# Automating the Design of Graphical Presentations of Relational Information

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# Overview

- Automate the design of 2D graphical presentations for relational data
- Why is this hard?
  - Must express design criteria so that the machine can understand them (*expressiveness criteria*).
  - Must express information in an understandable way given the capabilities of the output medium (*effectiveness criteria*).

# Goal

Given application data, a presentation tool (APT) creates an image that effectively displays the data.

# Credo

"…an important responsibility of a user interface is to make intelligent use of human visual abilities and output media whenever it presents information to the user."

# The Graphical Presentation Problem

- What is an effective encoding of information?
- Example:

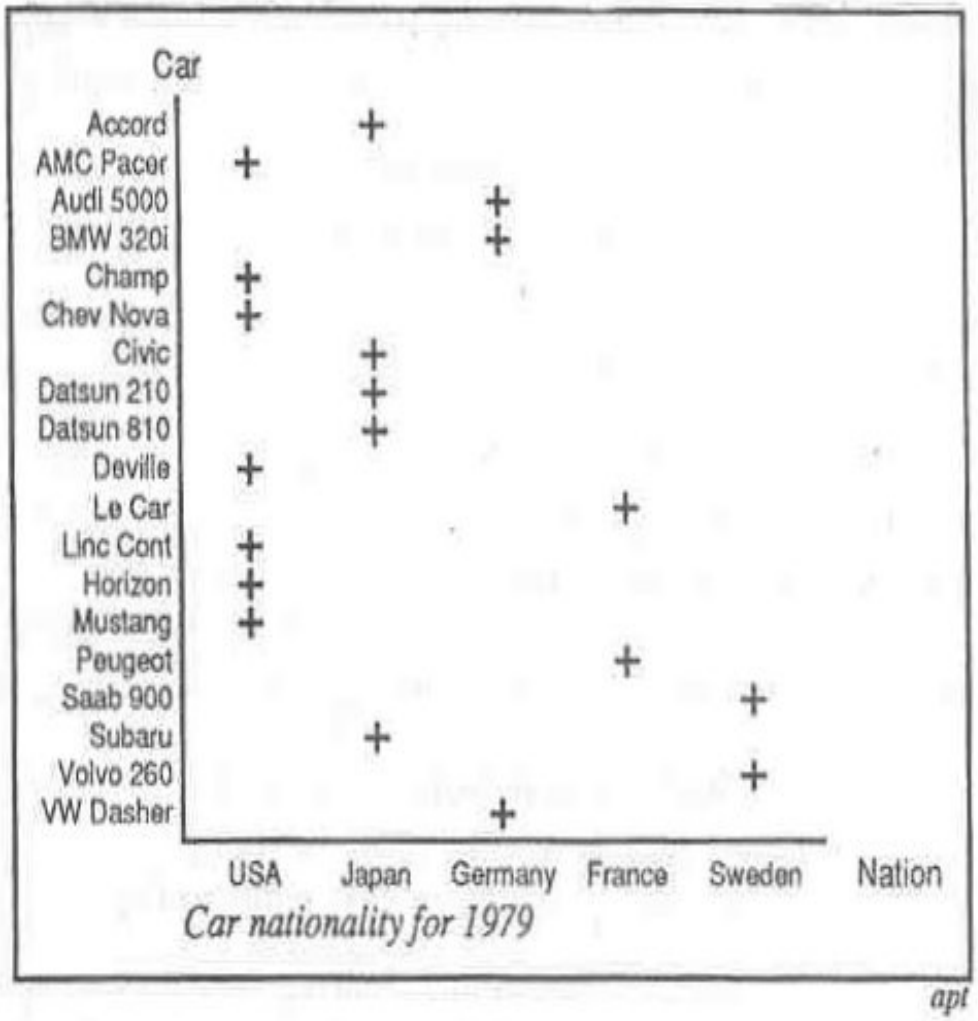
  Given a car database:

  - Present the ***Price*** and ***Mileage*** relations.
  - The details about the set of *Cars* can be omitted.
- Many ways of encoding any information.

# Approach: Expressiveness Criteria

- Graphical presentations -
  - "sentences of graphical languages"
  - essentially logical statements
- A set of facts is *expressible* in a language
  - if and only if it contains a sentence that describes exactly that set of facts
  - no more, no less.

# Expressiveness Criteria

# Expressiveness Criteria

A *graphical sentence s* describes objects and their locations.

- Object: Square, Circle, Triangle, Plus, Minus, Star, Smiley Face, etc.
- Location: Xmin, Xpos, Xmax, Ymin, Ypos, Ymax.

$$s \subset \left\{ \langle o, l \rangle \mid o \in O \wedge l \in L \right\}$$

# Expressiveness Criteria

- Example: You can describe a 1-D horizontal graph using a "horizontal position" language
- A graphical sentence can belong to this language if it describes either the horizontal axis or a "+" mark on that axis:

$$HorzPos(s) \Leftrightarrow s = h \cup m \wedge \langle o, l \rangle \in m \Rightarrow \begin{bmatrix} o = plusobj \wedge \\ Y\max(h) \leq Ypos(l) = const \wedge \\ X\min(h) \leq Xpos(l) \leq X\max(h) \end{bmatrix}$$

# Expressiveness Criteria

*Encodes* relation: given a language for presenting information (like HorzPos), *Encodes* is the relationship between the facts you are encoding and the objects on the screen

# Expressiveness Encoding

Example: given a relation r with tuples ($a_i$, $b_i$) (where a is an element of the set of marks and b is an element of the set of positions) for the HorzPos language, there are three *Encodes* relations:

Range of locations are encoded by the horizontal axis:

Encodes(h, {$b_1 \ldots b_n$}, HorzPos)

Each located object $o_i$ in the set of marks m encodes an $a_i$

Encode($o_i$, $a_i$, HorzPos)

# Expressiveness Encoding

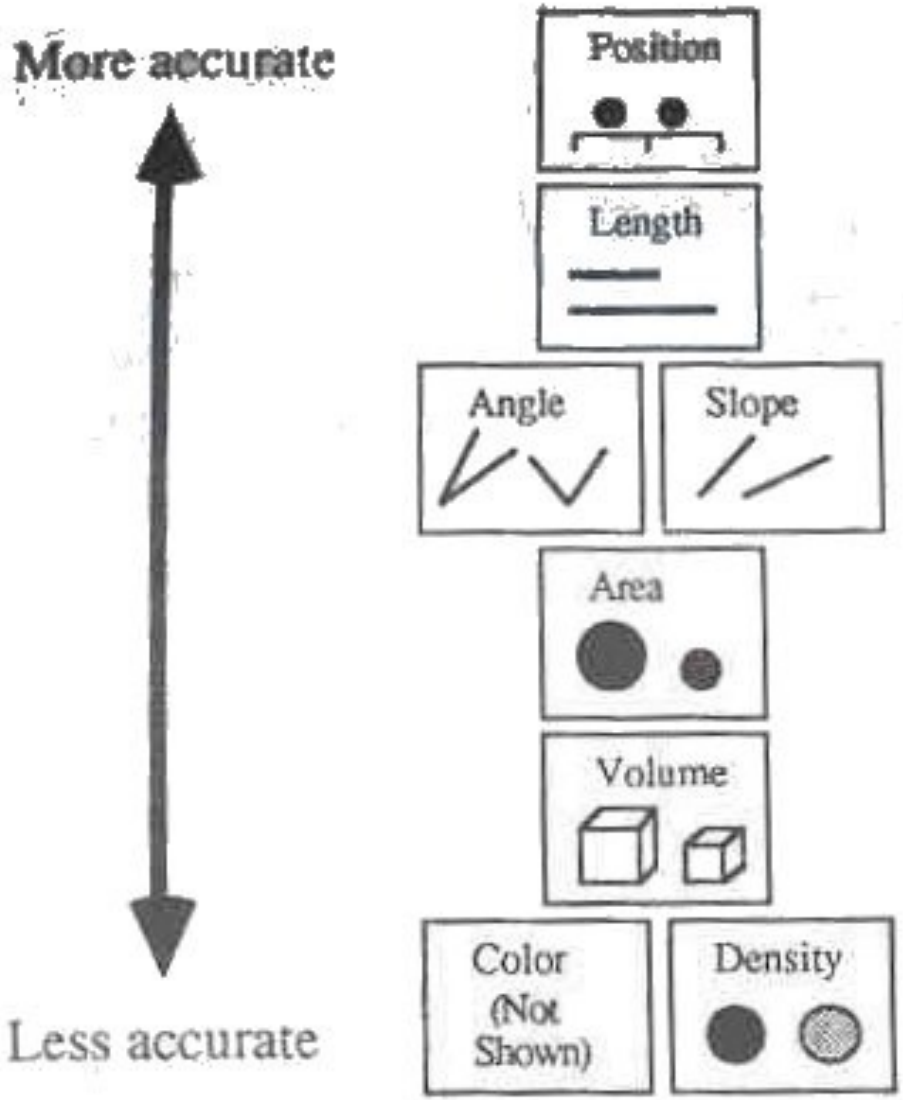
The relation r can be encoded by the position of each mark along the horizontal axis in the horzPos language

Encodes(position(m,h), r, HorzPos)

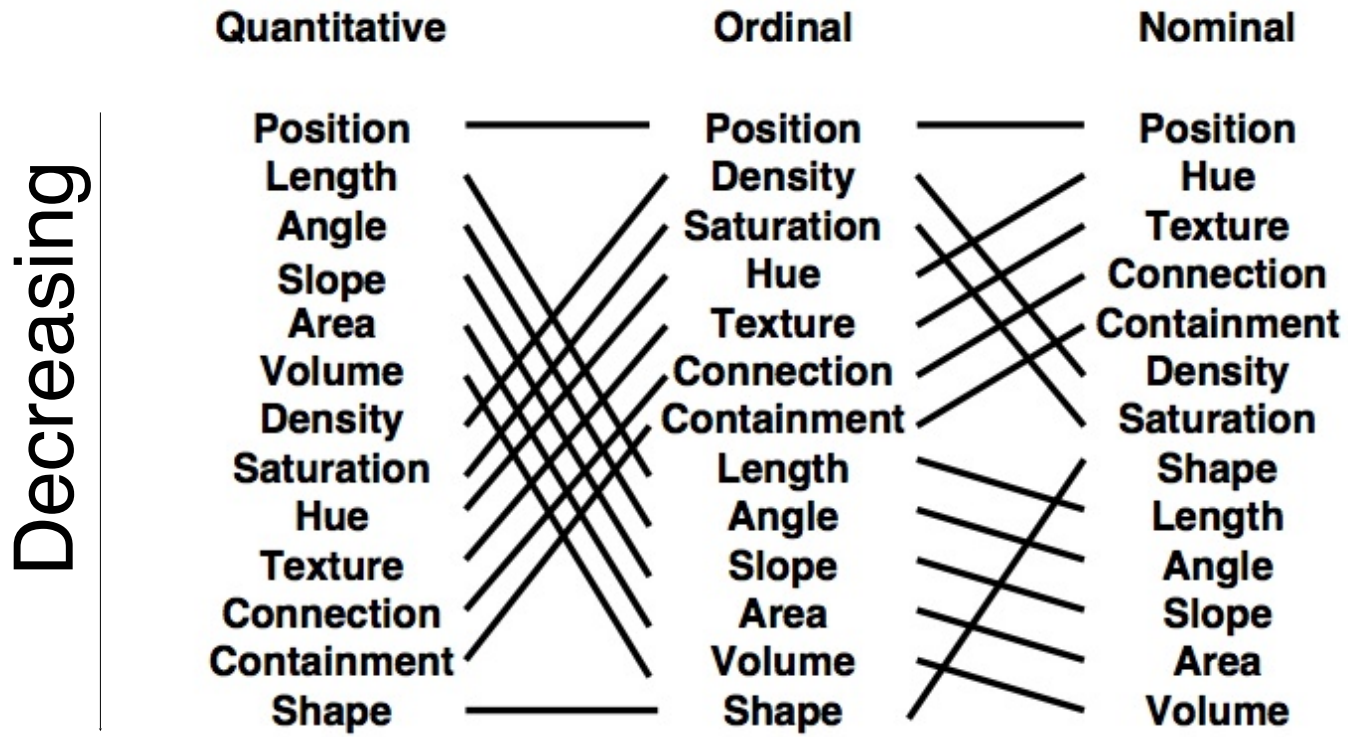
# Effectiveness Criteria

- How do we design an effective presentation automatically?
- Based on empirically verified knowledge, not mathematical rigor.
- A ranking of perceptual tasks is used to decide which graphical language to employ (Fig 14-15).

# Expressiveness Criteria



# Jock Mackinlay, 1986




[Mackinlay, Automating the Design of Graphical Presentations of Relational Information, 1986]

# Effectiveness Criteria

Principle of Importance Ordering:

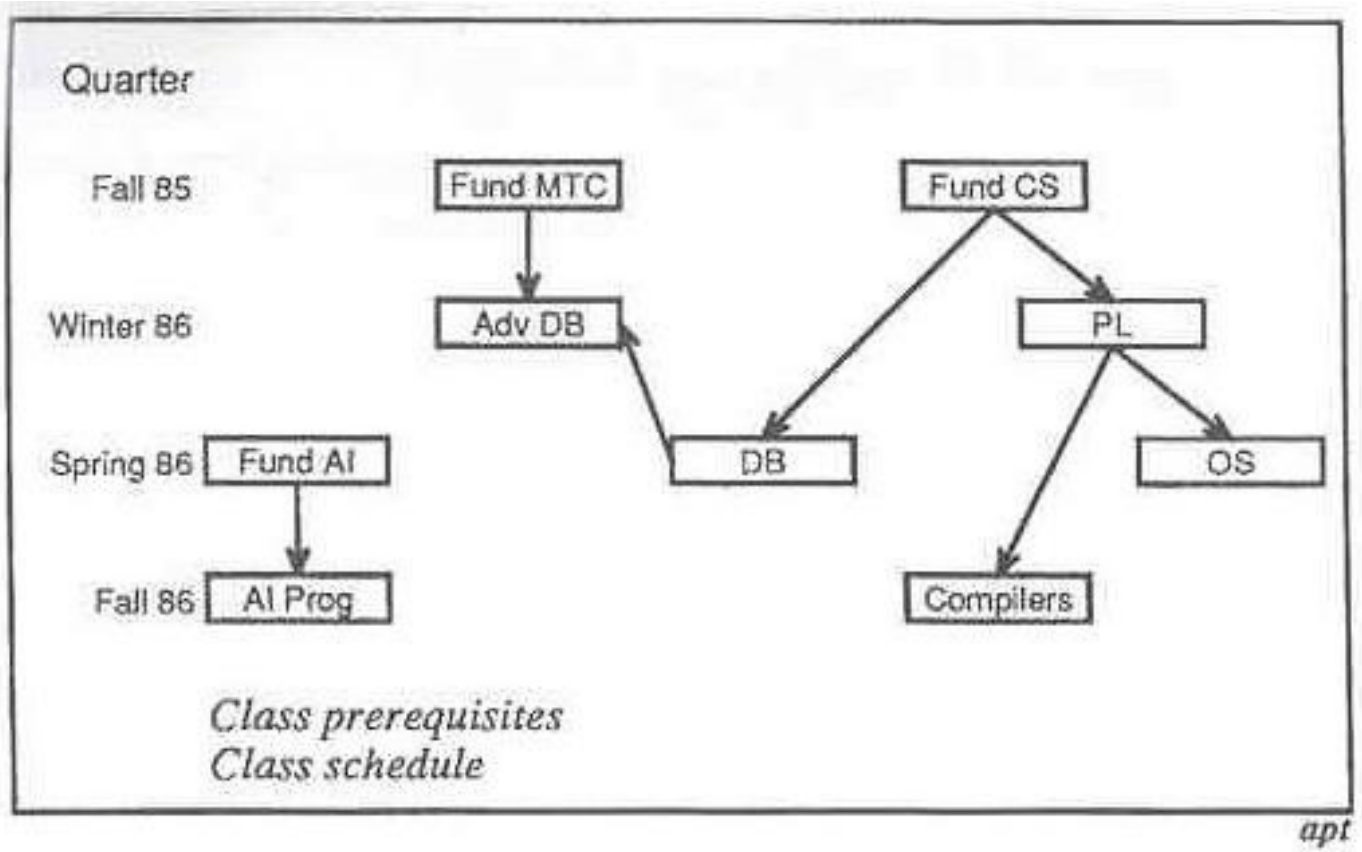
Encode more important information more accurately (use information higher in the ranking to encode more important information)

# Composition

- How do you design new presentation designs?
  - Can just have a laundry list of them
  - But it is better to take a bunch of simple "primitive" ones and combine them.
- Principle of Composition:
  - Compose two designs by merging parts that encode the same information.

# Composition

Merge different encoding techniques not usually combined



# Axis Composition

- Example: ozone measurements in two different cities.
  - Y-axis: ozone density
  - X-axis: date
  - first figure, from Yonkers, second from Stamford: overlay them.
- Only can do this if the axes encode the same information

# Axis Composition

- Formally:

$$v_i = v_j \neq \{\} \wedge h_i = h_j \neq \{\} \wedge$$
$$Encodes(h_i, x, l_i) \wedge Encodes(h_j, x, l_j) \wedge$$
$$Encodes(v_i, y, l_i) \wedge Encodes(v_j, y, l_j)$$

- Similar for single axis composition

# Mark Composition

Merges mark sets if the sets encode the same information in the same way

- position: positions of objects along existing axes are same

- retinal: retinal properties must be the same

# Implementation

- Uses logic programming to determine possible designs given the formalisms.
- Uses divide and conquer algorithm:
  - Partition
  - Selection
  - Composition

# Implementation

- Partitioning
  - A divide and conquer algorithm
  - Partition on most important element
- Selection
  - For each partition, a list of graphic design is generated based on expressiveness criteria
  - Then, the list is ordered by the effectiveness criteria
- Composition
  - Each partition's graphic design is tested to see if they both can be applied, if not the next most effective graphic design is used

# Partition

- Partition (divide)
  - order the attributes by importance
  - divide them up into groups that match expressiveness criteria
  - <Price, Mileage, Repair, Weight> can be partitioned into <Price>, <Mileage, Repair, Weight>.
  - <Mileage, Repair, Weight> must be repartitioned recursively until something that can be encoded is obtained

# Selection and Composition

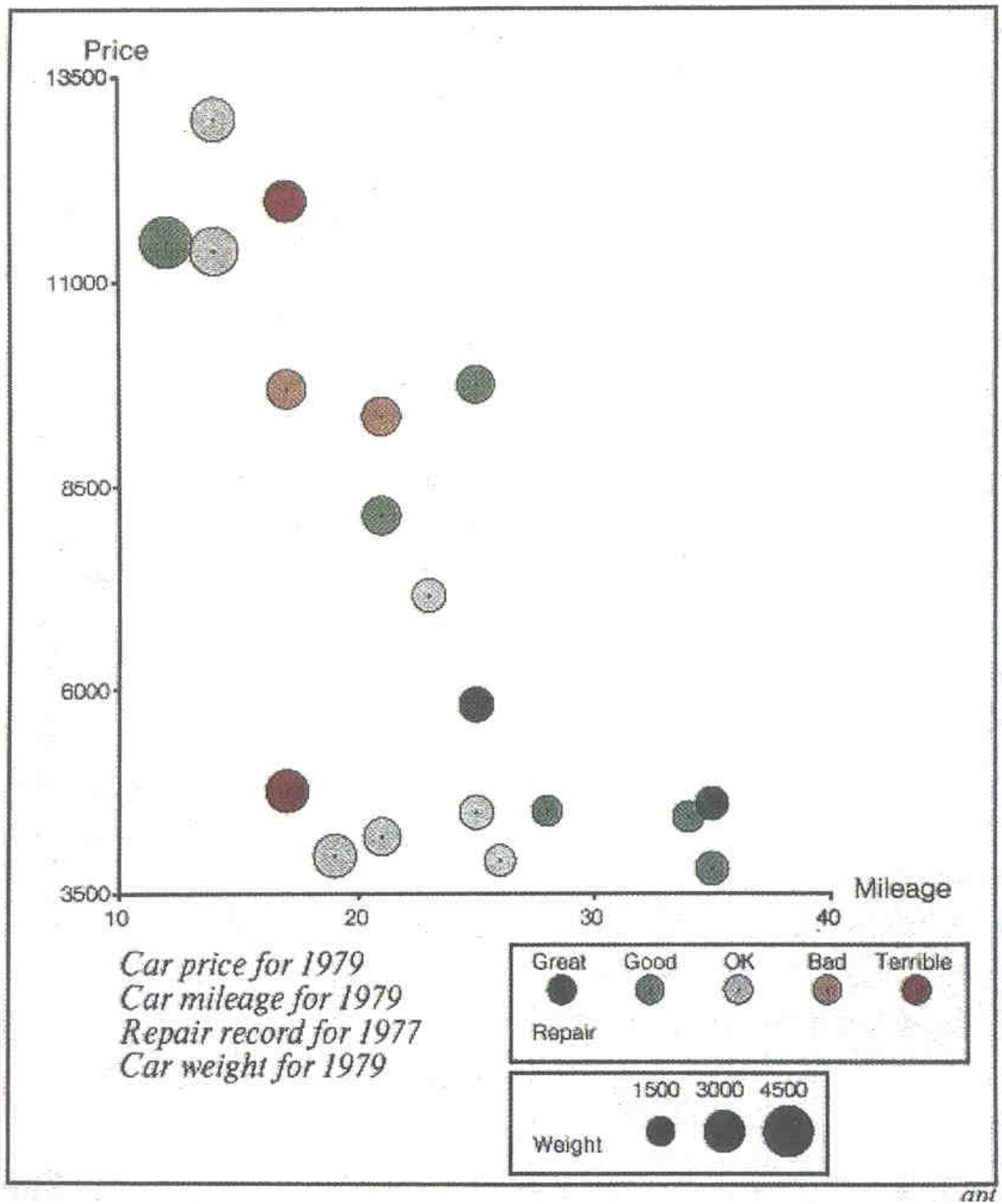
- Selection
  - For each partition, filter out incompatible design criteria
    - e.g., cannot use maps to encode <Price, Mileage, Repair, Weight>
- Composition
  - Composes the individual designs into a unified presentation of all information

# Summary

- Formalizes Bertin's graphical presentation scheme
- Shows that machine generated presentations are feasible
- Develops a formal model for analyzing graphical representations of data

# Discussion/Critique

- Strengths:
  - Was the first to develop a framework for automating graphical presentation creation
  - Defined criteria for evaluating presentation tools (effectiveness, expressiveness)
- Weaknesses:
  - Not clear that APT is particularly useful
  - Are APT generated presentations effective?
  - Can only do limited types of presentations


Price
13500
11000
8500
6000
3500
10
20
30
40
Mileage
Car price for 1979
Car mileage for 1979
Repair record for 1977
Car weight for 1979
Great
Good
OK
Bad
Terrible
Repair
1500
3000
4500
Weight