

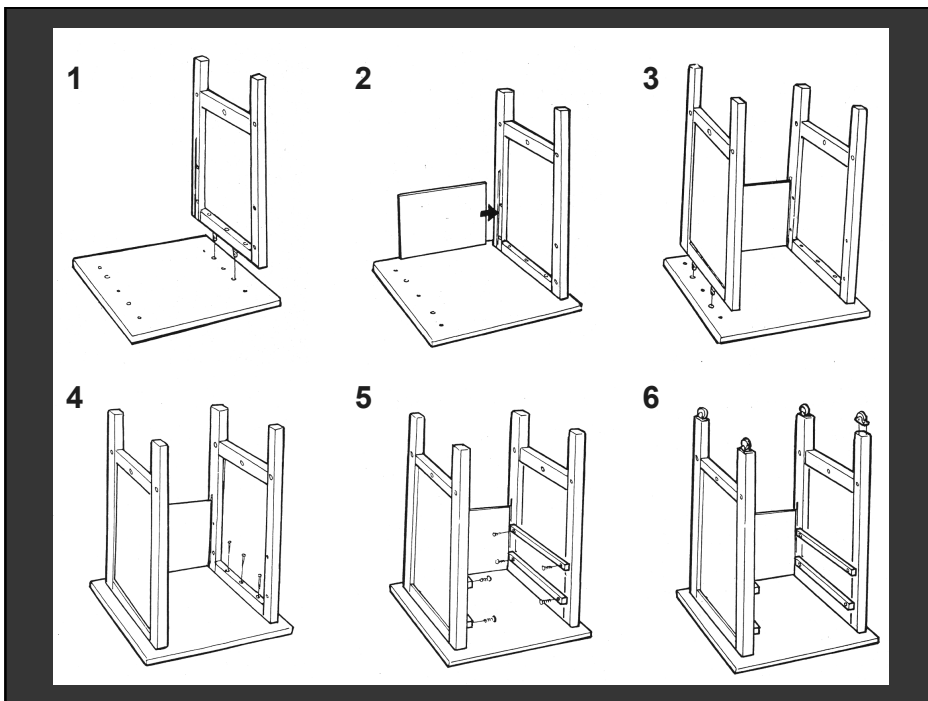
Deconstructing Visualizations

Maneesh Agrawala

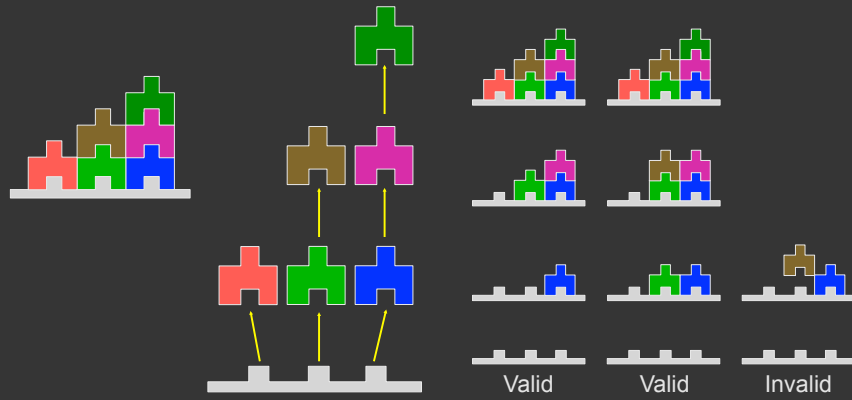
CS 448B: Visualization
Spring 2016

**Last Time: Identifying
Design Principles**

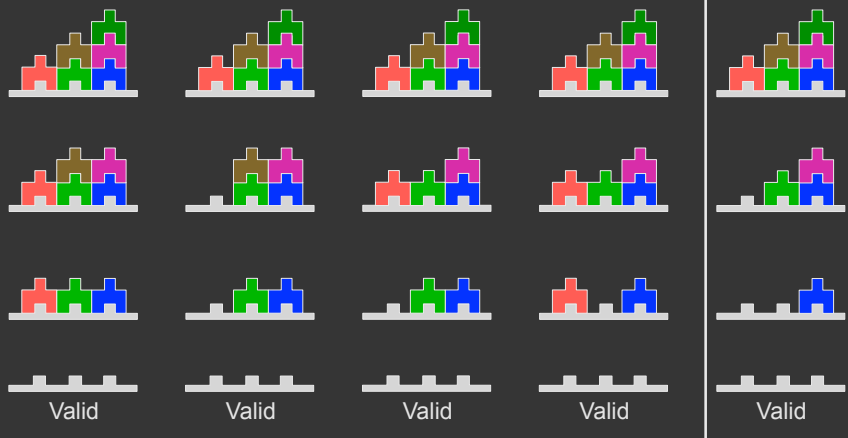
Bellevue to Seattle



Geometric Assembly Planning



Many Geometrically Valid Sequences



How do we choose the best sequence?

Identifying Design Principles



Stage 1: Production

Stage 2: Preference

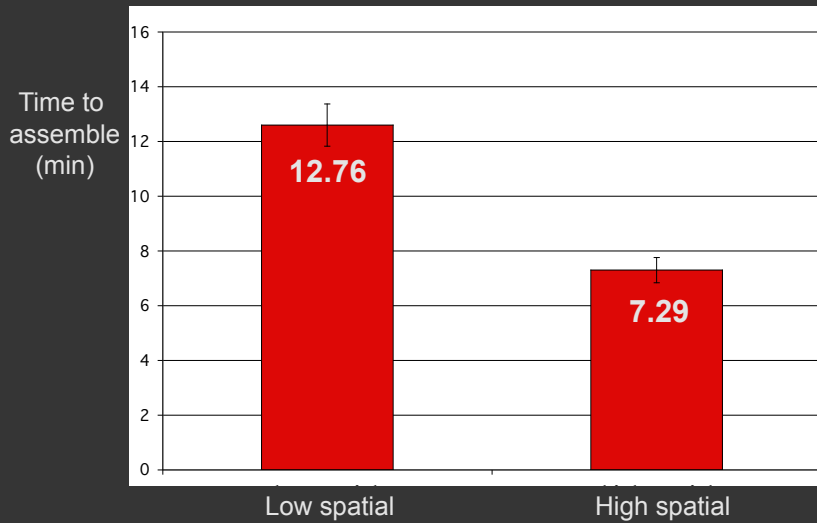
Stage 3: Comprehension

Stage 1: Production



- 43 Participants
- Assemble TV Stand without instructions
- Write instructions for novice assembler

Stage 1: Mean completion time



Stage 1: Instructions produced

Handwritten assembly instructions for a device. The instructions are organized into columns and rows, with numbered steps and diagrams. The text is somewhat messy and includes some corrections.

Column 1:

- First connect one side with the bottom shelf as shown.
- Make sure that the two holes at the top of the side are facing inward. Also make sure the two holes at the bottom are facing inward.
- Next connect the other side to the bottom shelf.
- Again make sure the holes are facing inward.
- Next connect the support to the sides using the 4 cable connectors.
- Next connect the top shelf to the sides using the remaining screws.
- Finally, attach the cables to the sides as shown.

Column 2:

1. The left piece.
2. The right piece.
3. The top piece.
4. The bottom piece.
5. The side piece.
6. The support.
7. The cable connector.
8. The top shelf.
9. The bottom shelf.
10. The side shelf.
11. The side shelf.
12. The side shelf.
13. The side shelf.
14. The side shelf.
15. The side shelf.
16. The side shelf.
17. The side shelf.
18. The side shelf.
19. The side shelf.
20. The side shelf.
21. The side shelf.
22. The side shelf.
23. The side shelf.
24. The side shelf.
25. The side shelf.
26. The side shelf.
27. The side shelf.
28. The side shelf.
29. The side shelf.
30. The side shelf.
31. The side shelf.
32. The side shelf.
33. The side shelf.
34. The side shelf.
35. The side shelf.
36. The side shelf.
37. The side shelf.
38. The side shelf.
39. The side shelf.
40. The side shelf.
41. The side shelf.
42. The side shelf.
43. The side shelf.
44. The side shelf.
45. The side shelf.
46. The side shelf.
47. The side shelf.
48. The side shelf.
49. The side shelf.
50. The side shelf.
51. The side shelf.
52. The side shelf.
53. The side shelf.
54. The side shelf.
55. The side shelf.
56. The side shelf.
57. The side shelf.
58. The side shelf.
59. The side shelf.
60. The side shelf.
61. The side shelf.
62. The side shelf.
63. The side shelf.
64. The side shelf.
65. The side shelf.
66. The side shelf.
67. The side shelf.
68. The side shelf.
69. The side shelf.
70. The side shelf.
71. The side shelf.
72. The side shelf.
73. The side shelf.
74. The side shelf.
75. The side shelf.
76. The side shelf.
77. The side shelf.
78. The side shelf.
79. The side shelf.
80. The side shelf.
81. The side shelf.
82. The side shelf.
83. The side shelf.
84. The side shelf.
85. The side shelf.
86. The side shelf.
87. The side shelf.
88. The side shelf.
89. The side shelf.
90. The side shelf.
91. The side shelf.
92. The side shelf.
93. The side shelf.
94. The side shelf.
95. The side shelf.
96. The side shelf.
97. The side shelf.
98. The side shelf.
99. The side shelf.
100. The side shelf.

Column 3:

1. Place one side piece perpendicular to unit surface & screw to top shelf piece.
2. Insert two plastic pegs into holes in the inside side of the narrow side piece & slide base piece into pegs.
3. Place second side piece onto the other side of partially assembled stand. The pegs will go into the holes on the base piece. Screw the 2nd side piece to the base piece.
4. Flip stand over & connect with extension arm appliances.

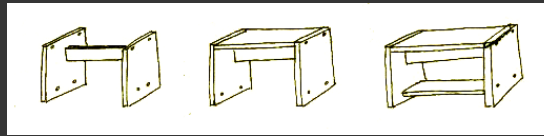
Column 4:

3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 59, 61, 63, 65, 67, 69, 71, 73, 75, 77, 79, 81, 83, 85, 87, 89, 91, 93, 95, 97, 99, 101, 103, 105, 107, 109, 111, 113, 115, 117, 119, 121, 123, 125, 127, 129, 131, 133, 135, 137, 139, 141, 143, 145, 147, 149, 151, 153, 155, 157, 159, 161, 163, 165, 167, 169, 171, 173, 175, 177, 179, 181, 183, 185, 187, 189, 191, 193, 195, 197, 199, 201, 203, 205, 207, 209, 211, 213, 215, 217, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 249, 251, 253, 255, 257, 259, 261, 263, 265, 267, 269, 271, 273, 275, 277, 279, 281, 283, 285, 287, 289, 291, 293, 295, 297, 299, 301, 303, 305, 307, 309, 311, 313, 315, 317, 319, 321, 323, 325, 327, 329, 331, 333, 335, 337, 339, 341, 343, 345, 347, 349, 351, 353, 355, 357, 359, 361, 363, 365, 367, 369, 371, 373, 375, 377, 379, 381, 383, 385, 387, 389, 391, 393, 395, 397, 399, 401, 403, 405, 407, 409, 411, 413, 415, 417, 419, 421, 423, 425, 427, 429, 431, 433, 435, 437, 439, 441, 443, 445, 447, 449, 451, 453, 455, 457, 459, 461, 463, 465, 467, 469, 471, 473, 475, 477, 479, 481, 483, 485, 487, 489, 491, 493, 495, 497, 499, 501, 503, 505, 507, 509, 511, 513, 515, 517, 519, 521, 523, 525, 527, 529, 531, 533, 535, 537, 539, 541, 543, 545, 547, 549, 551, 553, 555, 557, 559, 561, 563, 565, 567, 569, 571, 573, 575, 577, 579, 581, 583, 585, 587, 589, 591, 593, 595, 597, 599, 601, 603, 605, 607, 609, 611, 613, 615, 617, 619, 621, 623, 625, 627, 629, 631, 633, 635, 637, 639, 641, 643, 645, 647, 649, 651, 653, 655, 657, 659, 661, 663, 665, 667, 669, 671, 673, 675, 677, 679, 681, 683, 685, 687, 689, 691, 693, 695, 697, 699, 701, 703, 705, 707, 709, 711, 713, 715, 717, 719, 721, 723, 725, 727, 729, 731, 733, 735, 737, 739, 741, 743, 745, 747, 749, 751, 753, 755, 757, 759, 761, 763, 765, 767, 769, 771, 773, 775, 777, 779, 781, 783, 785, 787, 789, 791, 793, 795, 797, 799, 801, 803, 805, 807, 809, 811, 813, 815, 817, 819, 821, 823, 825, 827, 829, 831, 833, 835, 837, 839, 841, 843, 845, 847, 849, 851, 853, 855, 857, 859, 861, 863, 865, 867, 869, 871, 873, 875, 877, 879, 881, 883, 885, 887, 889, 891, 893, 895, 897, 899, 901, 903, 905, 907, 909, 911, 913, 915, 917, 919, 921, 923, 925, 927, 929, 931, 933, 935, 937, 939, 941, 943, 945, 947, 949, 951, 953, 955, 957, 959, 961, 963, 965, 967, 969, 971, 973, 975, 977, 979, 981, 983, 985, 987, 989, 991, 993, 995, 997, 999, 1001, 1003, 1005, 1007, 1009, 1011, 1013, 1015, 1017, 1019, 1021, 1023, 1025, 1027, 1029, 1031, 1033, 1035, 1037, 1039, 1041, 1043, 1045, 1047, 1049, 1051, 1053, 1055, 1057, 1059, 1061, 1063, 1065, 1067, 1069, 1071, 1073, 1075, 1077, 1079, 1081, 1083, 1085, 1087, 1089, 1091, 1093, 1095, 1097, 1099, 1101, 1103, 1105, 1107, 1109, 1111, 1113, 1115, 1117, 1119, 1121, 1123, 1125, 1127, 1129, 1131, 1133, 1135, 1137, 1139, 1141, 1143, 1145, 1147, 1149, 1151, 1153, 1155, 1157, 1159, 1161, 1163, 1165, 1167, 1169, 1171, 1173, 1175, 1177, 1179, 1181, 1183, 1185, 1187, 1189, 1191, 1193, 1195, 1197, 1199, 1201, 1203, 1205, 1207, 1209, 1211, 1213, 1215, 1217, 1219, 1221, 1223, 1225, 1227, 1229, 1231, 1233, 1235, 1237, 1239, 1241, 1243, 1245, 1247, 1249, 1251, 1253, 1255, 1257, 1259, 1261, 1263, 1265, 1267, 1269, 1271, 1273, 1275, 1277, 1279, 1281, 1283, 1285, 1287, 1289, 1291, 1293, 1295, 1297, 1299, 1301, 1303, 1305, 1307, 1309, 1311, 1313, 1315, 1317, 1319, 1321, 1323, 1325, 1327, 1329, 1331, 1333, 1335, 1337, 1339, 1341, 1343, 1345, 1347, 1349, 1351, 1353, 1355, 1357, 1359, 1361, 1363, 1365, 1367, 1369, 1371, 1373, 1375, 1377, 1379, 1381, 1383, 1385, 1387, 1389, 1391, 1393, 1395, 1397, 1399, 1401, 1403, 1405, 1407, 1409, 1411, 1413, 1415, 1417, 1419, 1421, 1423, 1425, 1427, 1429, 1431, 1433, 1435, 1437, 1439, 1441, 1443, 1445, 1447, 1449, 1451, 1453, 1455, 1457, 1459, 1461, 1463, 1465, 1467, 1469, 1471, 1473, 1475, 1477, 1479, 1481, 1483, 1485, 1487, 1489, 1491, 1493, 1495, 1497, 1499, 1501, 1503, 1505, 1507, 1509, 1511, 1513, 1515, 1517, 1519, 1521, 1523, 1525, 1527, 1529, 1531, 1533, 1535, 1537, 1539, 1541, 1543, 1545, 1547, 1549, 1551, 1553, 1555, 1557, 1559, 1561, 1563, 1565, 1567, 1569, 1571, 1573, 1575, 1577, 1579, 1581, 1583, 1585, 1587, 1589, 1591, 1593, 1595, 1597, 1599, 1601, 1603, 1605, 1607, 1609, 1611, 1613, 1615, 1617, 1619, 1621, 1623, 1625, 1627, 1629, 1631, 1633, 1635, 1637, 1639, 1641, 1643, 1645, 1647, 1649, 1651, 1653, 1655, 1657, 1659, 1661, 1663, 1665, 1667, 1669, 1671, 1673, 1675, 1677, 1679, 1681, 1683, 1685, 1687, 1689, 1691, 1693, 1695, 1697, 1699, 1701, 1703, 1705, 1707, 1709, 1711, 1713, 1715, 1717, 1719, 1721, 1723, 1725, 1727, 1729, 1731, 1733, 1735, 1737, 1739, 1741, 1743, 1745, 1747, 1749, 1751, 1753, 1755, 1757, 1759, 1761, 1763, 1765, 1767, 1769, 1771, 1773, 1775, 1777, 1779, 1781, 1783, 1785, 1787, 1789, 1791, 1793, 1795, 1797, 1799, 1801, 1803, 1805, 1807, 1809, 1811, 1813, 1815, 1817, 1819, 1821, 1823, 1825, 1827, 1829, 1831, 1833, 1835, 1837, 1839, 1841, 1843, 1845, 1847, 1849, 1851, 1853, 1855, 1857, 1859, 1861, 1863, 1865, 1867, 1869, 1871, 1873, 1875, 1877, 1879, 1881, 1883, 1885, 1887, 1889, 1891, 1893, 1895, 1897, 1899, 1901, 1903, 1905, 1907, 1909, 1911, 1913, 1915, 1917, 1919, 1921, 1923, 1925, 1927, 1929, 1931, 1933, 1935, 1937, 1939, 1941, 1943, 1945, 1947, 1949, 1951, 1953, 1955, 1957, 1959, 1961, 1963, 1965, 1967, 1969, 1971, 1973, 1975, 1977, 1979, 1981, 1983, 1985, 1987, 1989, 1991, 1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021, 2023, 2025, 2027, 2029, 2031, 2033, 2035, 2037, 2039, 2041, 2043, 2045, 2047, 2049, 2051, 2053, 2055, 2057, 2059, 2061, 2063, 2065, 2067, 2069, 2071, 2073, 2075, 2077, 2079, 2081, 2083, 2085, 2087, 2089, 2091, 2093, 2095, 2097, 2099, 2101, 2103, 2105, 2107, 2109, 2111, 2113, 2115, 2117, 2119, 2121, 2123, 2125, 2127, 2129, 2131, 2133, 2135, 2137, 2139, 2141, 2143, 2145, 2147, 2149, 2151, 2153, 2155, 2157, 2159, 2161, 2163, 2165, 2167, 2169, 2171, 2173, 2175, 2177, 2179, 2181, 2183, 2185, 2187, 2189, 2191, 2193, 2195, 2197, 2199, 2201, 2203, 2205, 2207, 2209, 2211, 2213, 2215, 2217, 2219, 2221, 2223, 2225, 2227, 2229, 2231, 2233, 2235, 2237, 2239, 2241, 2243, 2245, 2247, 2249, 2251, 2253, 2255, 2257, 2259, 2261, 2263, 2265, 2267, 2269, 2271, 2273, 2275, 2277, 2279, 2281, 2283, 2285, 2287, 2289, 2291, 2293, 2295, 2297, 2299, 2301, 2303, 2305, 2307, 2309, 2311, 2313, 2315, 2317, 2319, 2321, 2323, 2325, 2327, 2329, 2331, 2333, 2335, 2337, 2339, 2341, 2343, 2345, 2347, 2349, 2351, 2353, 2355, 2357, 2359, 2361, 2363, 2365, 2367, 2369, 2371, 2373, 2375, 2377, 2379, 2381, 2383, 2385, 2387, 2389, 2391, 2393, 2395, 2397, 2399, 2401, 2403, 2405, 2407, 2409, 2411, 2413, 2415, 2417, 2419, 2421, 2423, 2425, 2427, 2429, 2431, 2433, 2435, 2437, 2439, 2441, 2443, 2445, 2447, 2449, 2451, 2453, 2455, 2457, 2459, 2461, 2463, 2465, 2467, 2469, 2471, 2473, 2475, 2477, 2479, 2481, 2483, 2485, 2487, 2489, 2491, 2493, 2495, 2497, 2499, 2501, 2503, 2505, 2507, 2509, 2511, 2513, 2515, 2517, 2519, 2521, 2523, 2525, 2527, 2529, 2531, 2533, 2535, 2537, 2539, 2541, 2543, 2545, 2547, 2549, 2551, 2553, 2555, 2557, 2559, 2561, 2563, 2565, 2567, 2569, 2571, 2573, 2575, 2577, 2579, 2581, 2583, 2585, 2587, 2589, 2591, 2593, 2595, 2597, 2599, 2601, 2603, 2605, 2607, 2609, 2611, 2613, 2615, 2617, 2619, 2621, 2623, 2625, 2627, 2629, 2631, 2633, 2635, 2637, 2639, 2641, 2643, 2645, 2647, 2649, 2651, 2653, 2655, 2657, 2659, 2661, 2663, 2665, 2667, 2669, 2671, 2673, 2675, 2677, 2679, 2681, 2683, 2685, 2687, 2689, 2691, 2693, 2695, 2697, 2699, 2701, 2703, 2705, 2707, 2709, 2711, 2713, 2715, 2717, 2719, 2721, 2723, 2725, 2727, 2729, 2731, 2733, 2735, 2737, 2739, 2741, 2743, 2745, 2747, 2749, 2751, 2753, 2755, 2757, 2759, 2761, 2763, 2765, 2767, 2769, 2771, 2773, 2775, 2777, 2779, 2781, 2783, 2785, 2787, 2789, 2791, 2793, 2795, 2797, 2799, 2801, 2803, 2805, 2807, 2809, 2811, 2813, 2815, 2817, 2819, 2821, 2823, 2825, 2827, 2829, 2831, 2833, 2835, 2837, 2839, 2841, 2843, 2845, 2847, 2849, 2851, 2853, 2855, 2857, 2859, 2861, 2863, 2865, 2867, 2869, 2871, 2873, 2875, 2877, 2879, 2881, 2883, 2885, 2887, 2889, 2891, 2893, 2895, 2897, 2899, 2901, 2903, 2905, 2907, 2909, 2911, 2913, 2915, 2917, 2919, 2921, 2923, 2925, 2927, 2929, 2931, 2933, 2935, 2937, 2939, 2941, 2943, 2945, 2947, 2949, 2951, 2953, 2955, 2957, 2959, 2961, 2963, 2965, 2967, 2969, 2971, 2973, 2975, 2977, 2979, 2981, 2983, 2985, 2987, 2989, 2991, 2993, 2995, 2997, 2999, 3001, 3003, 3005, 3007, 3009, 3011, 3013, 3015, 3017, 3019, 3021, 3023, 3025, 3027, 3029, 3031, 3033, 3035, 3037, 3039, 3041, 3043, 3045, 3047, 3049, 3051, 3053, 3055, 3057, 3059, 3061, 3063, 3065, 3067, 3069, 3071, 3073, 3075, 3077, 3079, 3081, 3083, 3085, 3087, 3089, 3091, 3093, 3095, 3097, 3099, 3101, 3103, 3105, 3107, 3109, 3111, 3113, 3115, 3117, 3119, 3121, 3123, 3125, 3127, 3129, 3131, 3133, 3135, 3137, 3139, 3141, 3143, 3145, 3147, 3149, 3151, 3153, 3155, 3157, 3159, 3161, 3163, 3165, 3167, 3169, 3171, 3173, 3175, 3177, 3179, 3181, 3183, 3185, 3187, 3189, 3191, 3193, 3195, 3197, 3199, 3201, 3203, 3205, 3207, 3209, 3211, 3213, 3215, 3217, 3219, 3221, 3223, 3225, 3227, 3229, 3231, 3233, 3235, 3237, 3239, 3241, 3243, 3245, 3247, 3249, 3251, 3253, 3255, 3257, 3259, 3261, 3263, 3265, 3267, 3269, 3271, 3273, 3275, 3277, 3279, 3281, 3283, 3285, 3287, 3289, 3291, 3293, 3295, 3297, 3299, 3301, 3303, 3305, 3307, 3309, 3311, 3313, 3315, 3317, 3319, 3321, 3323, 3325, 3327, 3329, 3331, 3333, 3335, 3337, 3339, 3341, 3343, 3345, 3347, 3349, 3351, 3353, 3355, 3357, 3359, 3361, 3363, 3365, 3367, 3369, 3371, 3373, 3375, 3377, 3379, 3381, 3383, 3385, 3387, 3389, 3391, 3393, 3395, 3397, 3399, 3401, 3403, 3405, 3407, 3409, 3411, 3413, 3415, 3417, 3419, 3421, 3423, 3425, 3427, 3429, 3431, 3433, 3435, 3437, 3439, 3441, 3443, 3445, 3447, 3449, 3451, 3453, 3455, 3457, 3459, 3461, 3463, 3465, 3467, 3469, 3471, 3473, 3475, 3477, 3479, 3481, 3483, 3485, 3487, 3489, 3491, 3493, 3495, 3497, 3499, 3501, 3503, 3505, 3507, 3509, 3511, 3513, 3515, 3517, 3519, 3521, 3523, 3525, 3527, 3529, 3531, 3533, 3535, 3537, 3539, 3541, 3543, 3545, 3547, 3549, 3551, 3553, 3555, 3557, 3559, 3561, 3563, 3565, 3567, 3569, 3571, 3573, 3575, 3577, 3579, 3581, 3583, 3585, 3587, 3589, 3591, 3593, 3595, 3597, 3599, 3601, 3603, 3605, 3607, 3609, 3611, 3613, 3615, 3617, 3619, 3621, 3623, 3625, 3627, 3629, 3631, 3633, 3635, 3637, 3639, 3641, 3643, 3645, 3647, 3649, 3651, 3653, 3655, 3657, 3

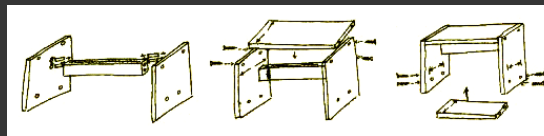
Stage 1: Classes of Diagrams



Parts menu



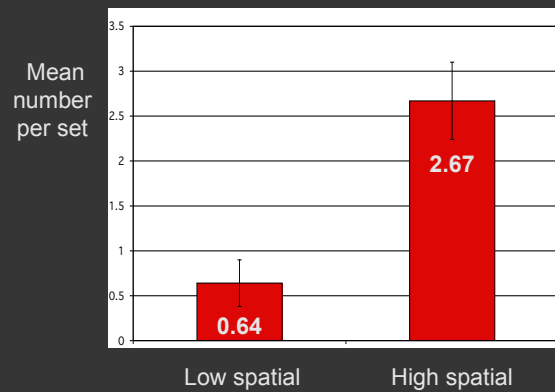
Structural diagrams



Action diagrams

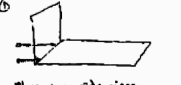
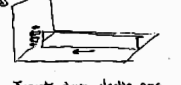
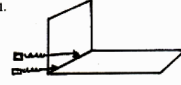
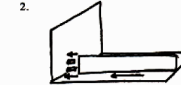


- Parts menu to differentiate parts
- Structural diagrams depict completed step
- Action diagrams show assembly action/operation

Stage 1: Action diagrams











- High spatial
 - More action diagrams
 - More 3D diagrams
 - Less text

Stage 2: Preference

 <p>1. Place one side piece perpendicular to work surface & screw to top shelf piece.</p>	 <p>2. Insert two plastic pegs into holes in the inside side of the second side piece & slide brace piece onto pegs.</p>	 <p>1. Place one side piece perpendicular to work surface & screw to top shelf piece.</p>	 <p>2. Insert two plastic pegs into holes in the inside side of the screwed side piece and slide brace piece onto pegs.</p>
<p>3. Turn one of the top side pieces onto the other side of partially assembled stand. The pegs will go into the holes on the brace piece. Screw the 2nd side piece to shelf piece.</p>	<p>4. Have somebody hold smaller, lower shelf between the two side pieces, level with screw holes. Screw the screws into the holes of the side pieces that are lined up. 2 screws per side.</p>	<p>3. Insert other set of pegs into second side piece and slide the second side piece onto the other side of partially assembled stand. The pegs will go into the holes on the brace piece. Screw the second side piece to top shelf piece.</p>	<p>4. Have somebody hold smaller, lower shelf between the two side pieces, level with screw holes. Screw the screws into the holes of the side pieces that are lined up. 2 screws per side.</p>
 <p>5. Insert wheels into holes in the two side pieces.</p>	<p>6. Flip stand over & garnish with entertainment appliances.</p>	 <p>5. Insert wheels into holes in the two side pieces.</p>	<p>6. Flip stand over and garnish with entertainment appliances.</p>

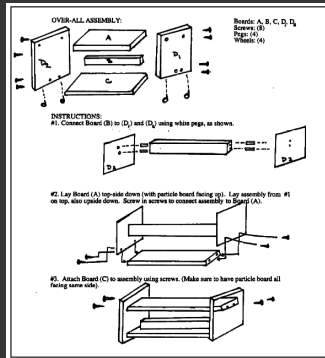
- 21 Participants
- Assemble TV Stand without instructions
- Rated 39 sets of redrawn instructions

Stage 2: Highest Rated

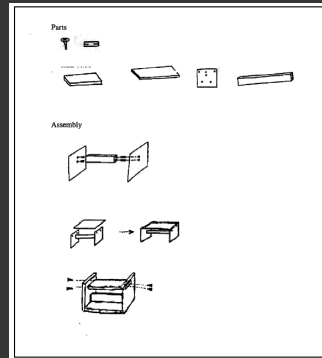
<p>1) Stand the following board up as shown in the picture. (You should have one of these boards, for use only for the next step.)</p> 	<p>2) Take the remaining long board and screw it to the shown. Make sure reflected surface faces up and the edges face same direction as the other board.</p> 
<p>2) Place the widest and longest board on a flat surface such that the notched surface faces up and the two holes on one of its sides face up with the bottom holes of the first board as shown in the picture. (You now have the finished edge of both boards from the same direction.)</p> 	<p>3) Place the remaining board and face it up with the all of its holes facing up. The picture.</p> 
<p>3) Place a white plastic rod in each of the holes of each side of the obtained board.</p> 	<p>4) Screw the boards together.</p> 
<p>4) Place this board as shown in the picture. Again, make sure the notched surface side faces the same direction as the finished surface of the other board.</p> 	<p>5) Place the wheels into the holes as indicated in the picture and then flip the unit over.</p> 

- Ratings similar across all participants
- Spatial ability does not affect preference

Stage 3: Comprehension



Set 1: Text + Action



Set 3: Parts menu + Structural + Action

- 44 Participants
- Given 1 of 4 instruction sets from Stage 2
- Assemble TV stand using instructions

Stage 3: Results

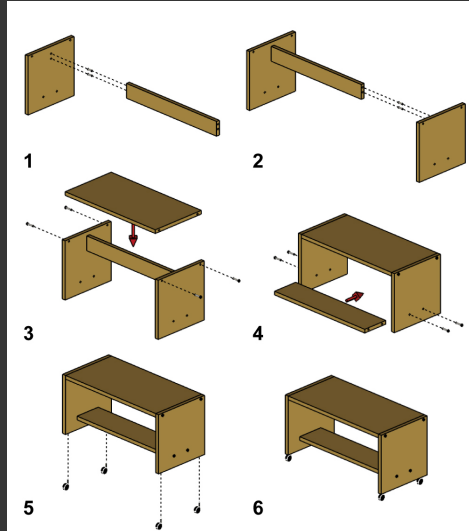
- No difference in assembly time by condition
- Instruction consultations: Low 8.9 High 7.1
- Box picture consultations: Low 9.1 High 3.4

Comments

- Should show relevant parts and attachments
- Structural diagrams and exploded view hard to use
- Text not very useful

Design Principles

Step-by-Step
Action diagrams
Good visibility



TV stand instructions generated by our system

Input

Geometry: Parts in assembled configuration

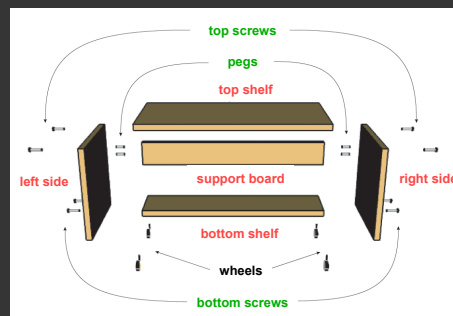
Orientations: Default viewpoint / orientation
Preferred orientation for each part

Groupings: Fasteners, significant parts, similar actions, symmetry

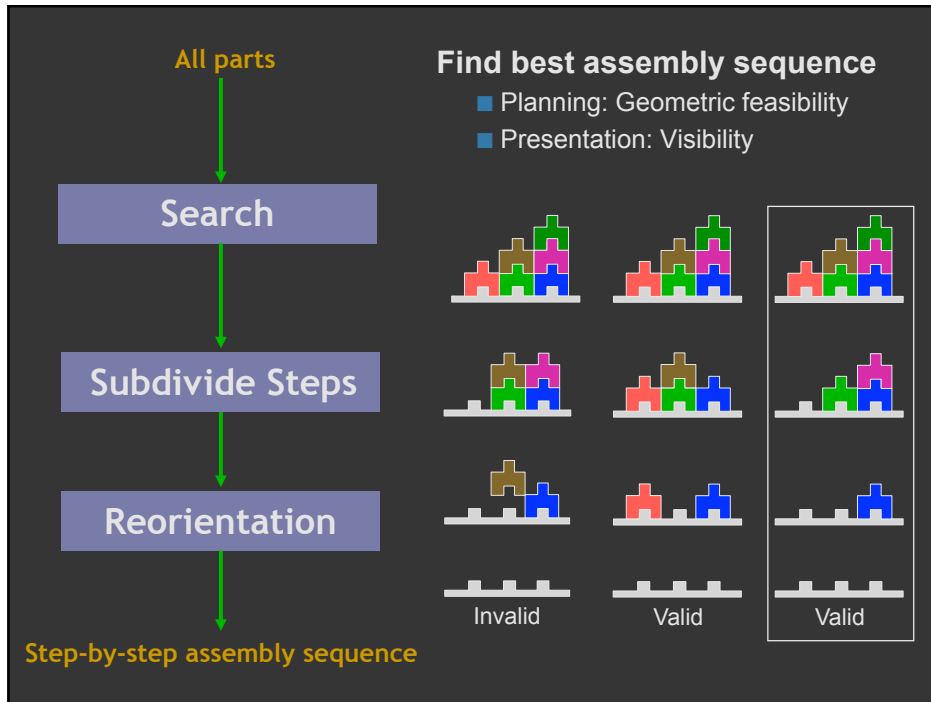
required
optional



Assembled geometry in default orientation



Parts grouped as fasteners and significant parts



Visibility Constraints

1. Parts being attached R

- Check that each part is visible

$$\min_{r \in R} (\text{Vis}(r, R-r)) * W_R$$

2. Previously attached parts A

- Check that context is visible

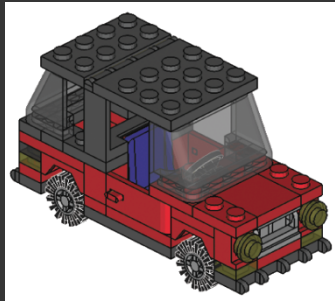
$$\text{Vis}(A, R) * W_A$$

3. Future unattached parts U

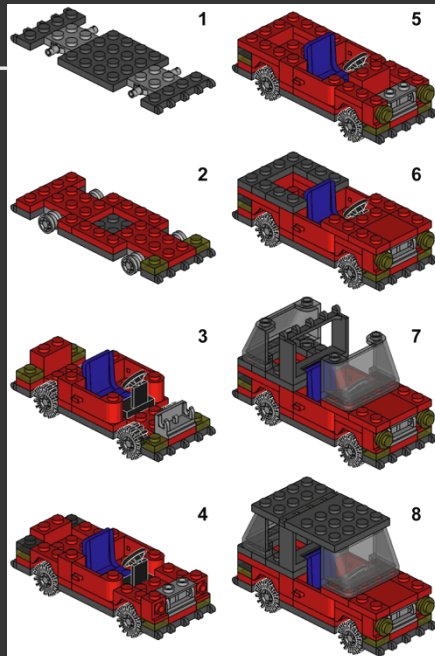
- Check that future parts will be visible

$$\min_{u \in U} (\text{Vis}(u, R)) * W_U$$

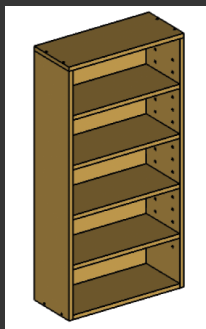
Lego Car



Input model

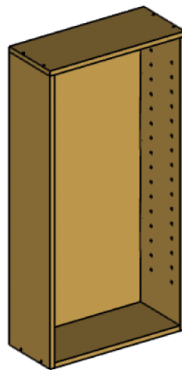


Bookcase

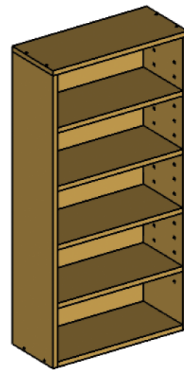


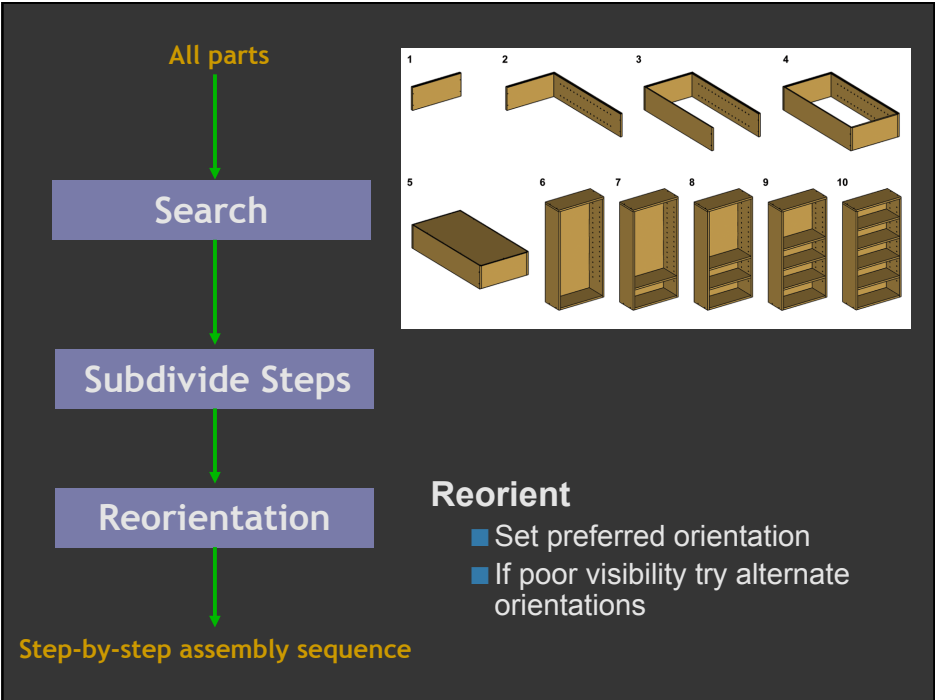
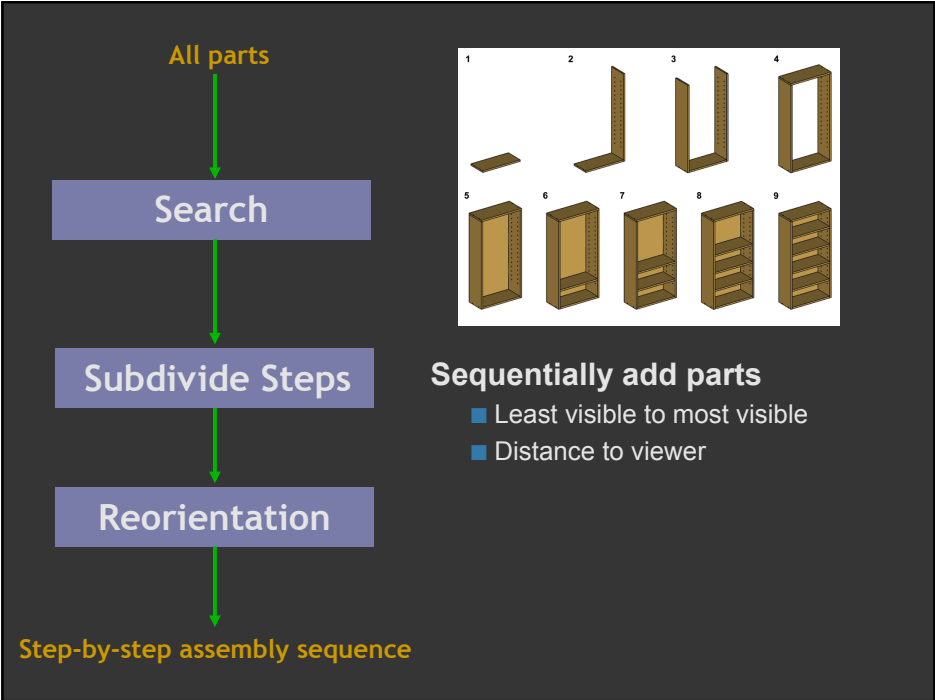
Input model

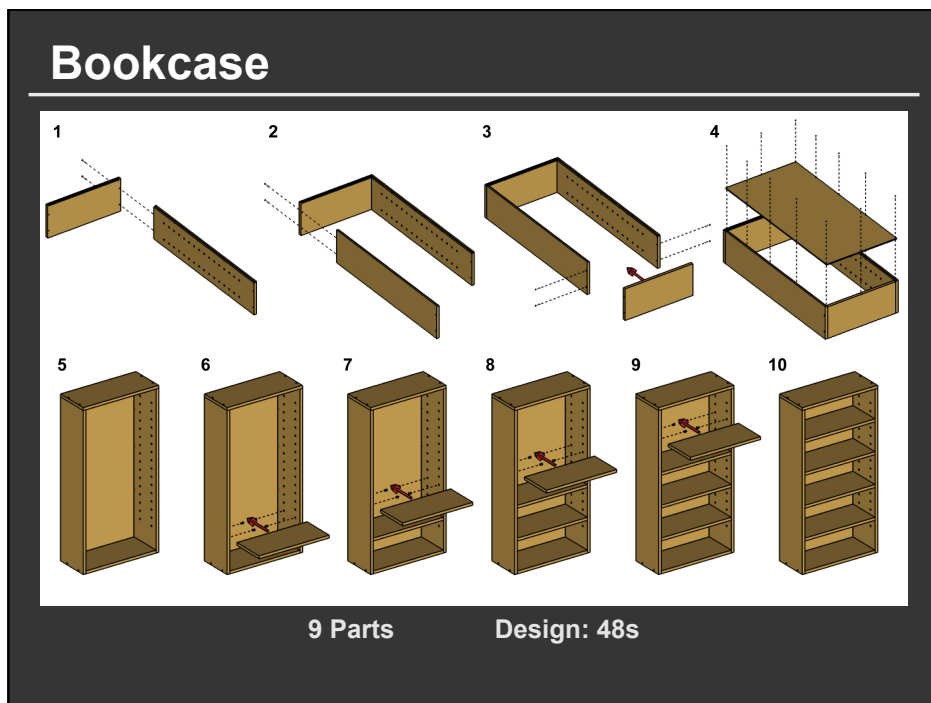
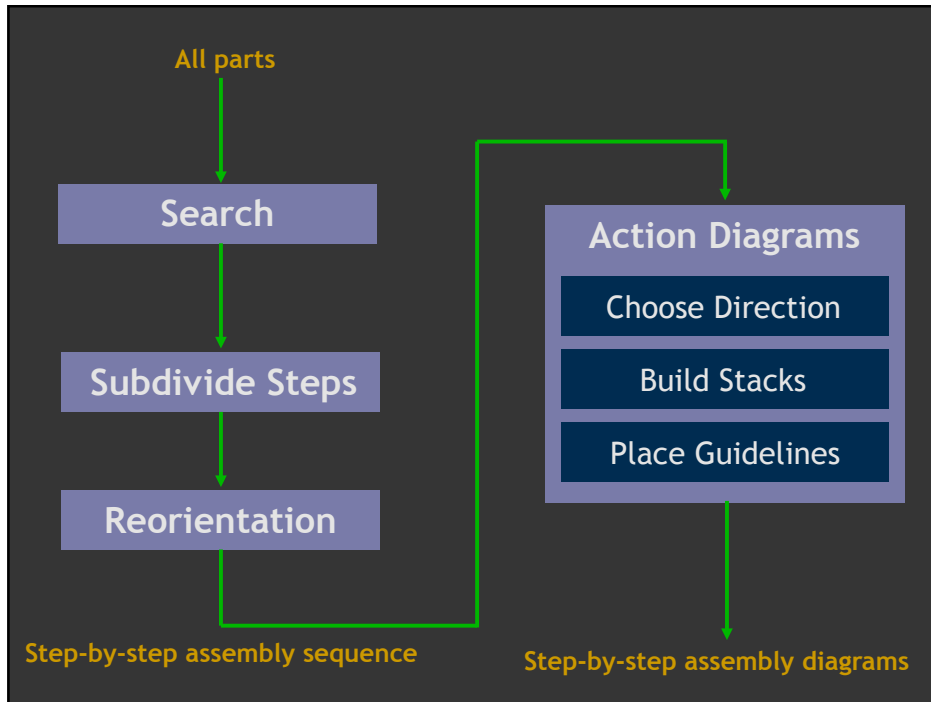
1



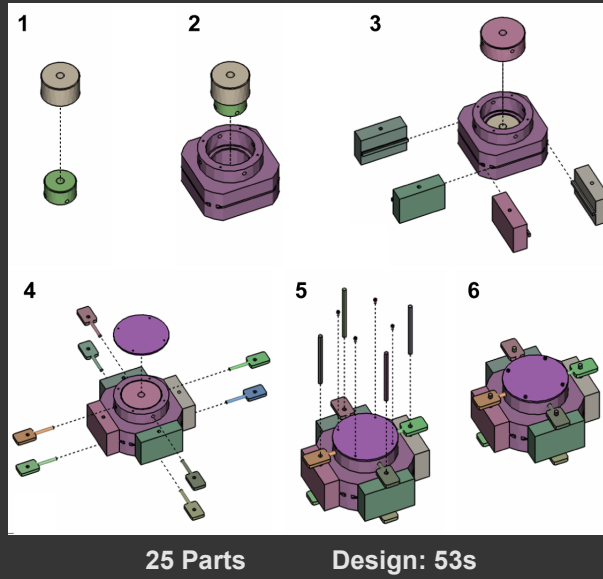
2







Test Object

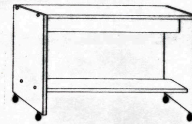


Evaluation

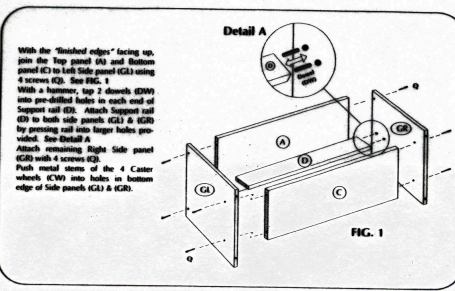
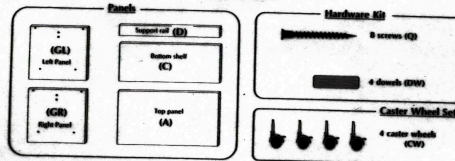


- 30 Participants
- Given 1 of 3 instruction sets: factory, hand-drawn, computer
- Assemble TV stand using instructions

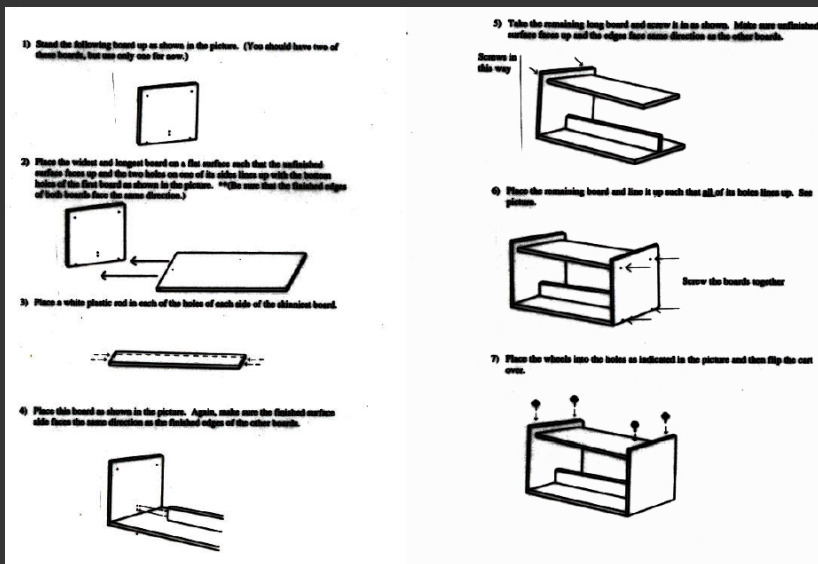
Factory



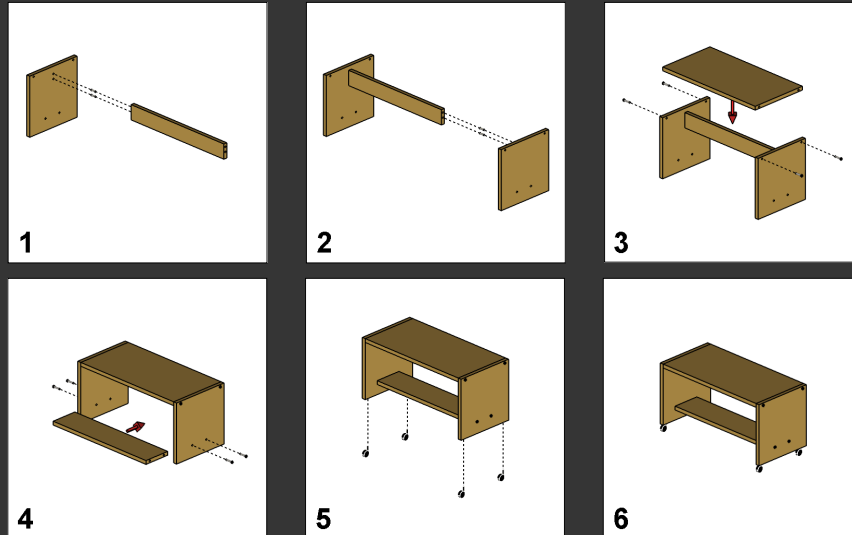
PARTS LIST



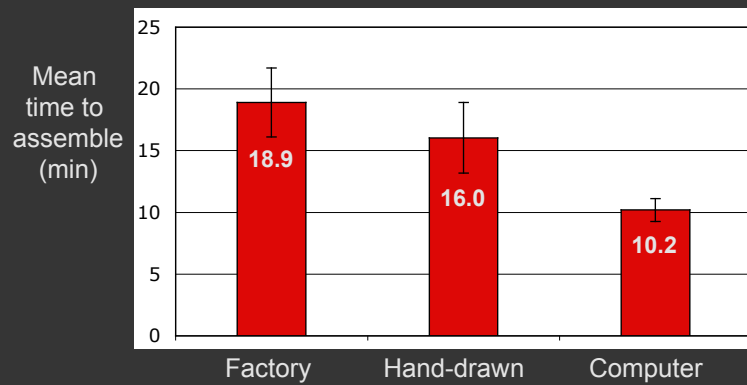
Hand-drawn



Computer Generated



Results

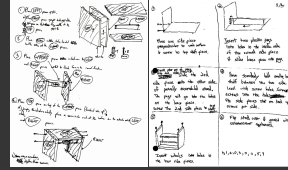


Errors: Factory 1.6 Hand-drawn 0.6 Computer 0.5
Task rated easiest in computer condition

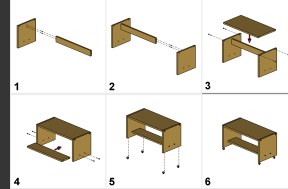
Summary

Identification of design principles

- Production
- Preference
- Comprehension



Instantiation of design principles



Validation of design principles



Announcements

Final project

Design new visualization method (e.g. software)

- Pose problem, Implement creative solution
- Design studies/evaluations less common but also possible (talk to us)

Deliverables

- Implementation of solution
- 6-8 page paper in format of conference paper submission
- Project progress presentations

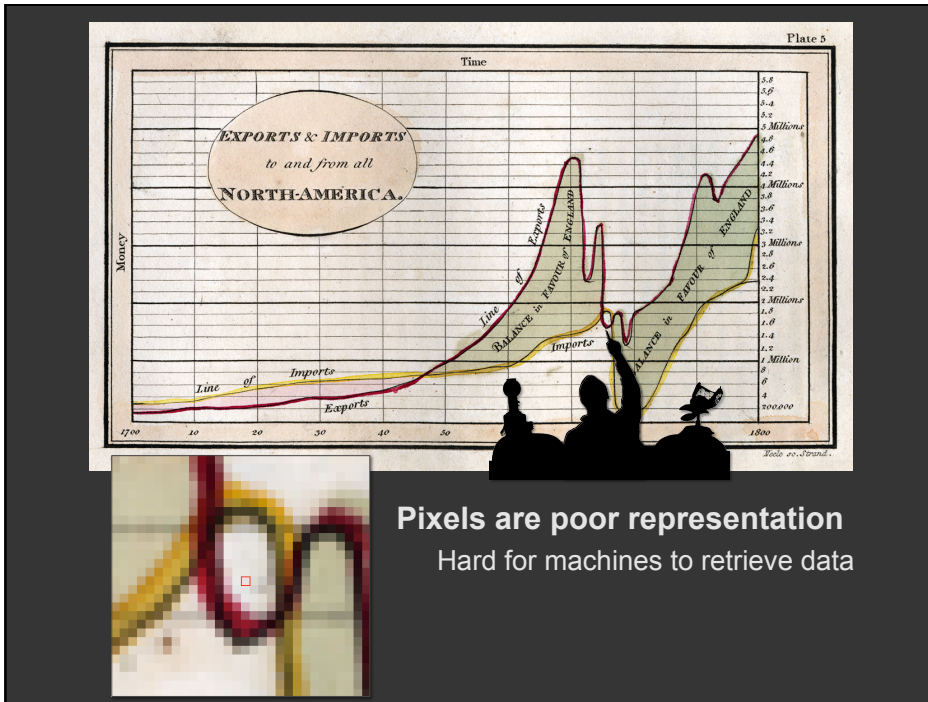
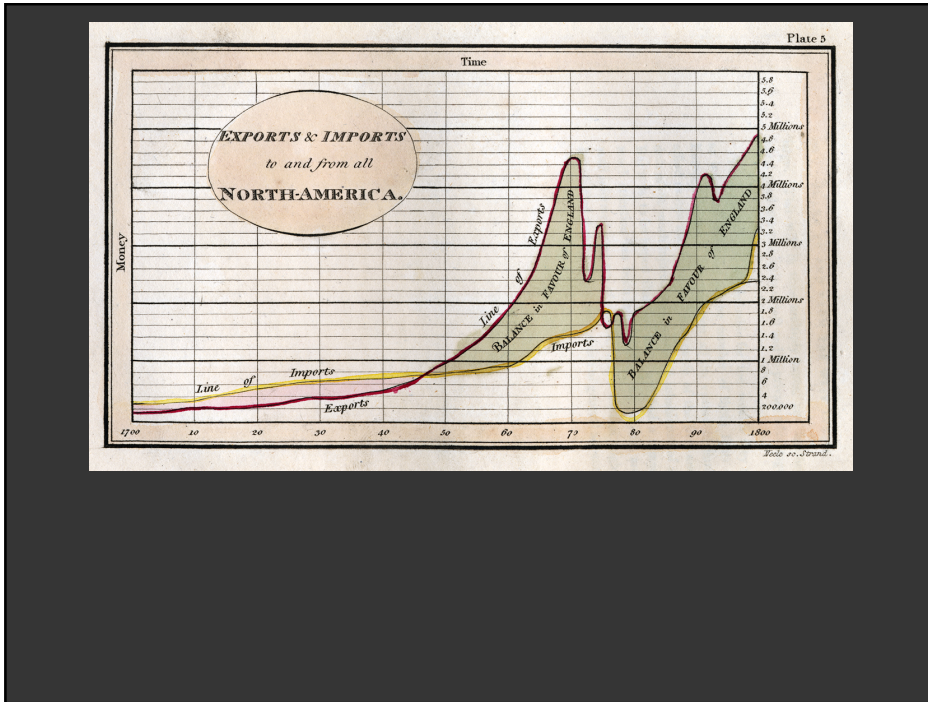
Schedule

- Project proposal: 5/11
- Project progress presentation: 5/23 in class (3-4 min) slide presentation
- Final poster presentation: 6/3 12:15-3:15pm Location: TBD
- Final paper: 6/5 11:59pm

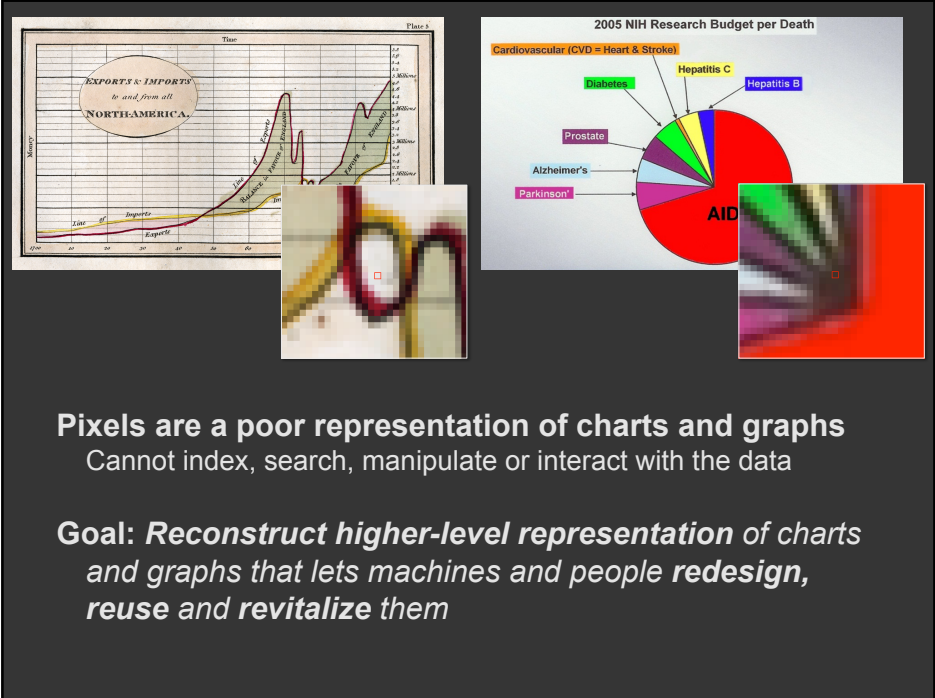
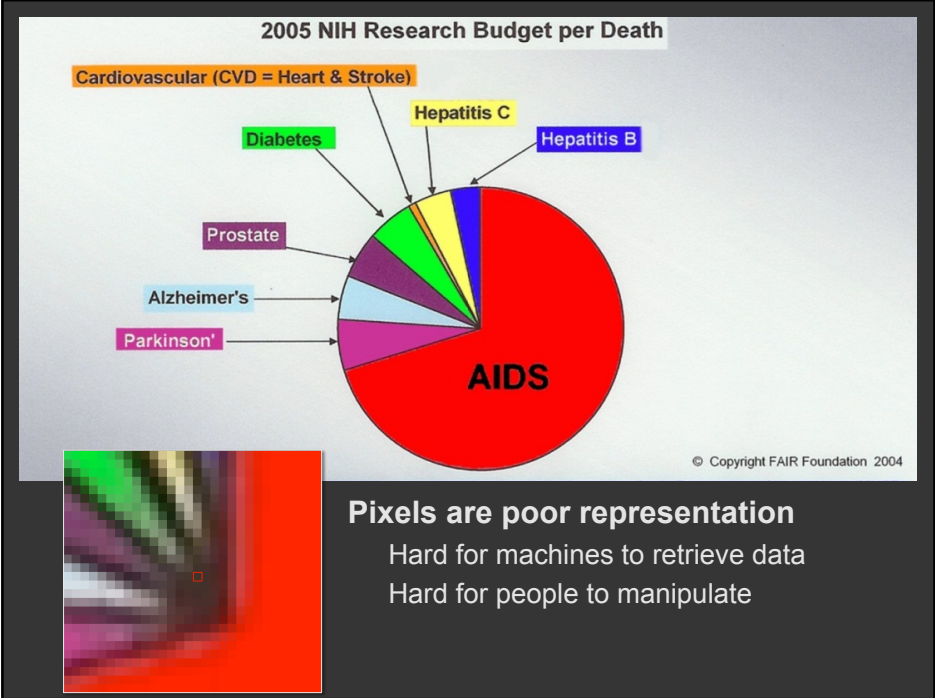
Grading

- Groups of up to 3 people, graded individually
- Clearly report responsibilities of each member

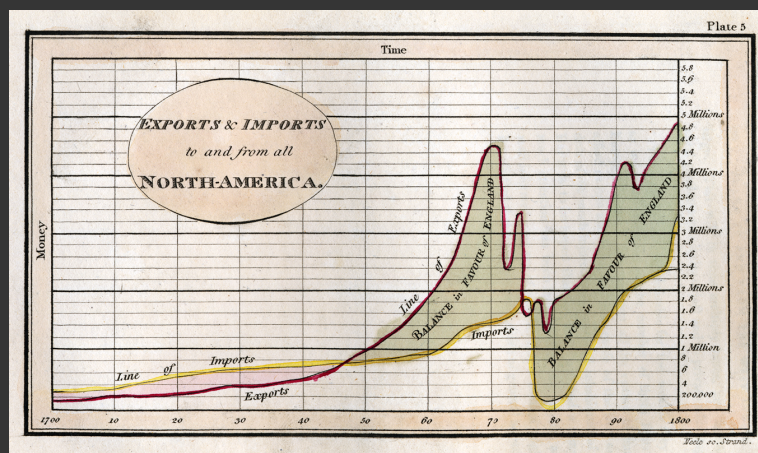
Deconstructing Visualizations



Pixels are poor representation
 Hard for machines to retrieve data

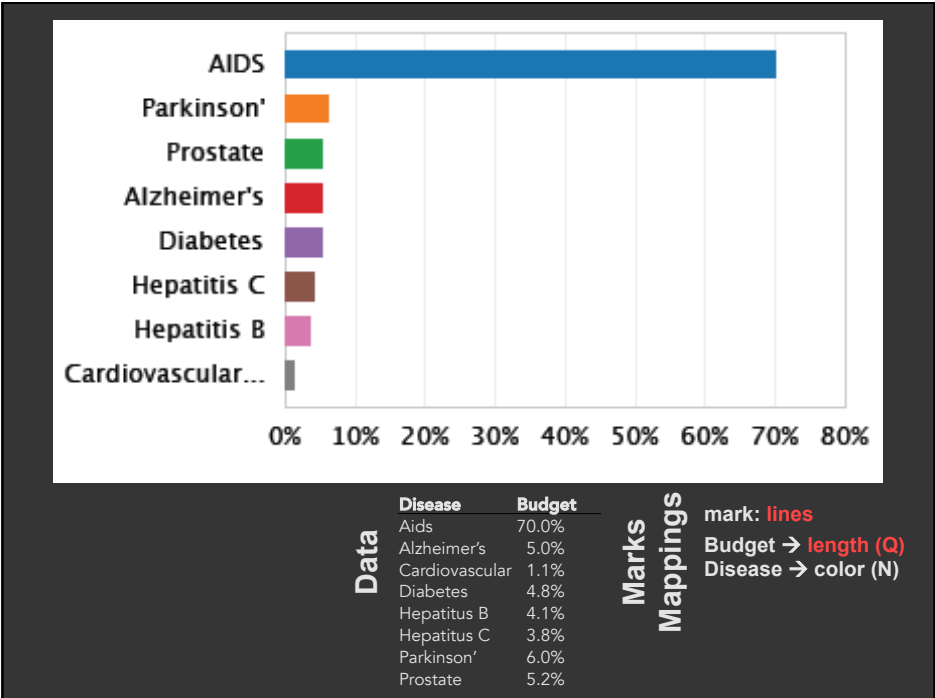
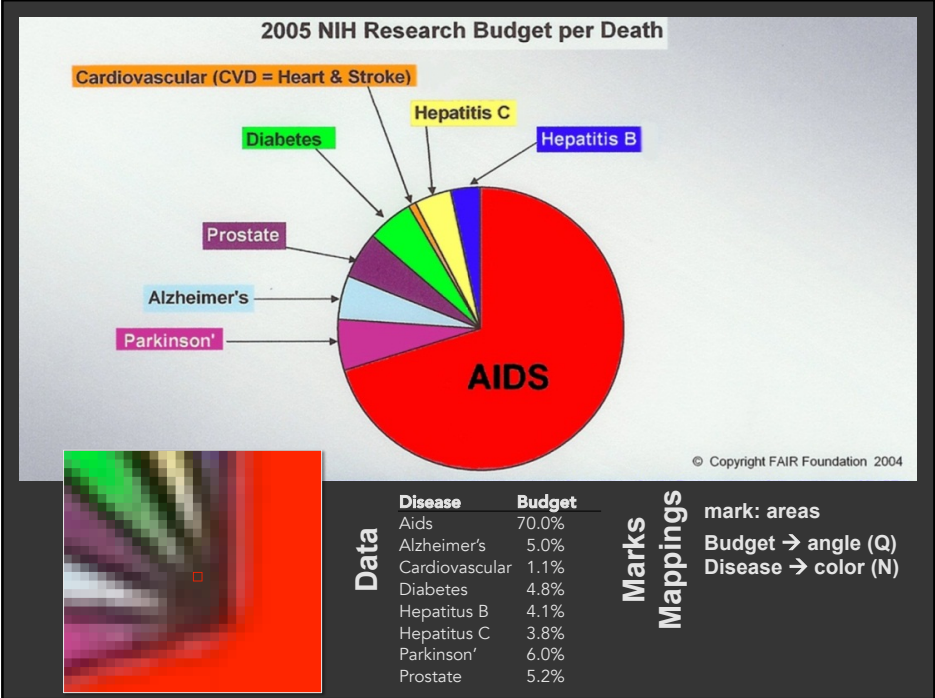


What is a good representation?



Year	Exports	Imports
1700	170,000	300,000
1701	171,000	302,000
1702	176,000	303,000
1703	180,000	312,000
1704	187,000	319,000
...

Marks mark: lines
Mappings Year → x-pos (Q)
 Exports → y-pos (Q)
 Imports → y-pos (Q)
 Exports → color (N)
 Imports → color (N)



Approach

Classification: Determine chart type

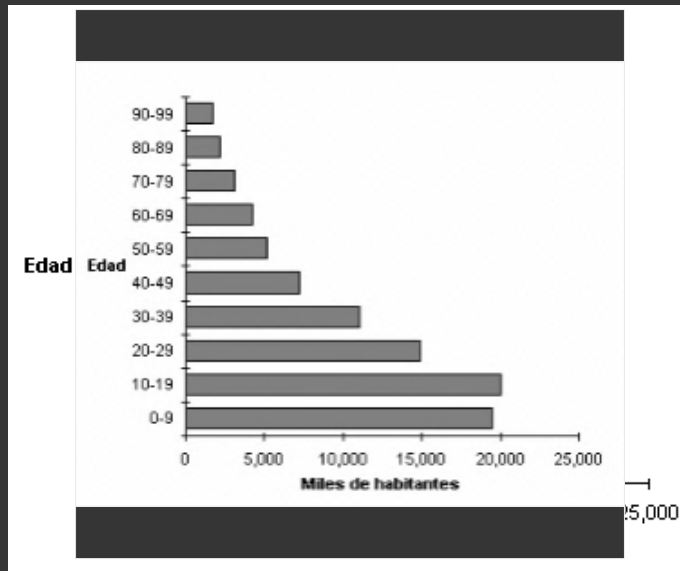
Mark extraction: Retrieve graphical marks

Data extraction: Retrieve underlying data table

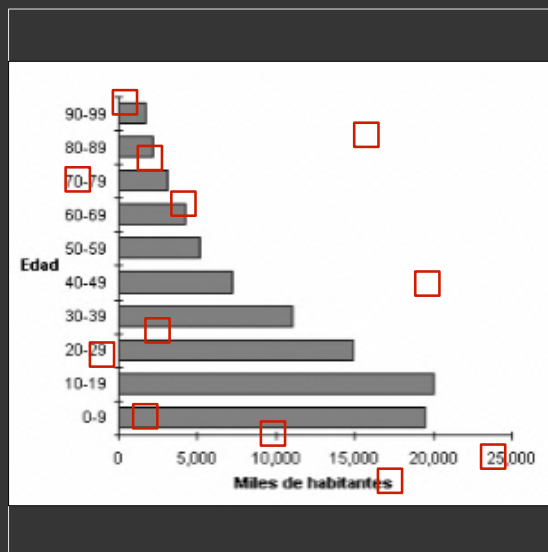
51

Classification

Training the Classifier



Training the Classifier



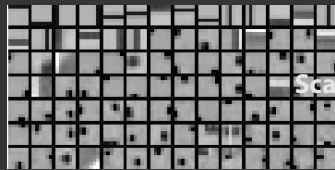
Training the Classifier



Bar Charts

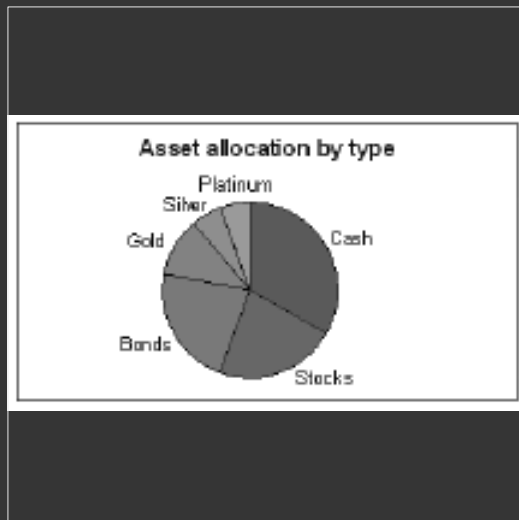


Pie Charts

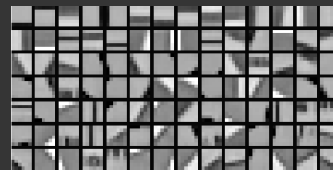
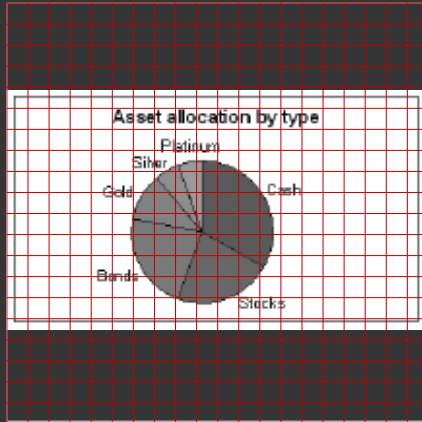


Scatter Plots

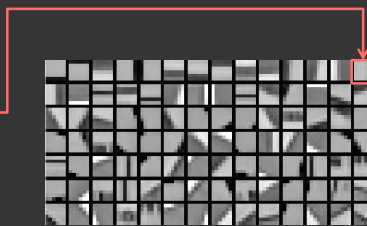
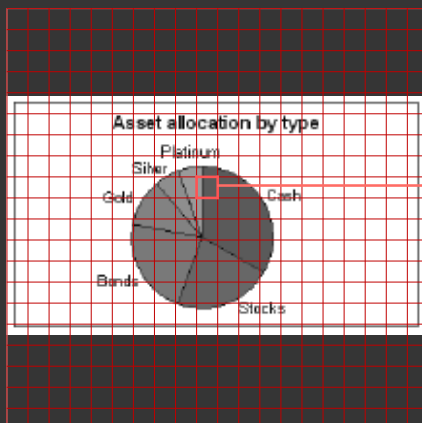
Classifying an Input Image



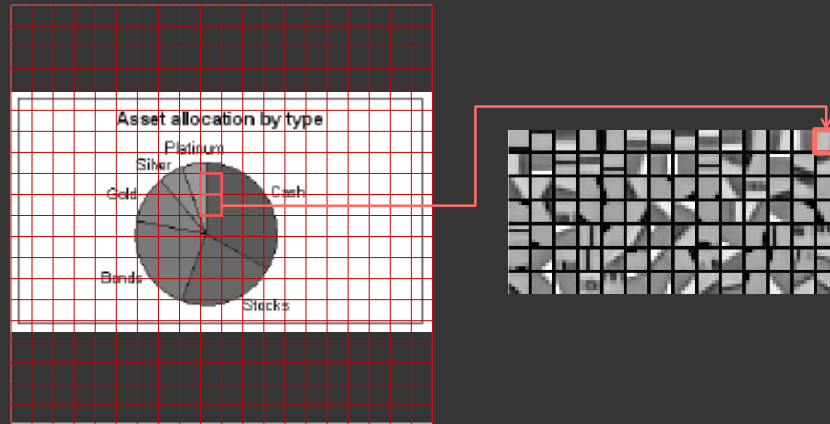
Classifying an Input Image



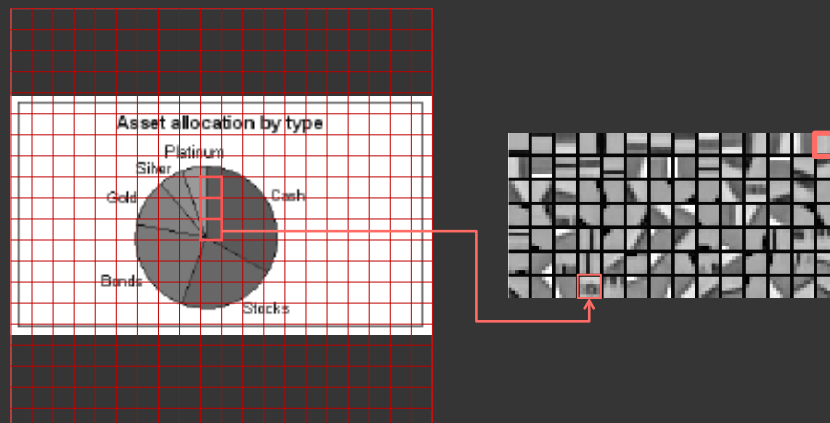
Classifying an Input Image



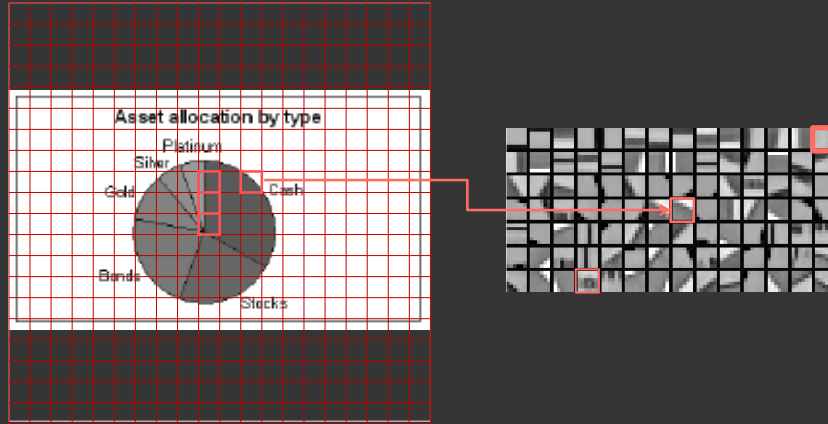
Classifying an Input Image



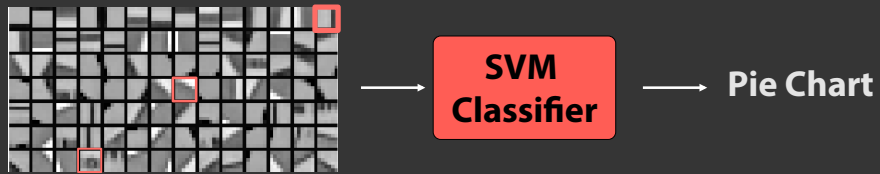
Classifying an Input Image



Classifying an Input Image



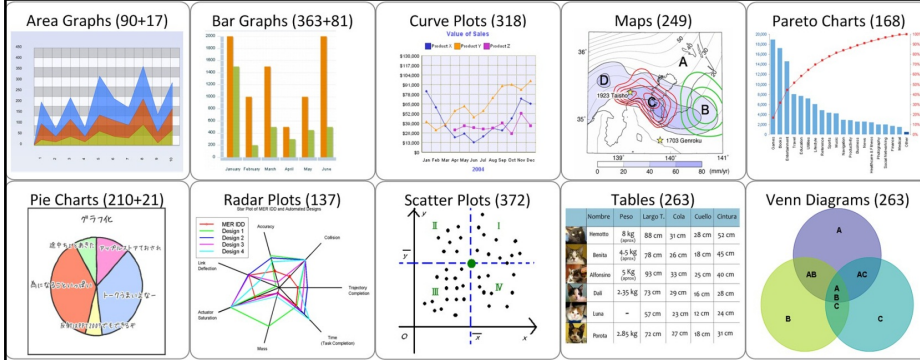
Classifying an Input Image



Corpus: 667 charts, 5 chart types [Prasad 2007]	Average Accuracy
[Prasad 2007] Multi-class SVM	84%
ReVision: Multi-class SVM	88%
ReVision: Binary SVM (yes/no for each chart type)	96%

Our Corpus

Over 2500 labeled images and 10 chart types



ReVision binary SVMs give 96% classification accuracy

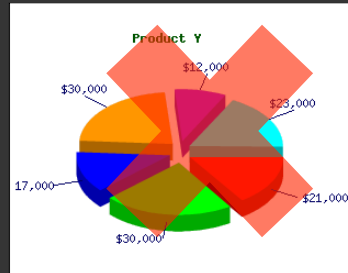
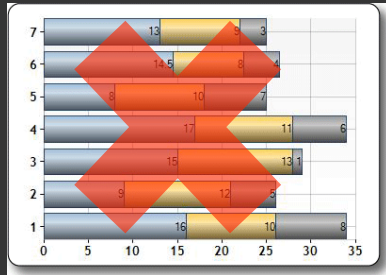
<http://vis.berkeley.edu/papers/revision>

Mark and Data Extraction

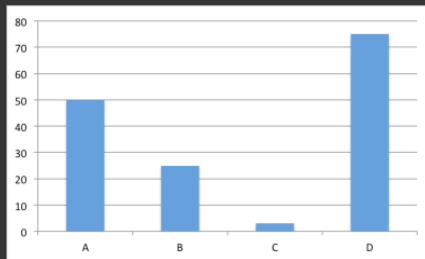
Assumptions

Bar charts and pie charts only

No shading or texture, 3D, stacked bars, or exploded pies



Bar Charts



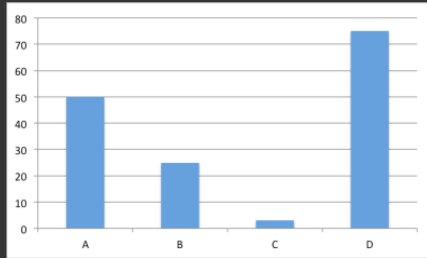
marks: lines



y-value x-value

50	A
25	B
4	C
75	D

Bar Charts



marks: lines



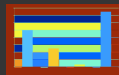
y-value x-value

50	A
35	B
4	C
75	D

Extract Marks

Extract Data

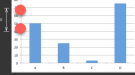
Find Foreground Rectangles



Identify Orientation and Baseline

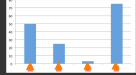


Recover Bar Values

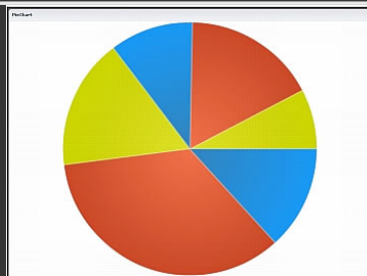


Scale: 2 pixels/unit

Associate Labels with Bars



Pie Charts



marks: areas



percentage category

22.3	A
22.4	B
10.8	C
5.6	D
5.6	E
33.3	F

Extract Marks

Extract Data

Fit Ellipse Using RNASAC



Unroll Pie and Find Transitions



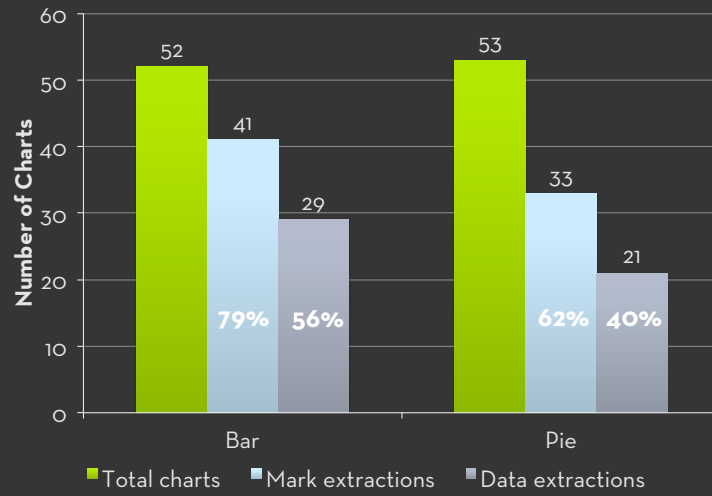
Compute Area Percentages



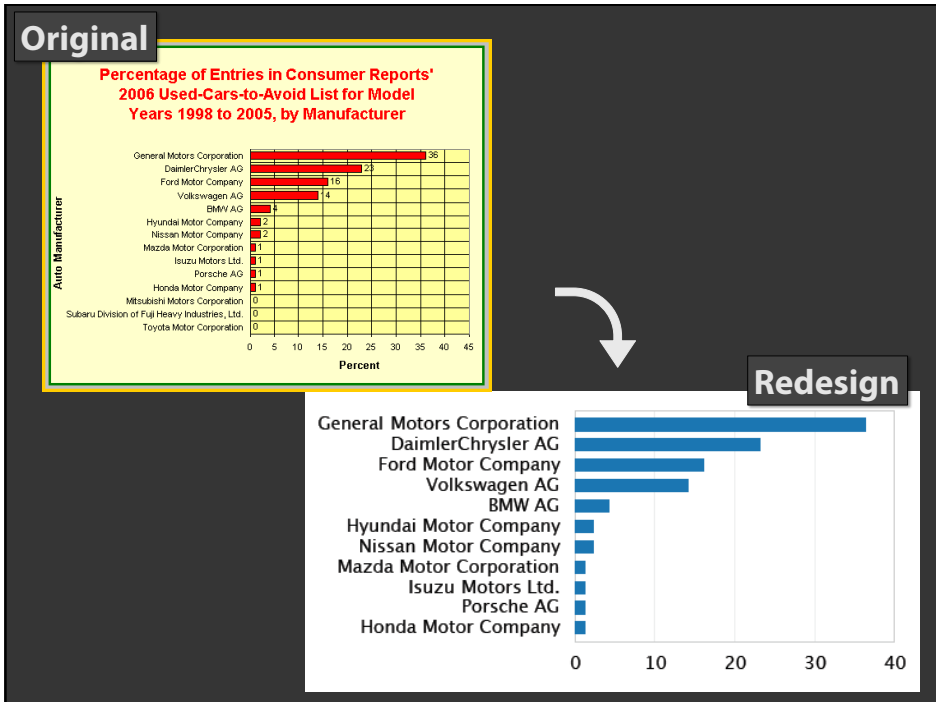
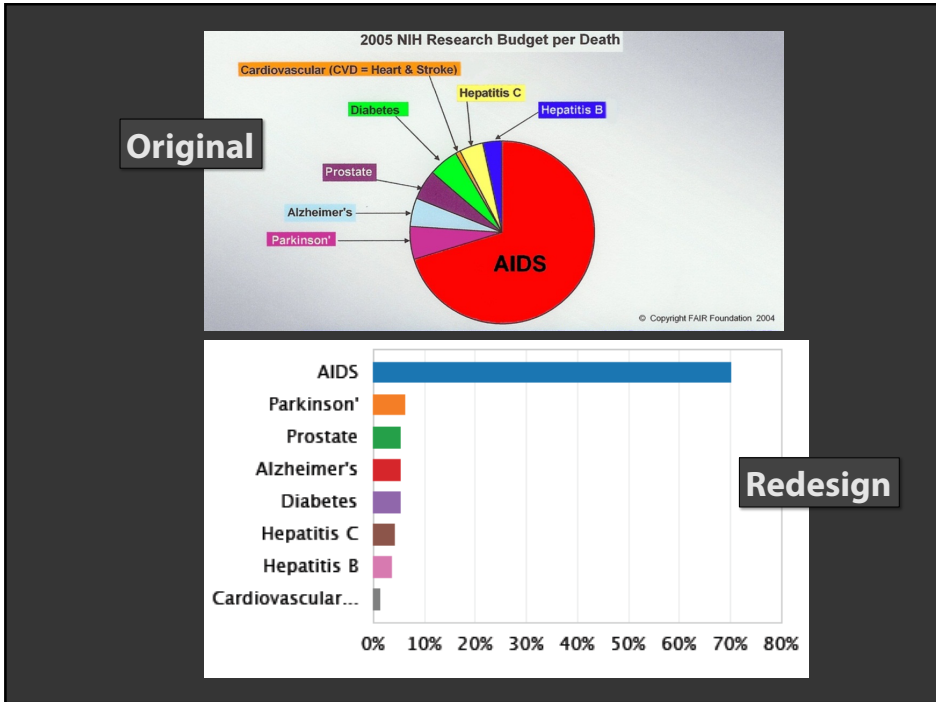
Scale: 50 pixels/percent

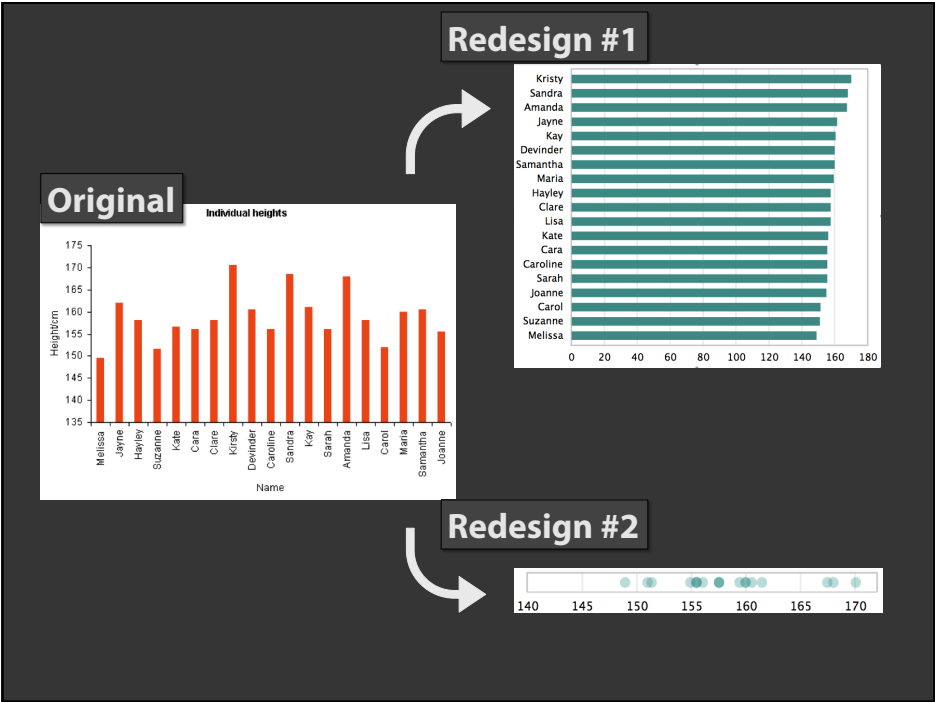
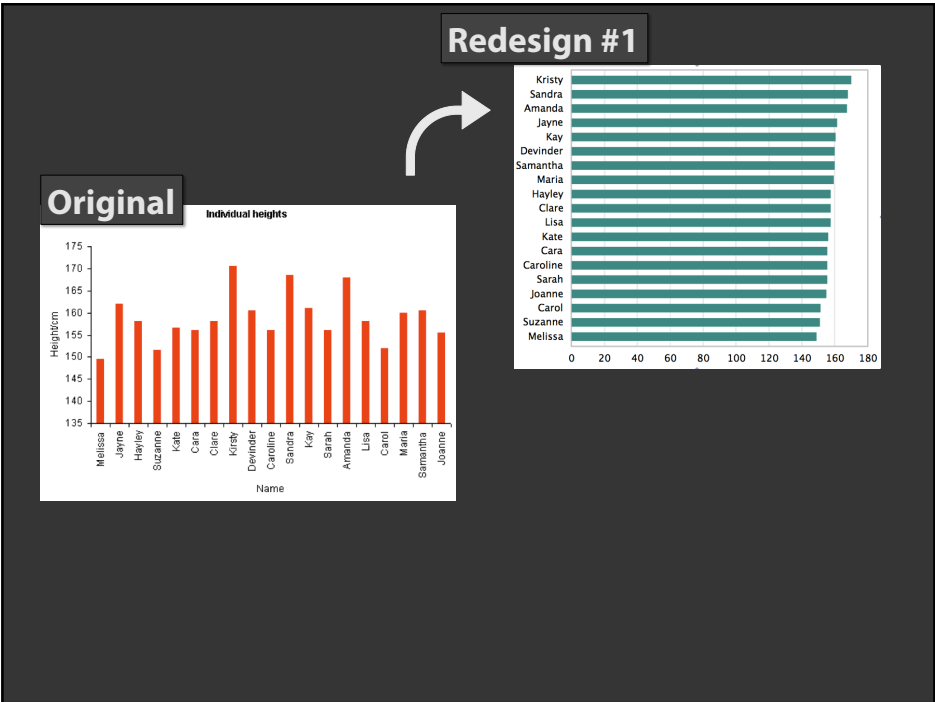
Associate Labels with Areas

Extraction Results



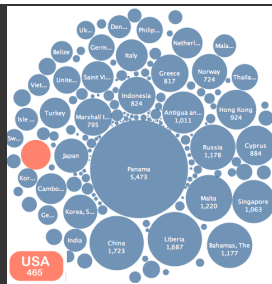
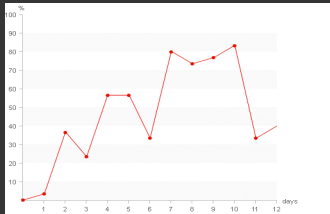
Redesign



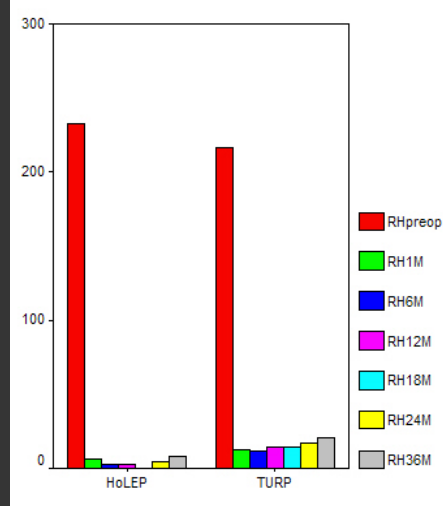


Limitations

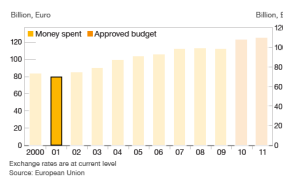
Additional Chart Types



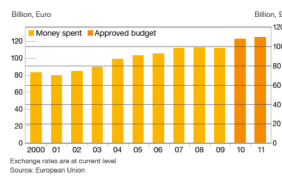
Handling Legends



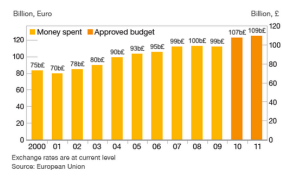
European Union budgets since 2000



European Union budgets since 2000

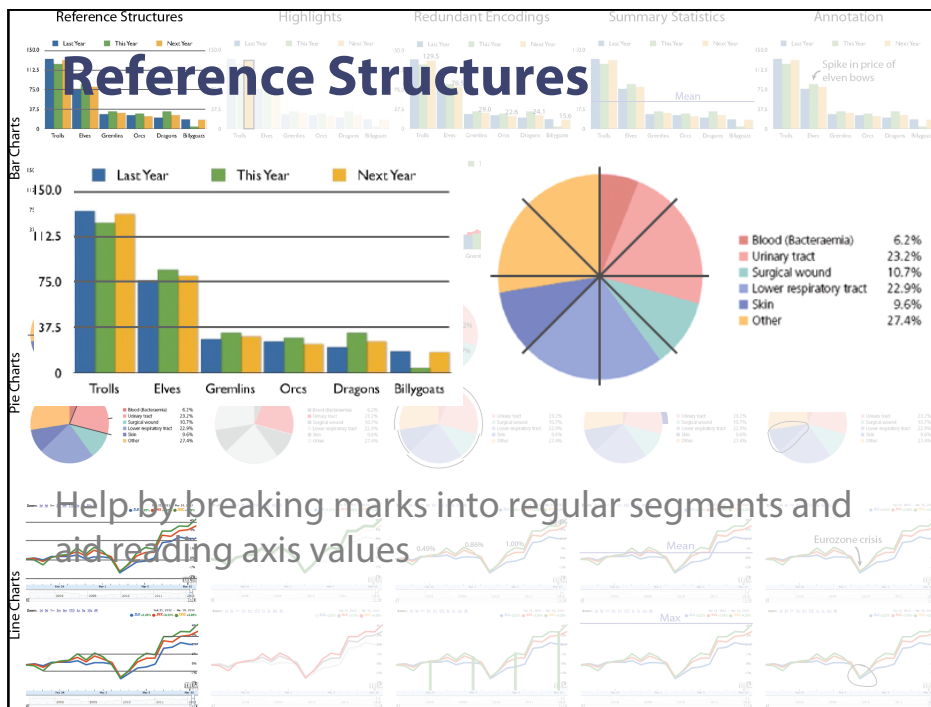


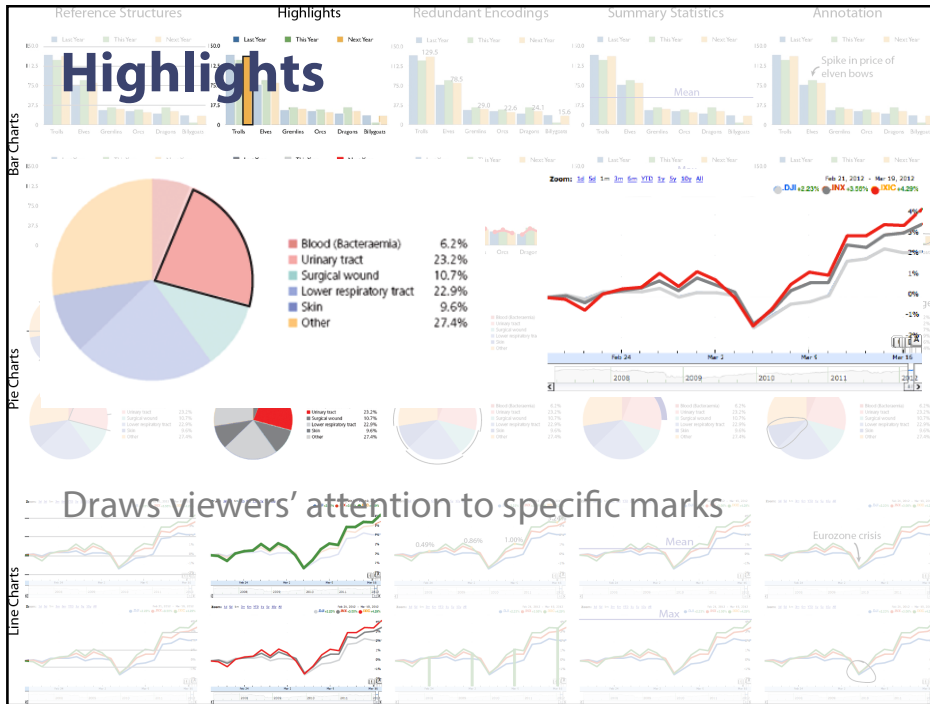
European Union budgets since 2000



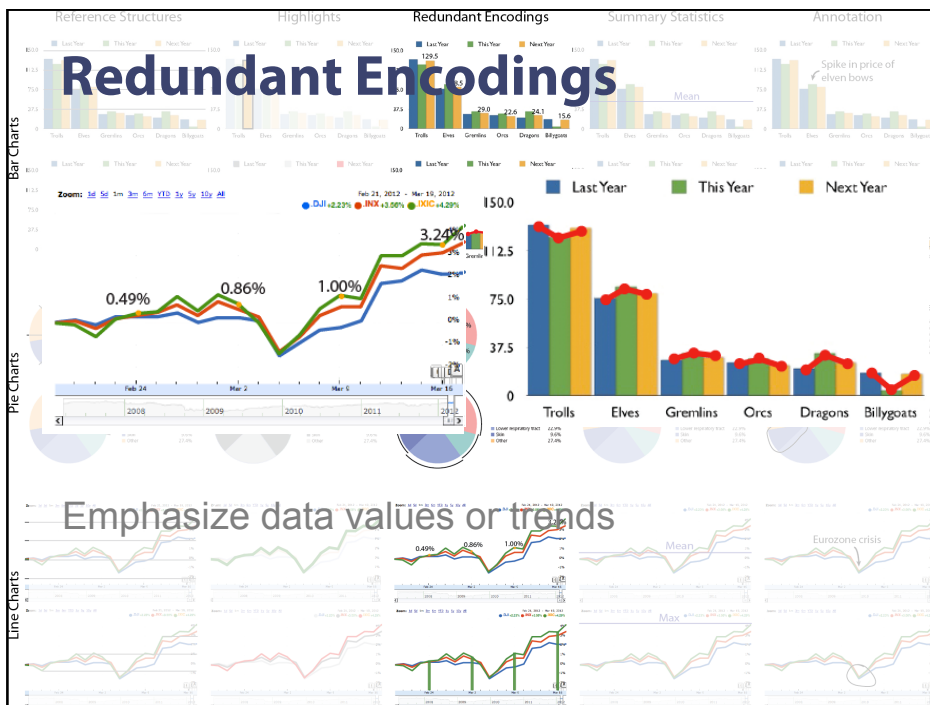
Graphical Overlays

Visual elements that are layered onto a chart to facilitate the perceptual and cognitive processes involved in chart reading

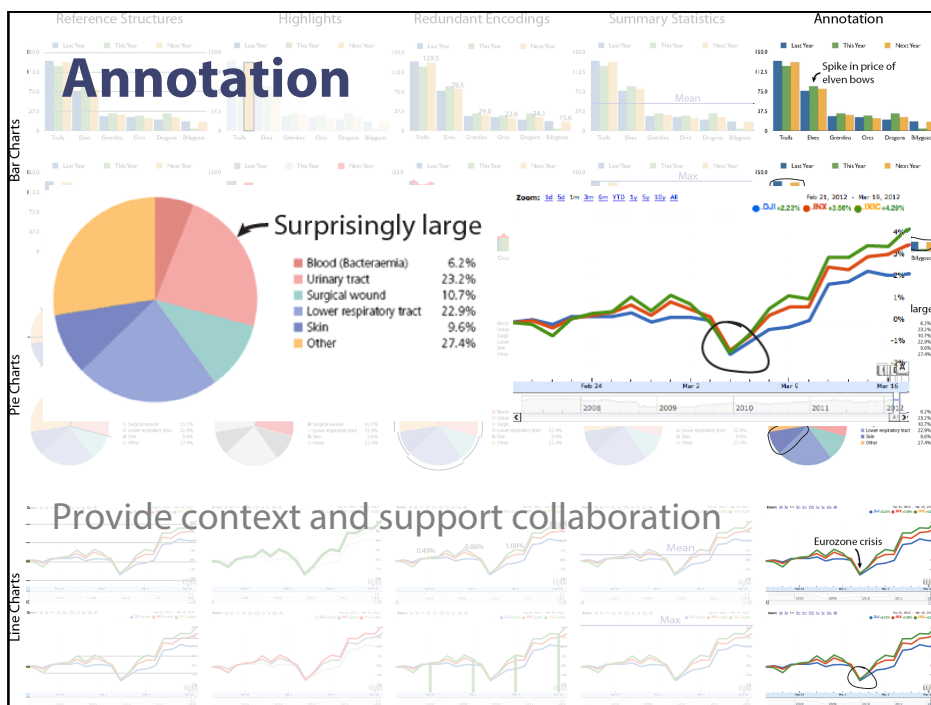
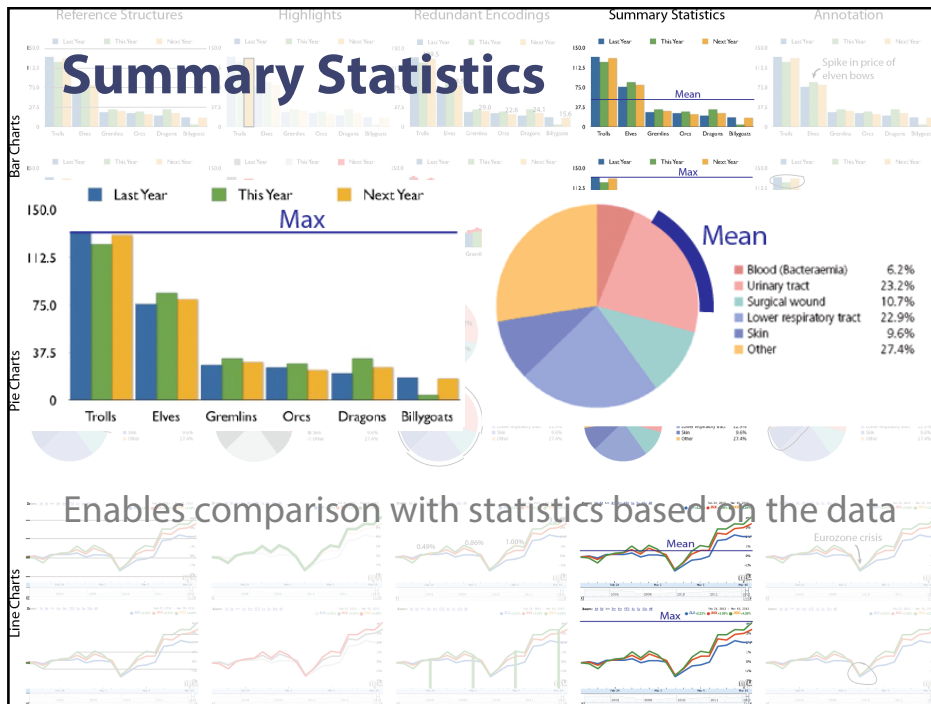




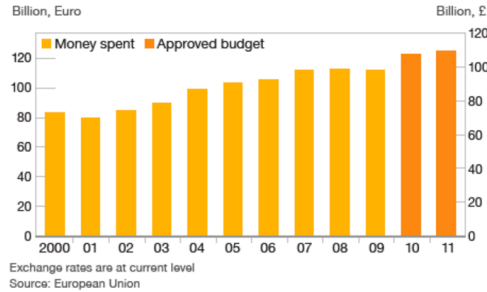
Draws viewers' attention to specific marks



Emphasize data values or trends



European Union budgets since 2000



mark: lines

year	money
2000	85
2001	78
2002	87
2003	90
2004	98
...	...

Most overlays only require access to marks

- Reference structures (**marks**)
- Highlights (**marks**)
- Redundant encodings (**marks** and *data*)
- Summary statistics (**marks**)
- Annotations (**marks**)

Graphical overlay gallery

This gallery contains examples of graphical overlays, described in our [paper](#). We have extracted marks and data from the charts using [ReVision](#) (for bars and pie charts) and [Datathief](#) (for line charts), but all of the overlays are generated in-browser. Try out some of the parameters, or click on an image thumbnail below the gallery to view some example overlays.

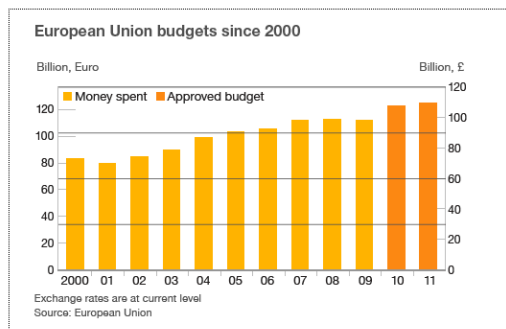


Chart type: Bar

Chart: 00281

Overlay type: Reference structures

Regular gridlines

Lines emanating from marks

Parameters

Overlay Underlay

Static Interactive

Divisions: 4

Line thickness: 1

Places regular gridlines at user defined intervals.

Demo

Interactive Documents

How can we facilitate reading text and charts together?

Syrian refugees: how many are there and where are they?

The humanitarian fallout of the conflict in Syria reaches new proportions as the number of estimated refugees reaches one million

- Download the data
- More data journalism and data visualisations from the Guardian

Mona Chabbi & Simon Rogers
theguardian.com, Wednesday 6 March 2013 13:03 GMT
Jump to comments (0)

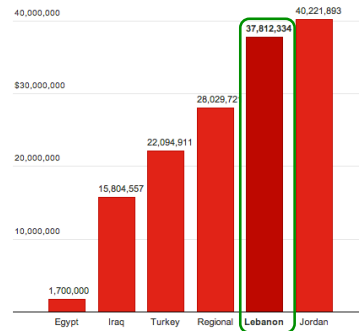
Share 2
Tweet 0
Stumble 1
Share 0
Email

Article history

Some contributions are made on a regional basis, but many donors prefer to contribute to efforts in a specific country. In line with the distribution of the refugees themselves, most funds are funnelled towards Jordan (28%), followed by Lebanon (26%), Turkey (15%) and Iraq (11%).

Where the money goes

Where the international community has donated to help Syria's refugees



SOURCE: UNHCR
GET THE DATA EMBED FULLSCREEN

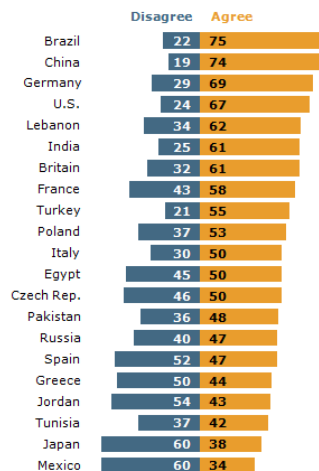
theguardian

Goal: Extract references between text and chart

Problem: Diversity of writing styles

Example 1: Pew Research

Are People Better Off in Free Market Economy?

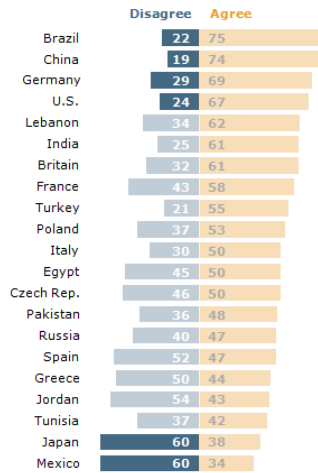


PEW RESEARCH CENTER Q26.

Skepticism for capitalism is lowest in Brazil (22%), China (19%), Germany (29%) (although East Germans are less supportive than West Germans) and the U.S. (24%). Skepticism for free markets is highest in Mexico (60%) and Japan (60%).

Example 1: Pew Research

Are People Better Off in Free Market Economy?



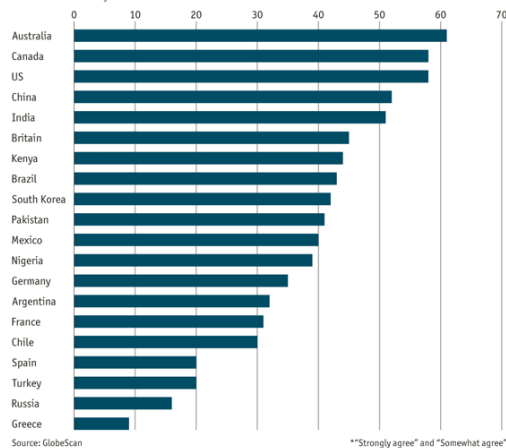
Skepticism for capitalism is lowest in **Brazil (22%)**, **China (19%)**, **Germany (29%)** (although East Germans are less supportive than West Germans) and the **U.S. (24%)**. Skepticism for free markets is highest in **Mexico (60%)** and **Japan (60%)**.

PEW RESEARCH CENTER Q26.

Example 2: Economist

Public opinion on the rich

Respondents who agree* that most rich people in their country deserve their wealth, %
December 2011–February 2012



Top earners have attracted more opprobrium as their salaries and the performance of the economy have headed in opposite directions. Europeans and Latin Americans tend to have similar attitudes to the rich; the Anglo-Saxon world is a bit more forgiving.

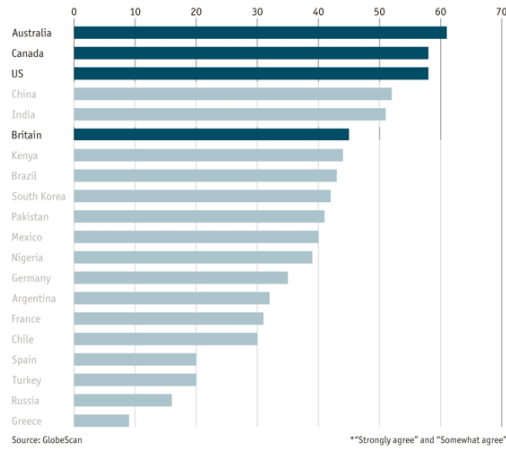
Source: GlobeScan

**"Strongly agree" and "Somewhat agree"

Example 2: Economist

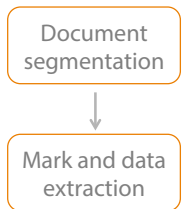
Public opinion on the rich

Respondents who agree* that most rich people in their country deserve their wealth, %
December 2011–February 2012

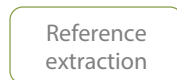


Top earners have attracted more opprobrium as their salaries and the performance of the economy have headed in opposite directions. Europeans and Latin Americans tend to have similar attitudes to the rich; **the Anglo-Saxon world** is a bit more forgiving.

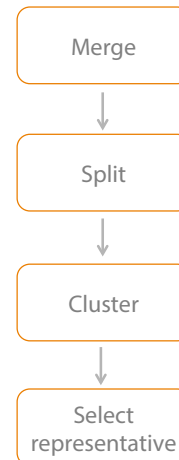
Preprocessing



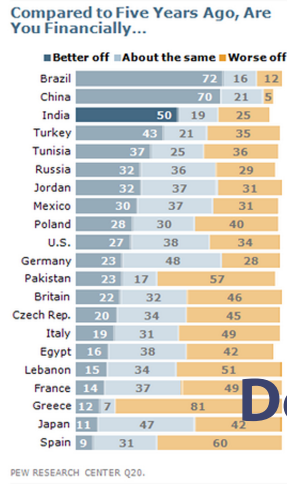
Crowdsourcing



Clustering and Merging

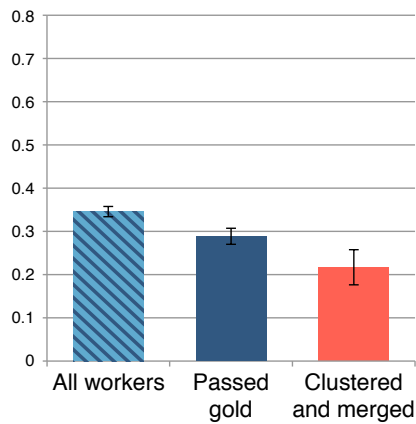


People may think their personal situation is better than economic conditions in their nation, but only in Brazil (72%) and China (70%) do large majorities think their families are better off than they were five years ago. On balance, **Indians (50%)** and Turks (43%) also say their situations have improved.



Demo

Evaluation

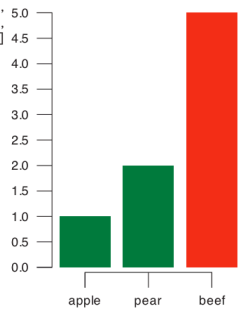


Avg. F₁ distance: expert specified references vs. crowd specified references

Ongoing and Future Work

Deconstructing D3 Charts

```
1 items = [{name: "apple", type: "fruit", cost: 1.00},
2           {name: "pear", type: "fruit", cost: 2.00},
3           {name: "beef", type: "meat", cost: 5.00}]
4 var bars = svg.selectAll("rect")
5               .data(items)
6               .enter()
7               .append("rect");
8 bars.attr("x", function(d, i)
9           {return i * 25;})
10        .attr("y", function(d)
11           {return h - d.price * 10;})
12        .attr("height", function(d)
13           {return d.price * 10;})
14        .attr("fill", function(d, i)
15           {if(d.type === "fruit"){return "green";}
16            else if (d.type === "meat"){return "red";}})
17        .attr("width", "20px")
18        .attr("stroke-width", 0);
```



Data			
deconID	name	type	cost
2	apple	fruit	1.00
3	pear	fruit	2.00
4	beef	meat	5.00

Marks		
fill	xPosition	height
green	35 px	20 px
green	60 px	40 px
red	85 px	100 px

Mappings	
type	↪ fill
cost	↪ height
cost	↪ yPos
cost	↪ area
deconID	↪ xPos

D3 Code

D3 Chart

Our Deconstruction

Automatically convert D3 code into mapping based representation to enable redesign and style reuse

Deconstructing and Restyling D3 Visualizations. Jonathan Harper and Maneesh Agrawala. User Interface Software Technology (UIST) 2014.

Takeaways

A *chart* is a collection of *mappings between data and marks*

We *can reconstruct* this representation *from chart bitmaps*

Such reconstruction *enables redesign, reuse and revitalization*