ‘mill’) and would have been able to select from among alternative actions consequent upon the outcome of its previous actions
      - **Conditional branching: Choice, information**
    - Programmed with instructions contained on punched cards
The First Personal Computer

- In 1971, Intel released the first microprocessor.
  - Able to process four bits of data at a time!

- The Altair 8800 (1975)
  - by a company called *Micro Instrumentation and Telemetry Systems* (MITS) sold for $397
  - Came as a kit for assembly who had to to write software for the machine
    - in machine code!
  - 256 byte memory -- about the size of a paragraph

- Microsoft
  - Was born to create a BASIC compiler for the Altair
    - *Beginners All-purpose Symbolic Instruction Code*
graphical user interface (GUI)

- On-Line System (NLS) (1960s)
  - Doug Engelbart's *Augmentation of Human Intellect* project @ Stanford Research Institute
    - pioneer of human-computer interaction
    - also developed hypertext
  - Incorporated a mouse-driven cursor and multiple windows.
    - WIMP (windows, icons, menus and pointers)
    - See his demo
      - [http://sloan.stanford.edu/MouseSite/1968Demo.html](http://sloan.stanford.edu/MouseSite/1968Demo.html)

- XEROX PARC
  - Xerox Alto (1973)
    - first computer to use the *desktop metaphor* and GUI
Questions

- Transparent vs Opaque Technology?
- Describe two computing devices used before the XX century.
- Which communications protocol marks the transition from the ARPANET to the Internet?
Modeling

Describing and Understanding the World
“The most direct and in a sense the most important problem which our conscious knowledge of nature should enable us to solve is the anticipation of future events, so that we may arrange our present affairs in accordance with such anticipation”. (Hertz, 1894)
Branching L-Systems

- Add branching symbols [ ]
- Simple example
  - Main trunk shoots off one side branch
- Angle 10
- Axiom F
- F=F[+F]F

Gen. 1
[+F]
F
F

Gen. 2

Gen. 3

Gen. 8

Flocking Behavior

- Boids by Craig Reynolds (1986)
  - 3 Steering behaviors
    - **Separation**: steer to avoid crowding local flockmates
      - Maintain minimum distance to others
    - **Alignment**: steer towards the average heading of local flockmates
      - Adjust speed according to others in vicinity
    - **Cohesion**: steer to move toward the average position of local flockmates
  - Each boid sees only flockmates within a certain small neighborhood around itself.
Questions

1. Describe the Hertz Modelling Process
2. What are Boids and how do they work?
3. Propose a L-System Rule to draw the following artificial plant
Data Representation

Encoding the World

Pixels: picture elements
Encoding in the Modeling Relation

- How to encode data?
  - What is data?
    - Information without context and knowledge
    - Part of Syntax
  - Keeping Numbers
    - The most fundamental need for modeling and information
Encoding Numbers: Counting

- Tallying is the earliest form of modeling
  - Fingers (digits), stones (Lit “calculus”= Pebble), bones
  - **Lebombo bone**
    - Oldest counting tool is a piece of baboon fibula with 29 notches from 35,000 BC, discovered in the mountains between South Africa and Swaziland
    - Probably representing the number of days in a Moon Cycle (A Model!)
  - Czechoslovakian wolf’s bone
    - with 55 notches in groups of 5, from 30,000 BC.

The **Ishango Bone**
- Oldest Mathematical Artefact?
  - 10,000 BC, border of Zaire and Uganda
  - Used as a counting tool?
    - 9, 11, 13, 17, 19, 21: odd numbers
    - 11, 13, 17, 19: prime numbers
    - 60 and 48 are multiples of 12

http://www.simonsingh.com/The_Ishango_Bone.html
Converting Binary to Decimal

- $2^8 = 256$
- $2^7 = 128$
- $2^6 = 64$
- $2^5 = 32$
- $2^4 = 16$
- $2^3 = 8$
- $2^2 = 4$
- $2^1 = 2$
- $2^0 = 1$

$\ldots d_4 d_3 d_2 d_1 d_0 = \ldots + d_4 \times 2^4 + d_3 \times 2^3 + d_2 \times 2^2 + d_1 \times 2^1 + d_0 \times 2^0$
Base Conversion

- **Decimal to Binary**
  - **Repeated Division by 2**
    - Divide the decimal number by 2
    - If the remainder is 0, write down a 0
    - If the remainder is 1, write down a 1
    - Continue until the quotient is 0
    - Remainders are written beginning at the least significant digit (right) and each new digit is written to more significant digit (the left) of the previous digit.

<table>
<thead>
<tr>
<th>decimal</th>
<th>quotient</th>
<th>Remain.</th>
<th>binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>29</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>29</td>
<td>14</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>14</td>
<td>7</td>
<td>0</td>
<td>010</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>1</td>
<td>1010</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
<td>11010</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>111010</td>
</tr>
</tbody>
</table>
Dealing with rational numbers

- $2^4 = 16$
- $2^3 = 8$
- $2^2 = 4$
- $2^1 = 2$
- $2^0 = 1$
- $2^{-1} = 0.5$
- $2^{-2} = 0.25$
- $2^{-3} = 0.125$

...$d_2d_1d_0.d_{-1}d_{-2}... = \ldots + d_2 \times 2^2 + d_1 \times 2^1 + d_0 \times 2^0 + d_{-1} \times 2^{-1} + d_{-2} \times 2^{-2} + \ldots$
Binary Arithmetic

- **Addition Rules**
  - $0+0 = 0$, with no carry,
  - $1+0 = 1$, with no carry,
  - $0+1 = 1$, with no carry,
  - $1+1 = 0$, and you carry a $1$

\[
\begin{array}{c}
1 \\
1010 \\
1100 \\
\hline
1111 \\
10101110 \\
11000
\end{array}
\]

\[
\begin{array}{c}
10110 \\
1110 \\
\hline
10110 \\
11000
\end{array}
\]

\[(10+12=22) \quad (10+14=24)\]
Binary Multiplication

\[
\begin{array}{cccccc}
& & & 1010 & & \\
& & 1110 & & & \\
& & & \hline
& & & \text{111} & & \\
& & 0000 & & & \\
& 1010_ & & & & \\
& 1010_ & & & & \\
& 1010_ & & & & \\
\end{array}
\]

\[1111000\]

\(10 \times 12 = 120\)

\[
\begin{array}{cccc}
1010 & & & \\
1100 & & & \\
\hline
0000 & & & \\
0000_ & & & \\
1010_ & & & \\
1010_ & & & \\
\end{array}
\]

\[10001100\]

\((10 + 14 = 140)\)
Hexadecimal

- Base 16
  - 16 symbols: 0,1,2,3,4,5,6,7,8,9, A, B, C, D, E, F
  - Easy to convert to and from Binary
    - 16 is a power of 2: $16 = 2^4$
    - It takes 4 binary digits for every hexadecimal one
    - Good to represent binary in compressed form!

<table>
<thead>
<tr>
<th>Hex</th>
<th>Bin</th>
<th>Hex</th>
<th>Bin</th>
<th>Hex</th>
<th>Bin</th>
<th>Hex</th>
<th>Bin</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0000</td>
<td>4</td>
<td>0100</td>
<td>8</td>
<td>1000</td>
<td>C</td>
<td>1100</td>
</tr>
<tr>
<td>1</td>
<td>0001</td>
<td>5</td>
<td>0101</td>
<td>9</td>
<td>1001</td>
<td>D</td>
<td>1101</td>
</tr>
<tr>
<td>2</td>
<td>0010</td>
<td>6</td>
<td>0110</td>
<td>A</td>
<td>1010</td>
<td>E</td>
<td>1110</td>
</tr>
<tr>
<td>3</td>
<td>0011</td>
<td>7</td>
<td>0111</td>
<td>B</td>
<td>1011</td>
<td>F</td>
<td>1111</td>
</tr>
</tbody>
</table>
Encoding Text

- **ASCII**
  - **American Standard Code for Information Interchange**
    - between binary numbers and computer and roman symbols
    - Standard to allow computers to communicate textual data
  - **Uses 7 bits to encode 128 symbols or characters**
    - \(2^7 = 128\). It fills a byte, but the 8th bit is used to encode additional symbols for other languages and graphics
  - Usually described in hexadecimal
  - **4 groups of 32 characters**
    - **00 to 1F: control characters**
      - Mostly printer/display operations: carriage return (0Dh), line feed (0Ah), back space (08h), etc.
    - **20 to 3F: punctuation, numeric, and special characters**
      - Space (20h), digits 0-9 (30h-39h)
        - Arranged so that by subtracting 30h from the ASCII code for any digit, we obtain the numeric equivalent of the digit
    - **40 to 5F: uppercase letters, plus some special characters**
    - **60 to 7F: lowercase letters, plus some special characters and a control character (DEL)**
<table>
<thead>
<tr>
<th>Dec</th>
<th>Hk</th>
<th>Oct</th>
<th>Char</th>
<th>Dec</th>
<th>Hk</th>
<th>Oct</th>
<th>Char</th>
<th>Dec</th>
<th>Hk</th>
<th>Oct</th>
<th>Char</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>000</td>
<td>BEL</td>
<td>32</td>
<td>20</td>
<td>010</td>
<td>SPACE</td>
<td>64</td>
<td>40</td>
<td>100</td>
<td>E6</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>001</td>
<td>BEL</td>
<td>33</td>
<td>21</td>
<td>041</td>
<td>033</td>
<td>65</td>
<td>41</td>
<td>101</td>
<td>E6</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>002</td>
<td>BEL</td>
<td>34</td>
<td>22</td>
<td>042</td>
<td>E0</td>
<td>66</td>
<td>42</td>
<td>102</td>
<td>E6</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>003</td>
<td>BEL</td>
<td>35</td>
<td>23</td>
<td>043</td>
<td>E8</td>
<td>67</td>
<td>43</td>
<td>103</td>
<td>E6</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>004</td>
<td>BEL</td>
<td>36</td>
<td>24</td>
<td>044</td>
<td>E4</td>
<td>68</td>
<td>44</td>
<td>104</td>
<td>E6</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>005</td>
<td>BEL</td>
<td>37</td>
<td>25</td>
<td>045</td>
<td>E2</td>
<td>69</td>
<td>45</td>
<td>105</td>
<td>E6</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>006</td>
<td>BEL</td>
<td>38</td>
<td>26</td>
<td>046</td>
<td>E1</td>
<td>70</td>
<td>46</td>
<td>106</td>
<td>E6</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>007</td>
<td>BEL</td>
<td>39</td>
<td>27</td>
<td>047</td>
<td>E9</td>
<td>71</td>
<td>47</td>
<td>107</td>
<td>E6</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>008</td>
<td>BEL</td>
<td>40</td>
<td>28</td>
<td>048</td>
<td>E6</td>
<td>72</td>
<td>48</td>
<td>108</td>
<td>E6</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>009</td>
<td>BEL</td>
<td>41</td>
<td>29</td>
<td>049</td>
<td>E7</td>
<td>73</td>
<td>49</td>
<td>109</td>
<td>E6</td>
</tr>
<tr>
<td>10</td>
<td>A</td>
<td>010</td>
<td>LF</td>
<td>42</td>
<td>30</td>
<td>050</td>
<td>E8</td>
<td>74</td>
<td>50</td>
<td>110</td>
<td>E6</td>
</tr>
<tr>
<td>11</td>
<td>B</td>
<td>011</td>
<td>VT</td>
<td>43</td>
<td>31</td>
<td>051</td>
<td>E4</td>
<td>75</td>
<td>51</td>
<td>111</td>
<td>E6</td>
</tr>
<tr>
<td>12</td>
<td>C</td>
<td>012</td>
<td>FF</td>
<td>44</td>
<td>32</td>
<td>052</td>
<td>E2</td>
<td>76</td>
<td>52</td>
<td>112</td>
<td>E6</td>
</tr>
<tr>
<td>13</td>
<td>D</td>
<td>013</td>
<td>CR</td>
<td>45</td>
<td>33</td>
<td>053</td>
<td>E1</td>
<td>77</td>
<td>53</td>
<td>113</td>
<td>E6</td>
</tr>
<tr>
<td>14</td>
<td>E</td>
<td>014</td>
<td>SO</td>
<td>46</td>
<td>34</td>
<td>054</td>
<td>E9</td>
<td>78</td>
<td>54</td>
<td>114</td>
<td>E6</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
<td>015</td>
<td>SI</td>
<td>47</td>
<td>35</td>
<td>055</td>
<td>E7</td>
<td>79</td>
<td>55</td>
<td>115</td>
<td>E6</td>
</tr>
<tr>
<td>16</td>
<td>G</td>
<td>016</td>
<td>DLE</td>
<td>48</td>
<td>36</td>
<td>056</td>
<td>E8</td>
<td>80</td>
<td>56</td>
<td>116</td>
<td>E6</td>
</tr>
<tr>
<td>17</td>
<td>H</td>
<td>017</td>
<td>DC1</td>
<td>49</td>
<td>37</td>
<td>057</td>
<td>E4</td>
<td>81</td>
<td>57</td>
<td>117</td>
<td>E6</td>
</tr>
<tr>
<td>18</td>
<td>I</td>
<td>018</td>
<td>DC2</td>
<td>50</td>
<td>38</td>
<td>058</td>
<td>E2</td>
<td>82</td>
<td>58</td>
<td>118</td>
<td>E6</td>
</tr>
<tr>
<td>19</td>
<td>J</td>
<td>019</td>
<td>DC3</td>
<td>51</td>
<td>39</td>
<td>059</td>
<td>E1</td>
<td>83</td>
<td>59</td>
<td>119</td>
<td>E6</td>
</tr>
<tr>
<td>20</td>
<td>K</td>
<td>020</td>
<td>DC4</td>
<td>52</td>
<td>40</td>
<td>060</td>
<td>E9</td>
<td>84</td>
<td>60</td>
<td>120</td>
<td>E6</td>
</tr>
<tr>
<td>21</td>
<td>L</td>
<td>021</td>
<td>NAK</td>
<td>53</td>
<td>41</td>
<td>061</td>
<td>E7</td>
<td>85</td>
<td>61</td>
<td>121</td>
<td>E6</td>
</tr>
<tr>
<td>22</td>
<td>M</td>
<td>022</td>
<td>SYN</td>
<td>54</td>
<td>42</td>
<td>062</td>
<td>E8</td>
<td>86</td>
<td>62</td>
<td>122</td>
<td>E6</td>
</tr>
<tr>
<td>23</td>
<td>N</td>
<td>023</td>
<td>ETB</td>
<td>55</td>
<td>43</td>
<td>063</td>
<td>E4</td>
<td>87</td>
<td>63</td>
<td>123</td>
<td>E6</td>
</tr>
<tr>
<td>24</td>
<td>O</td>
<td>024</td>
<td>CAN</td>
<td>56</td>
<td>44</td>
<td>064</td>
<td>E2</td>
<td>88</td>
<td>64</td>
<td>124</td>
<td>E6</td>
</tr>
<tr>
<td>25</td>
<td>P</td>
<td>025</td>
<td>EM</td>
<td>57</td>
<td>45</td>
<td>065</td>
<td>E1</td>
<td>89</td>
<td>65</td>
<td>125</td>
<td>E6</td>
</tr>
<tr>
<td>26</td>
<td>Q</td>
<td>026</td>
<td>SUB</td>
<td>58</td>
<td>46</td>
<td>066</td>
<td>E9</td>
<td>90</td>
<td>66</td>
<td>126</td>
<td>E6</td>
</tr>
<tr>
<td>27</td>
<td>R</td>
<td>027</td>
<td>ESC</td>
<td>59</td>
<td>47</td>
<td>067</td>
<td>E7</td>
<td>91</td>
<td>67</td>
<td>127</td>
<td>E6</td>
</tr>
<tr>
<td>28</td>
<td>S</td>
<td>028</td>
<td>FSS</td>
<td>60</td>
<td>48</td>
<td>068</td>
<td>E8</td>
<td>92</td>
<td>68</td>
<td>128</td>
<td>E6</td>
</tr>
<tr>
<td>29</td>
<td>T</td>
<td>029</td>
<td>GSB</td>
<td>61</td>
<td>49</td>
<td>069</td>
<td>E4</td>
<td>93</td>
<td>69</td>
<td>129</td>
<td>E6</td>
</tr>
<tr>
<td>30</td>
<td>U</td>
<td>030</td>
<td>RSS</td>
<td>62</td>
<td>50</td>
<td>070</td>
<td>E2</td>
<td>94</td>
<td>70</td>
<td>130</td>
<td>E6</td>
</tr>
<tr>
<td>31</td>
<td>V</td>
<td>031</td>
<td>US</td>
<td>63</td>
<td>51</td>
<td>071</td>
<td>E1</td>
<td>95</td>
<td>71</td>
<td>131</td>
<td>E6</td>
</tr>
</tbody>
</table>

Sources: www.asciiTable.com

Luis M. Rocha and Santiago Schnell
Bitmap Image

- Representation of a two-dimensional image as a finite set of digital values
- Picture elements or pixels

- **Resolution**: number of pixels in an image
  - 1024 x 768
- Each defined by one or more numbers
  - Color, intensity

$2^{24}$ (about 16 million)

- **RGB**: 3 Bytes, one for each primary colors: Red, Green, and Blue: 16,777,216 colors total

adapted from Cathy Wyss (I308)
Graphics Interchange Format

- Developed by CompuServe in 1987 (GIF87a)
  - Developed to facilitate exchange across computing platforms
  - Allows transparency
  - GIF89a
    - 1989: allows animated GIF images
- Uses LZW data compression
  - More efficient than plain bitmaps
  - Large images downloaded quicker
  - Patent owned by Unisys until 2003
    - CompuServe did not know that LZW was covered by a patent.
    - Before 1994, Unisys was not aware that GIF used LZW.
- Builds a dictionary of previously seen strings in the information being compressed.
  - The dictionary does not have to be transmitted

http://sheepfilms.co.uk
Questions

- What is a positional number system? Give an example of a number system that is not positional, and an example of one that is positional.

- Convert 1001001101.01 from binary to decimal. Please show your calculations.

- What is the ASCII encoding of the word TURING (Uppercase) in Decimal?
  - 84 85 82 73 78 71
  - 73 78 70 79 82 77 65 84 73 67 83
  - 65 82 73 83 84 79 84 76 69
  - 65 83 67 73 73 50

- How many bytes do you need to encode a bitmap figure with resolution 300 x 600 using the RGB format?
  - 960,000
  - 180,000
  - 480,000
  - 540,000
Deductive Modeling

Logic, Sets, Deduction

Penguins are black and white.
Some old TV shows are black and white.
Therefore, some penguins are old TV shows.

Logic: another thing that penguins aren’t very good at.
The Modeling Relation

Hertz' Modeling Paradigm

- **Symbols (Images)**
  - Initial Conditions
  - Formal Rules
  - Logical Consequence of Model
  - Predicted Result

- **World1**
  - Physical Laws
  - Encoding (Semantics)

- **World2**
  - Measure

- **Predicted Result**
  - Observed Result

- **Pragmatics**

- **Formal Rules**
  - From symbolic representations of observables
  - Produce Conclusions
Monty Python: Holy Grail

- Villagers: (enter yelling) A witch! A witch! We’ve found a witch! Burn her! Burn her!
- Bedimere: there are ways of telling if she’s a witch. What do you do with witches?
- Villagers: Burn them!
- Bedimere: And what do you burn, apart from witches?
- Villagers: Wood?
- Bedimere: Right! So why do witches burn?
- Villagers: Because they’re made of wood?
- Bedimere: Right! . Now, what else do you do with wood?
- Villagers: Build bridges with it!
- Bedimere: But do we not also build bridges from stone; does wood float in water?
- Villagers: Yes.
- Bedimere: And what else floats in water?
- King Arthur: (after more confused suggestions from the villagers) A duck!
- Bedimere: Right! So, if she weighs the same as a duck, she’d float in water, and she must be made of wood, so.
- Villagers: A witch! Burn her!
- (They weigh the woman on a large scale with a duck in the other balancing basket, but inexplicably the scales do not tilt one way or the other. As the villagers drag the woman away, the witch looks at the camera and says with resignation "it was a fair court".)
- Bedimere: (to King Arthur) Who are you who are so wise in the ways of science?

(C) Python (Monty) Pictures
http://www.RossAnthony.com
Deduction vs. Induction

- Propositional Logic is used to study *inferences*
  - Lists of propositions
  - How conclusions can be reached from premises
- Deductive Inference
  - If the premises are true, we have absolute *certainty* of the conclusion
    - February has 29 days only in leap years
    - Today is February 29th
    - This year is a leap year
- Inductive Inference
  - Conclusion supported by *good evidence* (significant number of examples/observations) but not full certainty -- *likelihood*
    - Ran WhiteBox for 1000 cycles, “dead box” observed
    - Ran WhiteBox for 1000 cycles, “dead box” observed
    - Ran WhiteBox for 1000 cycles, “dead box” observed
    - “Dead Box” always appears after 1000 cycles
Uncertainty in Induction

- Via Induction
  - Europeans could have thought that all Swans are White
    - by observing instance after instance
  - But black swans exist
    - From Australia
The structure of propositional logic

- **Simple propositions** are represented by single, lower case letters
  - Bloomington is a town – \( p \)
  - Indiana is a state – \( q \)

- **Complex propositions** are constructed by applying logical operations to simple propositions
  - Bloomington is a town and Indiana is a state – \( p \) and \( q \)

- **Logic Operations**
  - Conjunction [and] \( \land \)
  - Disjunction [or] \( \lor \)
  - Negation [not] \( \neg \)
  - Conditional [implies] \( \Rightarrow \) (if, then)
  - Biconditional [equivalent] \( \Leftrightarrow \) (if and only if)
Symbolic Logic

- Logic uses a set of symbols and rules to represent the structure of reasoning with precision.
- This kind of logic is known as *symbolic logic* and divides in *propositional* and *predicate* logic.

- A formal system for representing knowledge in terms of *declarative sentences* that express *propositions*

- *Proposition* is the meaning of the sentence, rather than the sentence itself.
Conjunction

- Conjunction: \( p \land q \) corresponds to English “and.”
- Proposition \( p \land q \) is true when \( p \) and \( q \) are both true.

Example – Uma is blond and clever

Truth table for conjunction:

<table>
<thead>
<tr>
<th>( p )</th>
<th>( q )</th>
<th>( p \land q )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Adapted from C. Heeren
Disjunction

- Disjunction: $p \lor q$ corresponds to English “or.”
- Proposition $p \lor q$ is true when $p$ or $q$ (or both) is true.

**Example** - Madonna is blond or clever

**Truth table for disjunction:**

<table>
<thead>
<tr>
<th>$p$</th>
<th>$q$</th>
<th>$p \lor q$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Adapted from C. Heeren
Implication or Conditional

Implication: \( p \implies q \) corresponds to English “if...then...” or “\( p \) only if \( q \)”

*Example:* Brandon will pass I101, only if he is awake in classes

Truth table for implication:

\[
\begin{array}{ccc}
 p & q & p \implies q \\
 0 & 0 & 1 \\
 0 & 1 & 1 \\
 1 & 0 & 0 \\
 1 & 1 & 1 \\
\end{array}
\]

*\( q \) is a necessary condition for \( p \)*

*\( p \) is a sufficient condition for \( q \)*

Having a microscope (or some other instrument) is a necessary condition for (our) seeing viruses

*If* someone sees viruses, *then* that person uses a microscope

Adapted from C. Heeren
Equivalence or Biconditional

Equivalence: \( p \iff q \) corresponds to English “if and only if...then...”

\((p \Rightarrow q) \land (q \Rightarrow p)\)

Example – Brandon will pass I101 if and only if he doesn’t sleep in classes

Truth table for equivalence:

<table>
<thead>
<tr>
<th>( p )</th>
<th>( q )</th>
<th>( p \iff q )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Equivalence related to **Necessary and Sufficient Condition**: \( q \) is a necessary and sufficient condition for \( p \) and \( p \) is a necessary and sufficient condition for \( q \)

Adapted from C. Heeren
Proof for the distributive rule

\[ p \lor (q \land r) \equiv (p \lor q) \land (p \lor r) \]

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Adapted from C. Heeren
Proofs for De Morgan’s Law I

\[ \neg(p \lor q) \equiv \neg p \land \neg q \]

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>(\neg p)</th>
<th>(\neg q)</th>
<th>(\neg p \land \neg q)</th>
<th>(p \lor q)</th>
<th>(\neg(p \lor q))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Adapted from C. Heeren
Classical Set Theory

- Propositional logic helps us make distinctions.
  - True and False, tautologies, contradictions
- Classical set theory is another form of representing the same kind of distinctions
  - Between and among groups that we perceive to share a characteristic or property.
Set Operations

The *union* of two sets $A$ and $B$ is:

$$A \cup B = \{ x : x \in A \lor x \in B \}$$

If $A = \{\text{Charlie, Lucy, Linus}\}$, and $B = \{\text{Lucy, Desi}\}$, then

$$A \cup B = \{\text{Charlie, Lucy, Linus, Desi}\}$$

Adapted from C. Heeren
Set Operations

The *intersection* of two sets $A$ and $B$ is:

$$A \cap B = \{ x : x \in A \land x \in B \}$$

If $A = \{x : x \text{ is a US president}\}$, and $B = \{x : x \text{ is deceased}\}$, then

$$A \cap B = \{x : x \text{ is a deceased US president}\}$$

- $B$: Set of Funny People
- $A$: Set of Clowns

Adapted from C. Heeren
Qualities of the Tazmanian Devil, Wile E. Coyote, and Elmer Fudd

**Tazmanian Devil**
- Australian (Tasmania)
- had his own cartoon show: Taz-Mania
- first appeared in early '50s
- spits and slobbers uncontrollably
- often distracted by she-devils

**Wile E. Coyote**
- preferred game is road runner
- usually hunts in deserts
- plans elaborately
- buys only ACME brand
- genius

**Elmer Fudd**
- funny hat
- no hair
- a foil for Bugs Bunny
- human
- won an Academy Award in 1940

**Shared Qualities**
- mammal
- brown fur
- fast
- personified (human-like)
- carnivore
- property of Warner Bros.
- Looney Tunes antagonist
- cartoon character
- Space Jam star
- hunts animals
- American first appeared in '40s
- uses weapons to hunt
- co-created by Chuck Jones
- Who Framed Roger Rabbit? cameo
Questions

- Build the truth tables of the following:
  - $\neg \neg a$
  - $a \land (b \land \neg a)$
  - $(a \implies b) \implies \neg b$

- Given a Universal Set $X = \{0, 1, 2, 3, 4, 5\}$, let $A=\{0,1,2\}$, $B=\{2,3,4\}$ and $C=\{1,2,3,5\}$.
  - Show that $(A \cap B) \cup C \neq (A \cup B) \cap C$
  - Express $\{5\}$ in terms of $A$, $B$, and $C$ using set operations
  - Express $\{2\}$ in terms of $A$, $B$, and $C$ using set operations
Inductive Modeling

Statistics, Probability, Fitting Data, Induction
Summarizing Data

- **Frequency**
  - Number of times a value occurs in a collection

- **Frequency Distribution**
  - Given a collection of data values, the specification of all the distinctive values in the collection together with the number of times each of these values *occurs* in the collection
  - Table that organizes data into mutually exclusive classes
  - Shows number of observations from data set that fall into each class

[Chase and Brown, “General Statistics”]
## Frequency Distribution

**Sorted Data:** 30 data values

<table>
<thead>
<tr>
<th>Class</th>
<th>Tallies</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.2</td>
<td>//</td>
<td>2</td>
</tr>
<tr>
<td>15.3</td>
<td>///</td>
<td>5</td>
</tr>
<tr>
<td>15.4</td>
<td>///</td>
<td>11</td>
</tr>
<tr>
<td>15.5</td>
<td>///</td>
<td>6</td>
</tr>
<tr>
<td>15.6</td>
<td>///</td>
<td>3</td>
</tr>
<tr>
<td>15.7</td>
<td>///</td>
<td>3</td>
</tr>
</tbody>
</table>
## Relative Frequency Distribution

<table>
<thead>
<tr>
<th>Class</th>
<th>Frequency (1)</th>
<th>Relative Freq. (1) ÷ 30</th>
<th>Cumulative Relative Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.2</td>
<td>2</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>15.3</td>
<td>5</td>
<td>0.16</td>
<td>0.23</td>
</tr>
<tr>
<td>15.4</td>
<td>11</td>
<td>0.37</td>
<td>0.60</td>
</tr>
<tr>
<td>15.5</td>
<td>6</td>
<td>0.20</td>
<td>0.80</td>
</tr>
<tr>
<td>15.6</td>
<td>3</td>
<td>0.10</td>
<td>0.90</td>
</tr>
<tr>
<td>15.7</td>
<td>3</td>
<td>0.10</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>
Frequency Histogram

<table>
<thead>
<tr>
<th>Class</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.2-15.4</td>
<td>2</td>
</tr>
<tr>
<td>15.5-15.7</td>
<td>5</td>
</tr>
<tr>
<td>15.8-16.0</td>
<td>11</td>
</tr>
<tr>
<td>16.1-16.3</td>
<td>6</td>
</tr>
<tr>
<td>16.4-16.6</td>
<td>3</td>
</tr>
<tr>
<td>16.7-16.9</td>
<td>3</td>
</tr>
</tbody>
</table>
Measuring Central Tendency

The number that is meant to convey the idea of a \textit{typical} or representative value for the data array or distribution.
Mean (Ungrouped Data)

Population Mean

\[
\mu = \frac{\sum X}{N}
\]

- \( \mu \) represents the population mean.
- \( \sum X \) is the sum of all observations in the population.
- \( N \) is the number of elements in the population.

Sample Mean

\[
\bar{X} = \frac{\sum X}{n}
\]

- \( \bar{X} \) represents the sample mean.
- \( \sum X \) is the sum of all observations in the sample.
- \( n \) is the number of elements in the sample.
The mean is the balancing point of the frequency distribution.

Histograms balance at the mean.
## Central Tendency Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>$\frac{\sum x}{n}$</td>
<td>Balance Point</td>
</tr>
<tr>
<td>Median</td>
<td>$(n +1) th$ item in $\frac{2}{array}$</td>
<td>Middle value in ordered array</td>
</tr>
<tr>
<td>Mode</td>
<td>none</td>
<td>Most frequent</td>
</tr>
</tbody>
</table>
Measuring Dispersion

The number that conveys an idea of how much *spread* or *variability* exists among the data values.
Sample Variance Formula

\[ s^2 = \frac{\sum (x - \bar{x})^2}{n - 1} \]

Where:
- \( n \) - sample size
- \( x \) - item or observation
- \( \bar{x} \) - sample mean
- \( \sum \) - sum of the values

\( n - 1 \) in denominator! (Use \( N \) if Population Variance)
### Example: Sample Dispersion

<table>
<thead>
<tr>
<th>Frequency Distribution</th>
<th>Class</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15.2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>15.3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>15.5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>15.6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>15.7</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>15.8</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>15.9</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>16.0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>16.1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>16.2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>16.3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>16.4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>16.8</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>1</td>
</tr>
</tbody>
</table>

**Frequency Distribution Table**

- **Mean:**
  
  \[
  \begin{align*}
  \text{Mean: } & 16.01 \\
  (15.2 - 16.01)^2 = & 0.6561 \\
  (15.3 - 16.01)^2 = & 0.5041 \\
  (15.5 - 16.01)^2 = & 0.2601 \\
  2 \times (15.6 - 16.01)^2 = & 0.3362 \\
  2 \times (15.7 - 16.01)^2 = & 0.1922 \\
  4 \times (15.8 - 16.01)^2 = & 0.1764 \\
  \text{Variance: } & 4.847/30 = 0.167138 \\
  \text{Standard Deviation: } & \sqrt{0.167138} = 0.408825 \\
  \text{Range: } & 16.8 - 15.2 = 1.6 \\
  \text{Variance: } & 4.847/30 = 0.167138 \\
  \text{Standard Deviation: } & \sqrt{0.167138} = 0.408825 \\
  \text{Range: } & 16.8 - 15.2 = 1.6 \\
  \text{Variance: } & 4.847/30 = 0.167138 \\
  \text{Standard Deviation: } & \sqrt{0.167138} = 0.408825 \\
  \text{Range: } & 16.8 - 15.2 = 1.6
  \end{align*}
\]

---

**Carpet Loom Example**

- **Mean:** 16.01
- **Range:** 16.8 – 15.2 = 1.6
- **Standard Deviation:** \( \sqrt{0.167138} = 0.408825 \)
- **Variance:** 4.847/30 = 0.167138
Example

A plumber charges $20 for driving to your house, plus $40 for each hour of work at your home.

Let

- $y$ = total charge
- $x$ = number of hours of work at your house

The relationship between $y$ and $x$ is

- $y = 20 + 40x$
General Linear Relationship

\[ y = b_0 + b_1 x \]
Errors or Residuals Graphically

\[ e = y - \hat{y} \]

\[ \hat{Y} = a + bX \]
Least Squares Criterion

\[ e = y - \hat{y} \]

- Adding all the errors may lead to very small errors due to terms cancelling out.
- Squares of errors eliminates this problem.
- The line that best fits the data is the one for which the sum of the squares of the errors (\( \text{SSE} \)) is smallest.

\[ \text{SSE} = \sum e^2 = \sum (y - \hat{y})^2 \]
Method for Regression

- Line of best fit or regression based on Least Squares Criterion

\[ \hat{y} = b_0 + b_1 x \]

\[ b_1 = \frac{\sum (x y - n \bar{x} \bar{y})}{\sum x^2 - n \bar{x}^2} \]

\[ b_0 = \bar{y} - b_1 \bar{x} \]
### Parameter Estimation Example

#### Data

<table>
<thead>
<tr>
<th>Student</th>
<th>Exam Score</th>
<th>G.P.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>74</td>
<td>2.6</td>
</tr>
<tr>
<td>B</td>
<td>69</td>
<td>2.2</td>
</tr>
<tr>
<td>C</td>
<td>85</td>
<td>3.4</td>
</tr>
<tr>
<td>D</td>
<td>63</td>
<td>2.3</td>
</tr>
<tr>
<td>E</td>
<td>82</td>
<td>3.1</td>
</tr>
<tr>
<td>F</td>
<td>60</td>
<td>2.1</td>
</tr>
<tr>
<td>G</td>
<td>79</td>
<td>3.2</td>
</tr>
<tr>
<td>H</td>
<td>91</td>
<td>3.8</td>
</tr>
</tbody>
</table>

- **$n = 8$**
- **$\bar{x} = 75.375$**
- **$\bar{y} = 2.8375$**

#### Calculations

- $b_1 = \frac{\sum xy - n\bar{xy}}{\sum x^2 - n\bar{x}^2}$
- $b_0 = \bar{y} - b_1 \bar{x}$

<table>
<thead>
<tr>
<th>$xy$</th>
<th>$x^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>192.4</td>
<td>5476</td>
</tr>
<tr>
<td>151.8</td>
<td>4761</td>
</tr>
<tr>
<td>289</td>
<td>7225</td>
</tr>
<tr>
<td>144.9</td>
<td>3969</td>
</tr>
<tr>
<td>254.2</td>
<td>6724</td>
</tr>
<tr>
<td>126</td>
<td>3600</td>
</tr>
<tr>
<td>252.8</td>
<td>6241</td>
</tr>
<tr>
<td>345.8</td>
<td>8281</td>
</tr>
<tr>
<td></td>
<td>46277</td>
</tr>
</tbody>
</table>

$$b_1 = \frac{1756.9 - 8 \times 75.375 \times 2.8375}{46277 - 8 \times 75.375^2} = 0.05556$$

$$b_0 = 2.8375 - 0.05556 \times 75.375 = -1.351$$
How good is the Linear Fit?

Portion of deviation from mean “explained” or “accounted for” by the regression line

Portion of deviation from mean “unexplained” by the regression line

\[ TSS = SSE + SSR \]

\[ TSS = \sum (\bar{y} - y)^2 \]

\[ SSE = \sum (y - \hat{y})^2 \]

\[ SSR = \sum (\bar{y} - \hat{y})^2 \]
Coefficient of determination

- Degree of linear relationship
  - To make a judgment about whether a linear relationship really exists between $x$ and $y$.
  - The proportion of the variability in $y$ values that is accounted for or explained by a linear relationship with $x$.

$$r^2 = \frac{SSR}{TSS} = \frac{\sum (\bar{y} - \hat{y})^2}{\sum (\bar{y} - y)^2}$$
Example: Coefficient of determination

$R^2 = 0.93$

93% of the GPA variability is explained by the Exam Score (with a linear relationship)
How do we assign probability to an event?

- The probability of an event $A$ in an experiment is supposed to measure how frequently $A$ is about to occur if we make many trials.

- If we flip our coin many times, H and T will appear about equally often – we say that H and T are “equally likely”.

We regard probability as the counterpart of relative frequency!
English Letter Frequency

- Six most common letters in English
  - E T A O I N
- Spanish
  - E A O S R N
- Other Languages
  - [http://people.bath.ac.uk/tab21/forcrypt.html](http://people.bath.ac.uk/tab21/forcrypt.html)
What is the probability of finding the letter “e” in an English text?

<table>
<thead>
<tr>
<th>Vowel</th>
<th>( f_{rel} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.082</td>
</tr>
<tr>
<td>E</td>
<td>0.127</td>
</tr>
<tr>
<td>I</td>
<td>0.070</td>
</tr>
<tr>
<td>O</td>
<td>0.075</td>
</tr>
<tr>
<td>U</td>
<td>0.028</td>
</tr>
</tbody>
</table>
Probability Notions

- **Experiment**
  - Any activity that yields a result or an outcome
    - Tossing a coin

- **Sample Space**
  - The set of all possible outcomes of an experiment.
    - One and only one of the outcome must occur
      - Flipping one coin: $S_1 = \{H, T\}$
      - Flipping two coins: $S_2 = \{HH, HT, TH, TT\}$

- **Event**
  - Subset of sample space
  - The event occurs if when we perform the experiment one of its elements occurs.
    - Non-match in two coin experiment is an event $E = \{HT, TH\}$

[Chase and Brown, “General Statistics”]
Probability of an Event

- **P(A)**
  - The expected proportion of occurrences of an event A if the experiment were to be repeated many times
  - 0 ≤ P(A) ≤ 1
  - P(A) = P({a_1}) + P({a_2}) + ... + P({a_n})
    - A = {a_1, a_2, ..., a_n}
  - Theoretical probability: P(A) = |A|/|S|
    - S1: P({T}) = ½ and P({H}) = ½
    - S2: P(nonmatch) = P({HT}) + P({TH}) = ¼ + ¼ = ½

- Estimated from limited experiments
  - Empirical probability
    - {T,T,H,T} ⇒ P({T}) = 0.75 and P({H}) ⇒ 0.25
  - Guessed
    - Subjective probability
      - “there is a 90% chance that I will pass this course”
Conditional Probability

- $P(B|A) = \frac{|A \cap B|}{|A|}$
- Probability of a IU student being an Informatics major, given that a student is enrolled in I101
  - $|I101| = 70$ students
  - $|IM| = |\{informatics\ major\}| = 400$
  - $P(IM|I101) = \frac{|IM \cap I101|}{|I101|} = \frac{35}{70} = 0.5$
  - $P(IM) = \frac{400}{20000} = 0.02$

- Multiplication Rule
  - $P(A \cap B) = P(A) \cdot P(B|A)$
Independent Events

- Two events $A$, $B$ are independent if the occurrence of one has no effect on the probability of the occurrence of the other.
  - $P(B|A) = P(B)$
  - Multiplication Rule
    - $P(A \land B) = P(A) \cdot P(B)$

Example
- Tossing coins
Questions

- Over a 20-game period, the number of hits by a baseball player was:
  - 1, 2, 0, 0, 1, 2, 2, 1, 0, 0, 4, 0, 1, 1, 3, 2, 1, 3, 0, and 1
  - Construct the Frequency distribution
  - In what proportion of games did he get at least 3 hits?
  - What is the mean, median, and mode

- What is the line that best fits the data with the least squares criterion?

- A coin is tossed three times and an H or T (H= Head, T=Tail) is recorded each time.
  - List the elements of the sample space S and list the elements of the event consisting of:
    - All heads
    - A head on the second toss
    - Two tails
  - Represent the sample space and the events above as a Venn Diagram

- One card is to be selected from an ordinary deck of 52 cards. Find the probability that:
  - The selected card is an ace
  - The selected card is not a 9
Uncertainty

Hartley and Shannon Information

"Do you think they mean us?"
Uncertainty in The Modeling Relation

Hertz’ Modeling Paradigm

- Measurements
  - Always uncertain
- Limited Information
  - Induction from available evidence, especially in the presence of randomness
- Vagueness or Imprecision of Language of Description
  - “being tall” means different things to different people
- Quality of Inferences
  - Error Estimation

Measurements

Limited Information

Vagueness or Imprecision of Language of Description

Quality of Inferences

Error Estimation

World₁

Physical Laws

World₂
Let’s talk about choices

- **Multiplication Principle**
  - “If some choice can be made in M different ways, and some subsequent choice can be made in N different ways, then there are M x N different ways these choices can be made in succession” [Paulos]
  
  - 3 shirts and 4 pants = 3 x 4 = 12 outfit choices
Nonspecificity

- A type of ambiguity
  - When there are choices
- Unspecified distinctions between several alternatives
  - Variety, imprecision
  - Indiscriminate choices
- Measured by Hartley measure
  - The amount of uncertainty associated with a set of alternatives (e.g. messages) is measured by the amount of information needed to remove the uncertainty

\[ H(A) = \log_2 |A| \]

- Measured in bits
- Number of Choices

\( A = \text{Set of Alternatives} \)

\( x_1, x_2, x_3, \ldots, x_n \)
Hartley Uncertainty

**Example**
- **Menu Choices**
  - A = 16 Entrees
  - B = 4 Desserts
- **How many dinner combinations?**
  - $16 \times 4 = 64$

The Hartley uncertainty is defined as:

$$H(A) = \log_2 |A|$$

**Measured in bits**

**Number of Choices**

- $H(A) = \log_2 (16) = 4$
- $H(B) = \log_2 (4) = 2$
- $H(A \times B) = \log_2 (16 \times 4) = \log_2 (16) + \log_2 (4) = 6$

This quantifies how many yes-no questions need to be asked to establish what the correct alternative is.
What about probability?

- Some alternatives may be more probable than others!
- A different type of ambiguity
  - Alternatives are distinct
    - Conflict, strife, discord
- Measured by Shannon’s *entropy* measure
  - The amount of uncertainty associated with a set of alternatives (e.g. messages) is measured by the *average* amount of information needed to remove the uncertainty
Entropy

- Shannon’s measure
  - The **average** amount of uncertainty associated with a set of **weighted** alternatives (e.g. messages) is measured by the **average** amount of information needed to remove the uncertainty.

\[
H_s(A) = -\sum_{i=1}^{n} p(x_i) \log_2(p(x_i))
\]

A = Set of weighted Alternatives

\( x_1 \)
\( x_2 \)
\( x_3 \)
\( x_n \)

Probability of alternative

Measured in bits

Luis M. Rocha and Santiago Schnell
Example English

- Given a symbol set \{A, B, C, D, E\}
- And occurrence probabilities \(P_A, P_B, P_C, P_D, P_E\)
- The Shannon entropy is
- The average minimum number of bits needed to represent a symbol

\[
H_S = -\left( p_A \log_2(p_A) + p_B \log_2(p_B) + p_C \log_2(p_C) + p_D \log_2(p_D) + p_E \log_2(p_E) \right)
\]

\[
H_S = 0
\]
0 questions

\[
H_S = 1.96
\]
\(\approx 2\) questions

\[
H_S = 2.32
\]
Shannon’s entropy

*on average*, how many *yes-no* questions need to be asked to establish what the symbol is.

\[ H_S(A) = -\sum_{i=1}^{n} p(x_i) \log_2(p(x_i)) \]

\[ H_S \in [0, \log_2|X|] \]

For one alternative

Uniform distribution
Questions

- What type of Uncertainty does the Hartley measure of uncertainty measure?
- What are the units of Shannon entropy?
- Does Shannon’s information theory deal with the semantics and pragmatics of a message? Please explain why?
- If we have a symbol set $X = \{A, B, C, D, E\}$ where the symbol occurrence frequencies are:
  - $A = 0.5$  
  - $B = 0.2$  
  - $C = 0.1$  
  - $D = 0.1$  
  - $E = 0.1$
- What is the average minimum number of bits needed to represent a symbol of the set $X$?
Pseudocode Decision

- If-then-else
  - If (letter = “a” or letter = “A”) then
    - display “1”
    - Count_A = Count_A + 1
  - Else
    - Display “0”
  - End-if

- Case
  - Case letter of
    - “a” or “A”: display “1”, count_b = count_b + 1
    - “b” or “B”: display “2”, count_b = count_b + 1
    - “c” or “C”: display “3”, count_b = count_b + 1
  - Else
    - Display “0”
  - End-case
Pseudocode Iteration or Loops

- **For**
  - For x = 1 to 100 do
    - y=rand(100) mod x
    - Display y
  - ENDFOR
  - Specifies exactly how many iterations to compute

- **While**
  - x = 1
  - While ((y ≤ 4) and (x≤100)) do
    - y=rand(100) mod x
    - Display y
    - X=x+1
  - ENDFWHILE
  - The number of iterations to compute may depend on the computation itself
Flow Chart

- **Pictorial representation of algorithm**
  - Parallelogram for input/output
  - Oval for start and stop
  - Rectangle for processing
  - Diamond for decision
  - Hexagon for preparations and loops
  - Circle for connector
  - Arrow for flow direction

Eliza Algorithm – More Details

- set up a language database
  - Words, synonyms, sentences
- begin the conversation (e.g. with a greeting)
- Repeat
  - read user input
    - Keeps track of the two most recent inputs from the user
  - generate Eliza's response
    - preprocess the user input
      - Remove all punctuation from inputs and check for duplicate input
      - Make some synonym replacements from a list of pairs (e.g. big for huge)
      - Change pronouns (e.g. I and me to you)
    - find a matching keyword
    - choose an appropriate response template
      - if a keyword is found
        - extract the part of the user's input following the keyword
        - apply transformations to the extracted input
        - plug the transformed input into the response
      - Else
        - generate a non-committal response
    - print the response on the screen
- until the conversation ends
Hanoi Problem for $n$ disks

- Algorithm to move $n$ disks from A to C
  - Move top $n-1$ disks from A to B
  - Move biggest disk to C
  - Move $n-1$ disks on B to C
- Recursion
  - Until H2

Use Hanoi_2 (H2) as building block (of 3 moves)
H3 uses H2 twice, plus 1 move of the largest disk

An Algorithm that uses itself to solve a problem
Pseudocode for Hanoi Problem

- **Hanoi** \((Start, Temp, End, n)\)
  - If \(n = 1\) then
    - Move **Start**'s top disk to **End**
  - Else
    - **Hanoi** \((Start, End, Temp, n-1)\)
    - Move **Start**'s top disk to **End**
    - **Hanoi** \((Temp, Start, End, n-1)\)
Computational Complexity

- Resources required during computation of an algorithm to solve a given problem
  - Time
    - how many steps does it take to solve a problem?
  - Space
    - how much memory does it take to solve a problem?

- The Hanoi Towers Problem
  - \( f(n) \) is the number of times the HANOI algorithm moves a disk for a problem of \( n \) disks
    - \( f(1) = 1, f(2) = 3, f(3) = 7 \)
    - \( f(n) = f(n-1) + 1 + f(n-1) = 2 \times f(n-1) + 1 \)
  - Every time we add a disk, the time to compute is at least double
    - \( f(n) = 2^n - 1 \)

\[
\begin{align*}
2^{10} &= 1,024 \\
2^{20} &= 1,048,576 \\
2^{30} &= 1,073,741,824 \\
2^{40} &= 1,099,511,627,776 \\
2^{64} &= 18,446,744,073,709,551,616
\end{align*}
\]

585 billion years in seconds!!!!!!!!!!

Earth: 5 billion years
Universe: 15 billion years
Fastest Computer: 135.5 teraflops - 135.5 trillion calculations a second (aprox \( 2^{47} \) moves a second)
\( 2^{17} \) s needed = 36 hours
Bremermann's Limit

Physical Limit of Computation

- Hans Bremermann in 1962
- “no data processing system, whether artificial or living, can process more than $2 \times 10^{47}$ bits per second per gram of its mass.”
  - Based on the idea that information could be stored in the energy levels of matter
  - Calculated using Heisenberg's uncertainty principle, the Hartley measure, Planck's constant, and Einstein's famous $E = mc^2$ formula

- A computer with the mass of the entire Earth and a time period equal to the estimated age of the Earth
  - would not be able to process more than about $10^{93}$ bits

transcomputational problems
Questions

Using pseudo-code, write down an algorithm to calculate the tip of a restaurant bill and the amount that each person of a group of $n$ needs to pay.

Consider the following recursive definition of a function:

- $Q(n) = Q(n - Q(n-1)) + Q(n - Q(n - Q(n-2)))$
  for $n > 2$
- with $Q(1) = Q(2) = 1$.

Please write down a pseudo-code algorithm to calculate $Q(10)$.

What is the Bremermann's Limit?

Discuss its implications to problem solving and modeling.
The Modeling Relation

Hertz’ Modeling Paradigm

- Organizing Data
  - After encoding
  - Modern Problems Require large storage capabilities
Data Modeling

Entity-relationship model and Relational Databases
The Entity-Relationship Model

- **Conceptual Data Model**
  - A kind of “pseudocode” for *models of data storage*

- **Entities**
  - Nouns: Objects, people, places
    - Represented by a rectangle
    - Attributes describe its proprieties

- **Relationship**
  - Verbs
    - An association among two or more entities.
    - Also have attributes

Adapted from Yuqing Melanie Wu (I308: Information Representation)
The Relational Database Model

- Relational database management system (RDBMS)
  - Most popular commercial database type.
  - A data model based on logic and set theory.
- Invented by Ted Codd in 1970
- Oxford, IBM, U. Michigan, IBM
- System R
  - IBM's San Jose research center
  - Structured English Query Language ("SEQUEL")
    - Data Manipulation Language (DML)
  - SEQUEL was later condensed to SQL due to a trademark dispute
  - In 1979, Relational Software, Inc. (now Oracle Corporation) introduced the first commercially available implementation of SQL

Ted Codd
A relational database is a collection of tables
- 2-dimensional
- Each table has a unique name in the database.
- Tables define Relations
  - Columns (number of sets)
    - Attributes plus key (primary set)
  - Row (number of relation instances)
    - A table is a set of rows: tuples

<table>
<thead>
<tr>
<th>ID</th>
<th>Title</th>
<th>Artist</th>
</tr>
</thead>
<tbody>
<tr>
<td>3592</td>
<td>Yes I am a Witch</td>
<td>Yoko Ono</td>
</tr>
<tr>
<td>2678</td>
<td>Big</td>
<td>Macy Gray</td>
</tr>
<tr>
<td>0623</td>
<td>Sound of Silver</td>
<td>LCD Soundsystem</td>
</tr>
<tr>
<td>0321</td>
<td>Welcome to Planet Sexor</td>
<td>Tiga</td>
</tr>
<tr>
<td>8854</td>
<td>Transparent Things</td>
<td>Fujiya &amp; Miyagi</td>
</tr>
</tbody>
</table>
### Customer

<table>
<thead>
<tr>
<th>Phone</th>
<th>Name</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>812-123-4567</td>
<td>Tom</td>
<td>......</td>
</tr>
<tr>
<td>812-304-2378</td>
<td>Bill</td>
<td>......</td>
</tr>
<tr>
<td>812-856-1190</td>
<td>Kate</td>
<td>......</td>
</tr>
</tbody>
</table>

### Book

<table>
<thead>
<tr>
<th>ISBN</th>
<th>Title</th>
<th>Publisher</th>
</tr>
</thead>
<tbody>
<tr>
<td>12345</td>
<td>Java</td>
<td>MIT press</td>
</tr>
<tr>
<td>49082</td>
<td>Snow White</td>
<td>......</td>
</tr>
<tr>
<td>72936</td>
<td>Honeymoon</td>
<td>......</td>
</tr>
</tbody>
</table>

### Sale

<table>
<thead>
<tr>
<th>ISBN</th>
<th>Phone</th>
<th>Price</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>12345</td>
<td>812-123-4567</td>
<td>$20</td>
<td>Feb 2, 05</td>
</tr>
<tr>
<td>49082</td>
<td>812-123-4567</td>
<td>$25</td>
<td>Dec 20, 04</td>
</tr>
<tr>
<td>12345</td>
<td>812-856-1190</td>
<td>$19</td>
<td>......</td>
</tr>
</tbody>
</table>

Adapted from Yuqing Melanie Wu (I308: Information Representation)
The Santiago de Compostela historical society is setting up a database of the monarchs in the “unified” Spain. This is a chronological list of the people who have ruled “unified” Spain; the dates given are the periods of said rule.

### Unified ‘Spain’

- **Habsburg Dynasty**
  - 1516 - 1556 Charles I (Emperor Charles V), King of Spain, Austria, Netherlands, Rome and Naples
  - 1556 - 1598 Philip II, King of Spain, Portugal, Austria, Netherlands, Rome and Naples
  - 1598 - 1621 Philip III, King of...
  - 1621 - 1665 Philip IV
  - 1665 - 1700 Charles II
- **Bourbon Dynasty**
  - 1700 - 1724 Philip V
  - 1724 Louis I
  - 1724 - 1746 Philip V (2nd time)
  - 1746 - 1759 Ferdinand VI
  - 1759 - 1788 Charles III
  - 1788 - 1808 Charles IV
  - 1808 Ferdinand VII
- **French Rule**
  - 1808 - 1813 Joseph Bonaparte
- **Bourbon Dynasty**
  - 1814 - 1833 Ferdinand VII
  - 1833 - 1868 Isabella II
  - 1874 - 1885 Alfonso XII
  - 1886 - 1931 Alfonso XIII
  - 1975 - present Juan Carlos I

The society has already decided to include the fields above. Please describe the entities and their attributes of each field in the database.
Informatics at IU
Humans
Information
Technology

SPEED LIMIT C