# Financial Applications of Fuzzy Case-Based Reasoning to Residential Property Valuation

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# Outline

- Problem Description & Motivation
- Related Work
- APVT Architecture
- Comparable-based Approach (Fuzzy CBR)
- CBR Design
- CBR Validation Stage
- Confidence Assessment
- Result Analysis
- Conclusions

# Introduction

Residential property valuation is the process of determining a monetary estimate of the value of a single family residence.

- at a given location
- at a given time

- Needed to determine:
  - –Collateral value for mortgage origination
  - –Asset value for mortgage insurance
  - –Portfolio value for mortgage packages, etc.

The estimate is called an appraisal
= $110,000

# Problem Description and Motivation

**Appraisals are needed to:**

- grant most new mortgages
- evaluate the value of packages of mortgages that may be purchased

**The current manual process for appraising properties usually:**

- requires an on-site visit by a human appraiser
- costs about $500
- lasts three to four days
- subject to human variability

**The most common method used by human appraisers is the “sales comparison approach” which involves:**

- finding recent sales comparable to the subject property
- adjusting the comparables’ sales price to reflect differences Vs subject
- reconciling the comparables’ adjusted prices to create an estimate

# Related Work (External)

- Commercial Vendors
  - GA-trained NN for each Census Track model
    - Very computational Intensive
    - Not scaleable nationwide
  - Non-fuzzy Case-based retrieval
    - Brittle Retrieval Process
  - Statistical regressions
    - Difficult to maintain
    - Inconsistent sign in coefficients
    - Not transparent

# Related Work (Internal)

Multiple methods were used by different GE researchers to develop property value estimators.

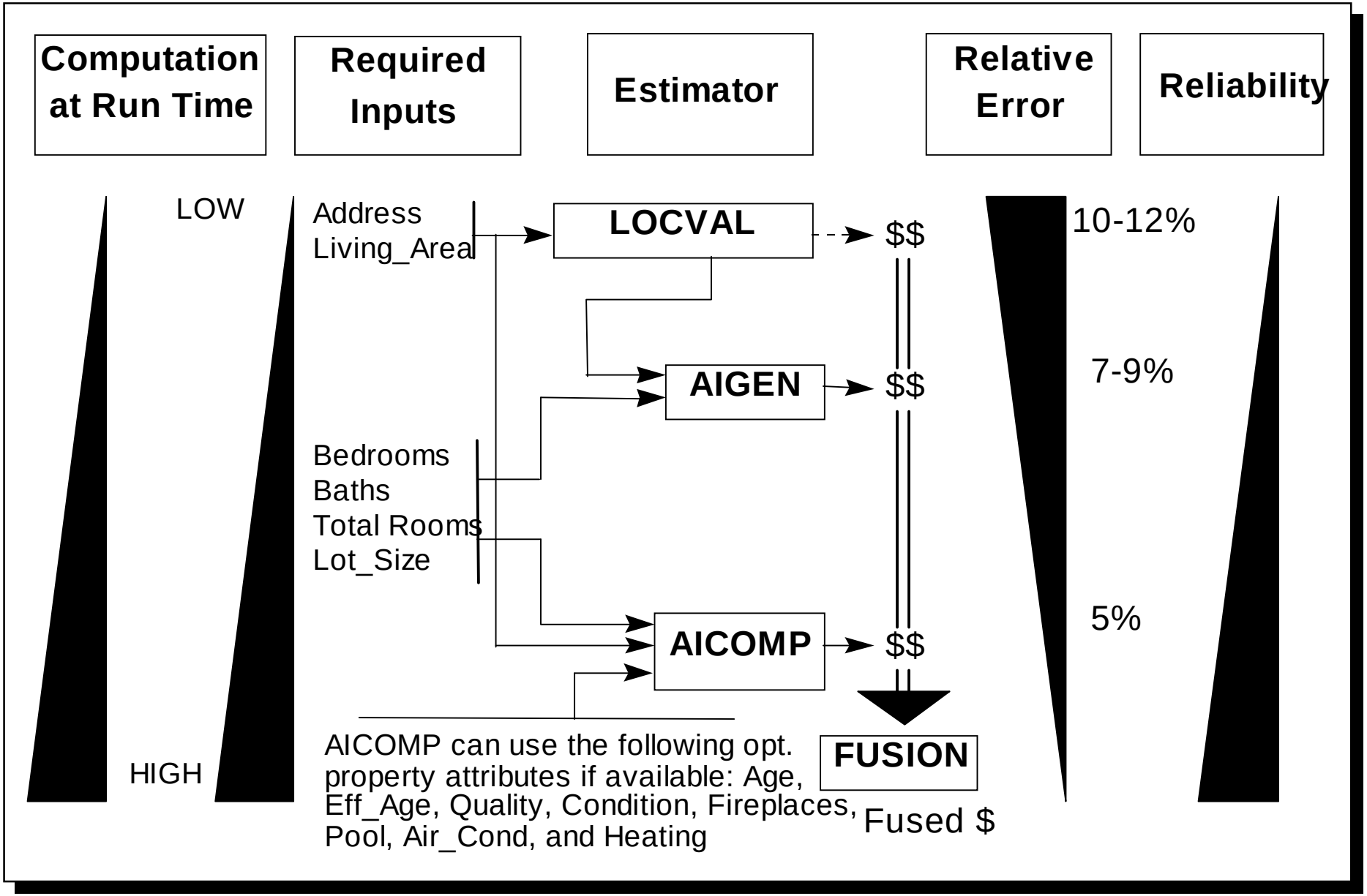
- –LocVal estimator
- –StatGen estimator
- –Index based estimator

| Method Used | Data Needed | Error (median) |
|---|---|---|
| Location Value | Address & Liv. Area | 10% |
| Statistical Formula | 10 attributes | 8% |
| Fuzzy-Neural Net | 10 attributes | 7% |
| Fuzzy CBR | 11-30 attributes | 5% |
| Human Appraiser | Site Inspection | 3% |

# Information Requirement and Prediction Accuracy

- Available information from DBs
- Maintenance costs related to information req.
- See next slide

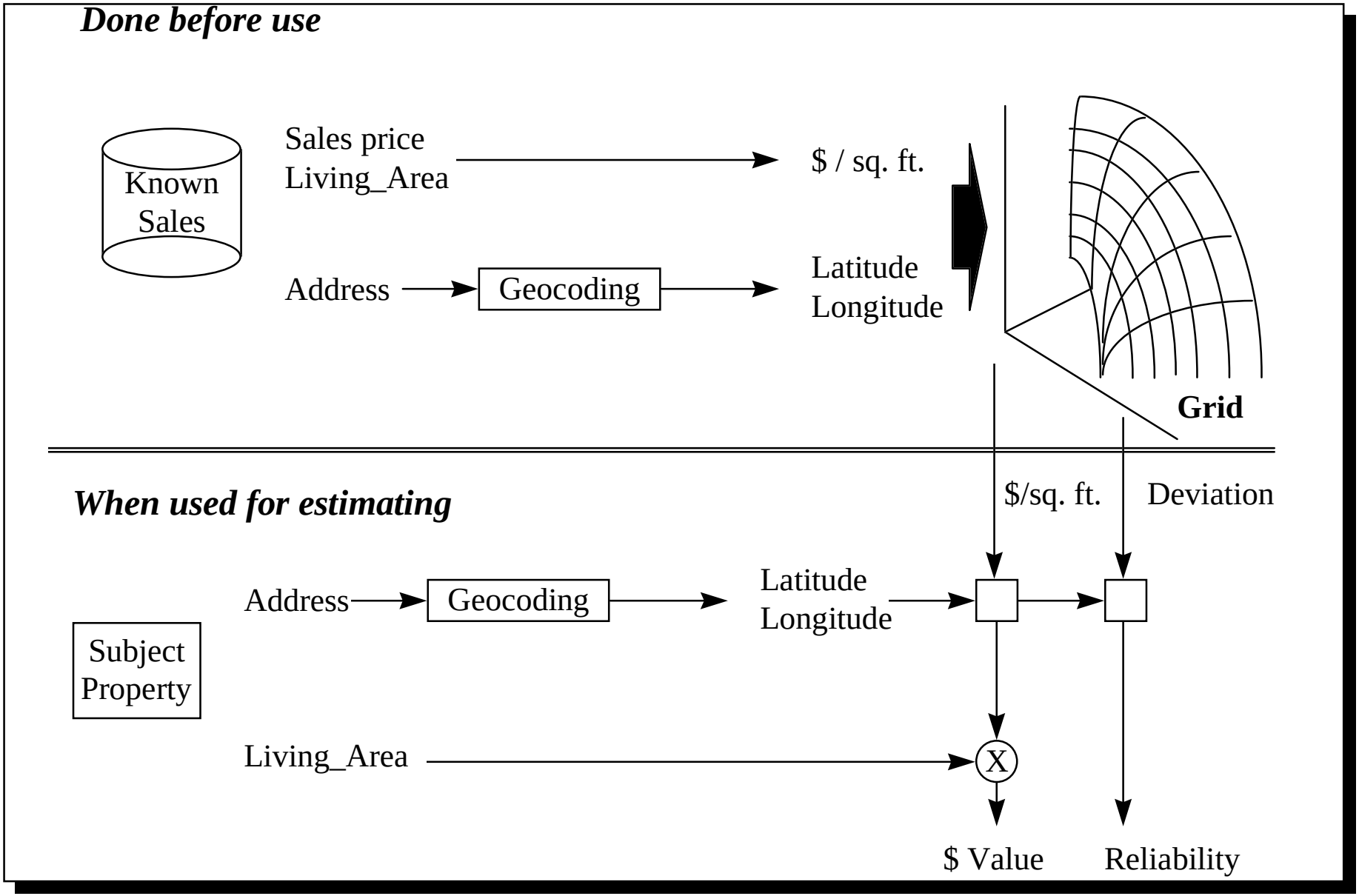
# AI Models For Valuation



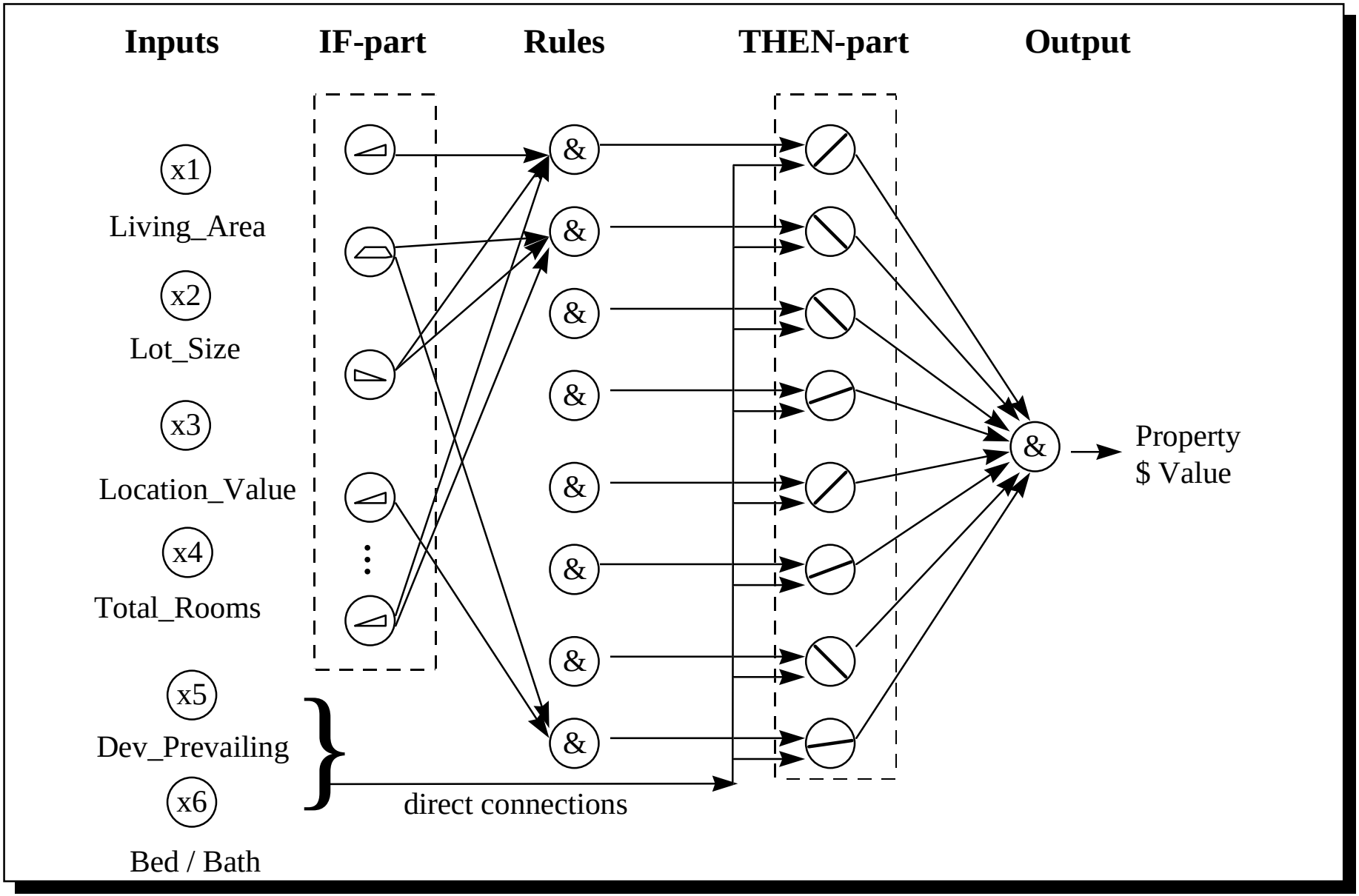
# APVT Architecture

- Components:
  - 2 Cascaded Generative Estimators (LocVal & AIGEN)
  - 1 Fuzzy CBR Estimator
  - 1 Fusion module
  - Output of each estimator and of fusion module
    - Value
    - Confidence
    - Justification (only for CBR and fusion)
- See Architecture Diagram

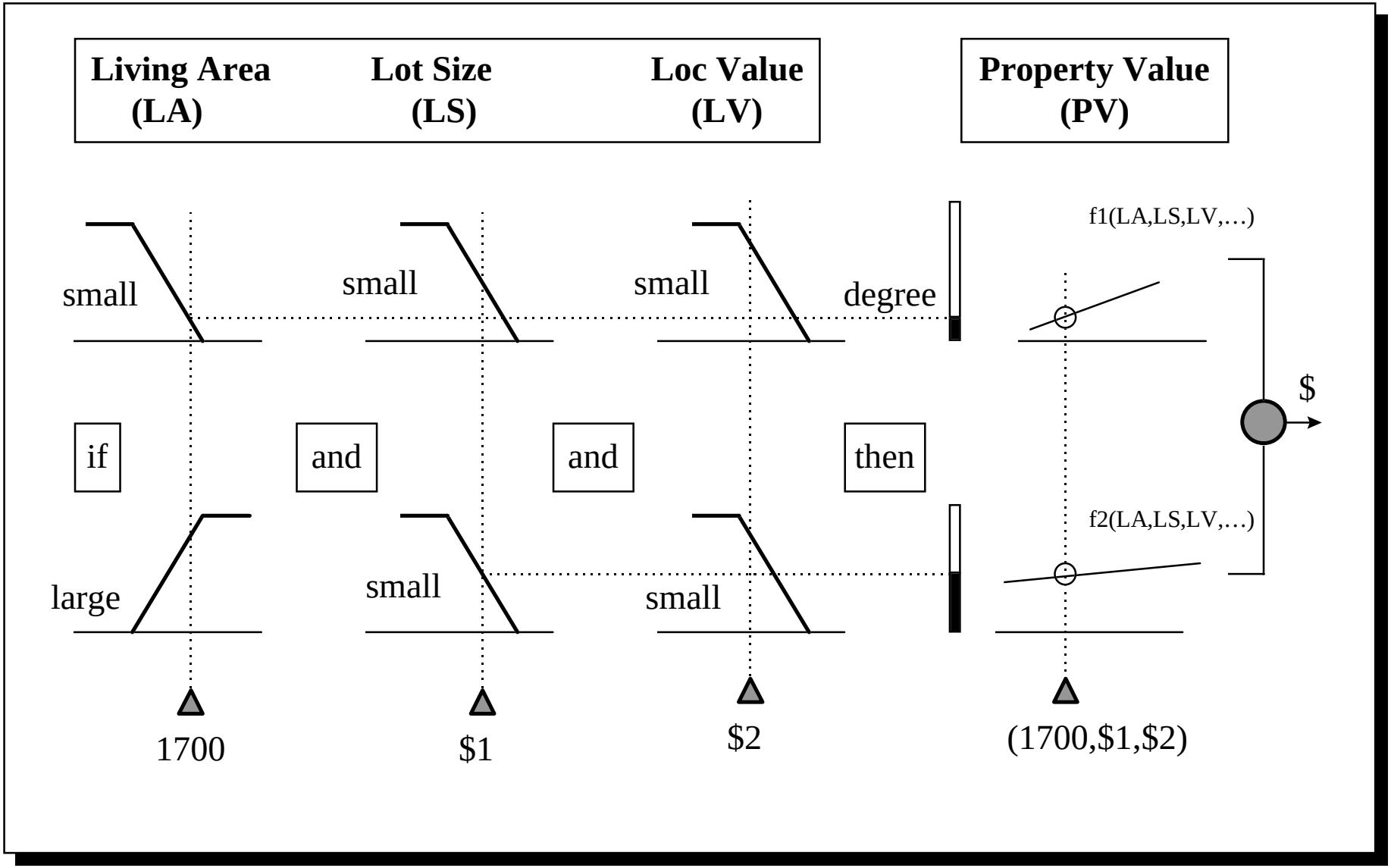
# Locational Value Estimator



# Generative Estimator (AIGEN)



# Generative Estimator (AIGEN) - cont.



# Comparable-based Approach (AICOMP)

- AICOMP is  a Comparable-based Approach built with Fuzzy CBR technology

- AICOMP Description
  - Process Flow
  - Preference Criteria & Similarity Measures
  - Comparable Adjustments
  - Comparable Filtering
  - Comparable Final Selection and Aggregation

# PROFIT Overview

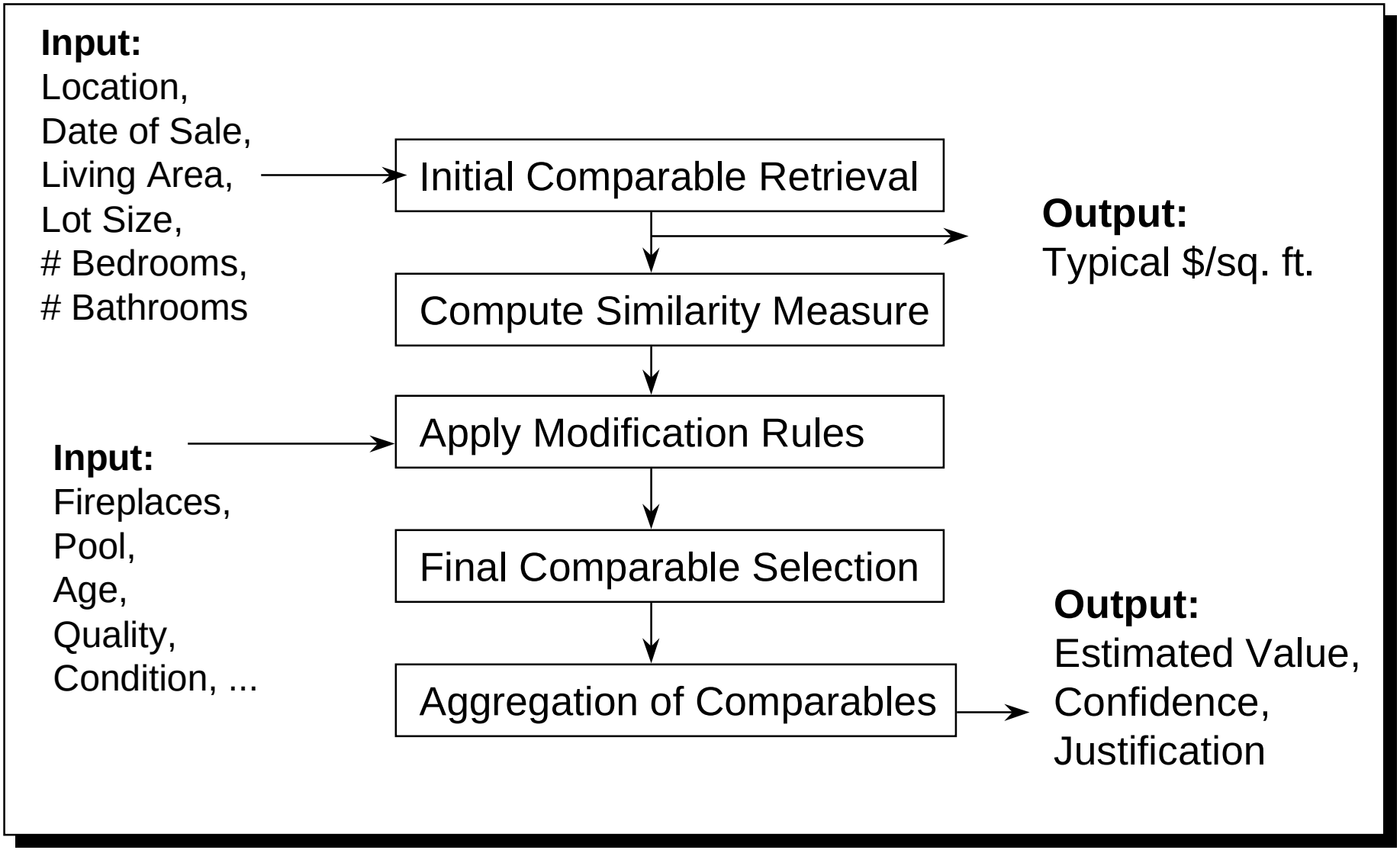
The PROperty Financial Information Technology (PROFIT) system uses:
- case-based reasoning techniques with
- fuzzy predicates and fuzzy-logic based similarity measures

The case-base consisted of over 250,000 properties that had sold in California during the last five years.

Each case consisted of up to 166 property attributes

| **Attribute** | **Value** |
|---|---|
| Sale Price | $185,000 |
| Address | 2 Bronco Ln. |
| Living Area | 2000 sq. ft |
| Bedrooms | 3 |
| Bathrooms | 2.5 |
| etc. | etc. |

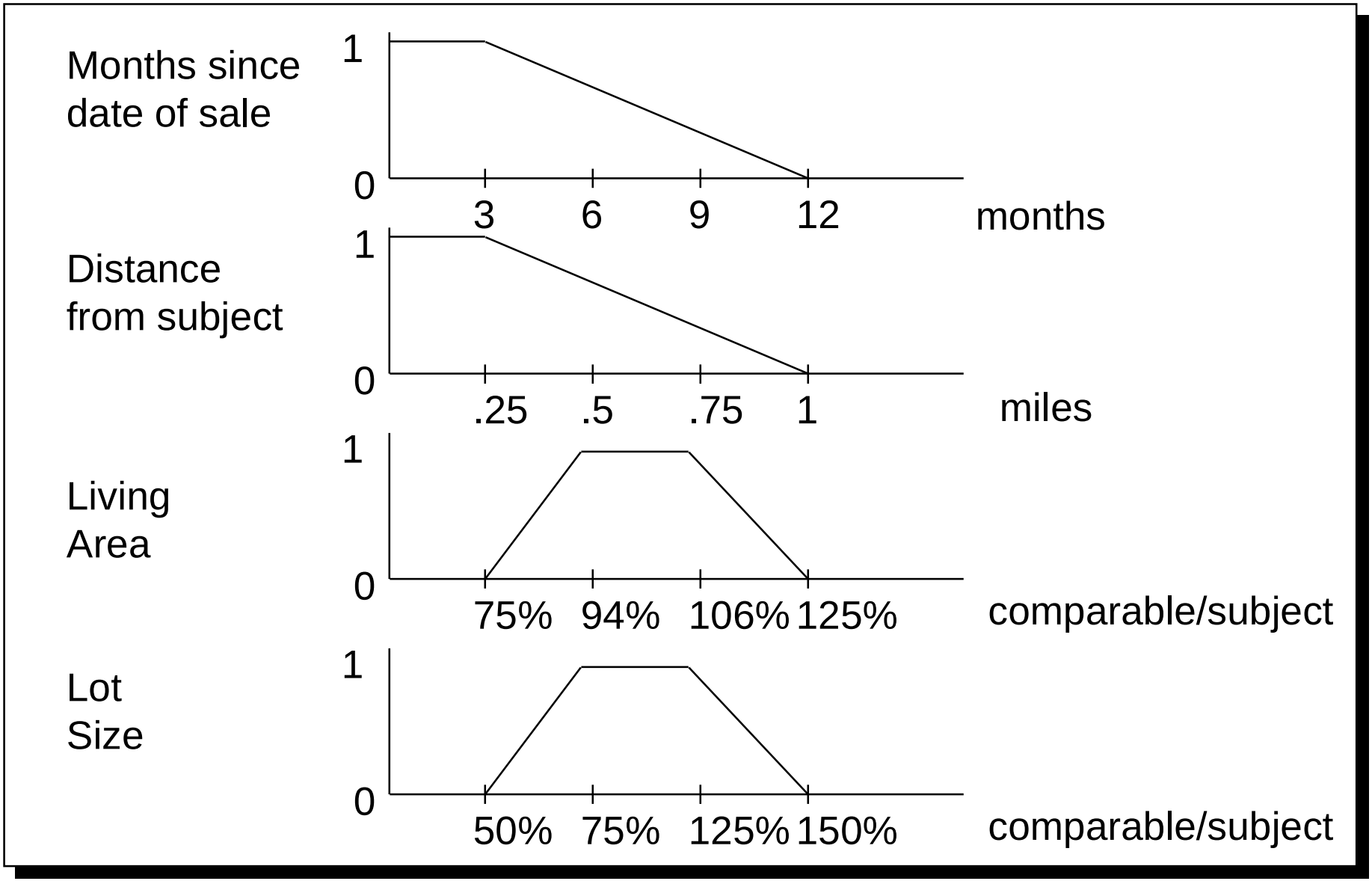
# AICOMP Process Flow



# Initial Case Retrieval

- Initial retrieval is  done by a standard SQL query against a DB.
- The query uses the following attributes & their corresponding maximum allowable deviations
  - Date of sale (within 12 months)
  - Distance (within 1 mile)
  - Living area (+ / - 25%)
  - Lot size (+ 100% / - 50%)
  - Number of bedrooms (+/- 3)
  - Number of bathrooms (+/- 3)
- Retrieved cases are ranked according to (fuzzy membership) preference functions

# Preference Functions



# Asymmetric Preference Functions

| Subject | Comparable | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5+ |
| 1 | 1.00 | 0.75 | 0.20 | 0.05 | 0.01 | **0.00** | **0.00** | **0.00** | **0.00** |
| 1.5 | 0.60 | 1.00 | 0.60 | 0.25 | 0.10 | 0.05 | **0.00** | **0.00** | **0.00** |
| 2 | 0.10 | 0.70 | 1.00 | 0.70 | 0.25 | 0.05 | **0.00** | **0.00** | **0.00** |
| 2.5 | 0.05 | 0.20 | 0.75 | 1.00 | 0.75 | 0.20 | 0.05 | **0.00** | **0.00** |
| 3 | 0.01 | 0.10 | 0.40 | 0.80 | 1.00 | 0.80 | 0.40 | 0.10 | 0.05 |
| 3.5 | **0.00** | 0.05 | 0.15 | 0.45 | 0.85 | 1.00 | 0.85 | 0.45 | 0.30 |
| 4 | **0.00** | **0.00** | 0.05 | 0.20 | 0.50 | 0.90 | 1.00 | 0.90 | 0.70 |
| 4.5 | **0.00** | **0.00** | **0.00** | 0.10 | 0.30 | 0.70 | 0.95 | 1.00 | 0.95 |
| 5+ | **0.00** | **0.00** | **0.00** | 0.05 | 0.15 | 0.35 | 0.75 | 0.95 | 1.00 |

**Example:**

Subject Bathrooms = 2

Comparable Bathrooms = 2.5

Preference = 0.7

# Preference Function for Number of Bedrooms

| Comparable's # Bedrooms | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| | 1 | 1.00 | 0.50 | 0.05 | 0.00 | 0.00 |
| Subject's | 2 | 0.20 | 1.00 | 0.50 | 0.05 | 0.00 |
| # Bedrooms | 3 | 0.05 | 0.30 | 1.00 | 0.60 | 0.05 |
| | 4 | 0.00 | 0.05 | 0.50 | 1.00 | 0.60 |
| | 5 | 0.00 | 0.00 | 0.05 | 0.60 | 1.00 |
| | 6+ | 0.00 | 0.00 | 0.00 | 0.20 | 0.80 |

**Example:**

Subject Bedrooms = 5

Comparable Bedrooms = 4

Preference = 0.6

# Similarity Measure Computation

- Preference Weighting and Aggregation
  - Weights obtained using Saaty's pairwise comparison method
  - The subject property is compared against each comparable along the six variables used in the initial retrieval
  - The preference functions are used to evaluate each variable
  - The similarity measure is the weighted sum of the the preferences

# Similarity Measurement Computation

| Attribute | Subject | Comparable | Comparison | Preference | Weight | Weighted Preferenc |
|---|---|---|---|---|---|---|
| Months since date of s | X | 6 months | 6 months | 0.67 | 0.222 | 0.1489 |
| Distance | X | 0.2 miles | 0.2 miles | 1.00 | 0.222 | 0.2222 |
| Living Area | 2000 | 1800 | 90% | 0.79 | 0.333 | 0.2633 |
| Lot Size | 20000 | 35000 | 175% | 0.33 | 0.111 | 0.0367 |
| # Bedroom | 3 | 3 | 0% | 1.00 | 0.056 | 0.0556 |
| # Bathrooms | 2.5 | 2 | 2.5 -> 2 | 0.75 | 0.056 | 0.0417 |
| **Similarity Measure (Sum of Weighted Preference/Sum of Weights) =** | | | | | | **0.768333** |

# Adjustment Rules

| | |
|---|---|
| **Living Area** | (subject - comp) * (22 + (Sales_Price_of_comp * .00003)) |
| **Lot Area** | (subject - comp) * 1 |
| **Fireplaces** | (subject - comp) * 2000 |
| **Effective Year Built** | |
| | w * (Age_comp-Age_subject) * (Sale_Price_comp/1000)<br>if (Age_subject + Age_comp) / 2 < 4 then w = 4 else<br>if (Age_subject + Age_comp) / 2 < 6 then w = 3 else<br>if (Age_subject + Age_comp) / 2 < 8 then w = 2 else<br>if (Age_subject + Age_comp) / 2 < 15 then w = 1 else<br>w = .5<br>max of 10% of salePrice |
| **Quality** | (.02 * sale price) for each level of difference:<br>(Luxury > Excellent > Good> Average > Fair > Poor) |
| **Pool** | $10000 for a pool |

# Adjustment Table for Bathrooms

| Subject | Comp | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5+ |
| 1 | **0.00** | *-1.50* | -3.00 | *-5.00* | *-8.00* | N/A | N/A | N/A | N/A |
| 1.5 | 1.00 | **0.00** | -1.00 | *-3.50* | *-6.00* | *-9.00* | N/A | N/A | N/A |
| 2 | *4.00* | *1.50* | **0.00** | -2.25 | *-4.00* | *-6.50* | N/A | N/A | N/A |
| 2.5 | *7.00* | *4.50* | 2.00 | **0.00** | -2.00 | *-4.50* | *-7.00* | N/A | N/A |
| 3 | *9.00* | *6.50* | 3.00 | 2.00 | **0.00** | -2.50 | -5.00 | *-7.50* | '@*-5 |
| 3.5 | N/A | *8.50* | *6.50* | *4.50* | *2.50* | **0.00** | *-3.00* | *-5.50* | '@*-5 |
| 4 | N/A | N/A | *8.50* | *7.00* | *5.50* | *3.00* | **0.00** | *-3.00* | '@*-5 |
| 4.5 | N/A | N/A | N/A | *10.00* | *8.00* | *6.00* | *3.00* | **0.00** | '@*-5 |
| 5+ | N/A | N/A | N/A | '@*5 | '@*5 | '@*5 | '@*5 | '@*5 | **0.00** |

# Adjustment Example

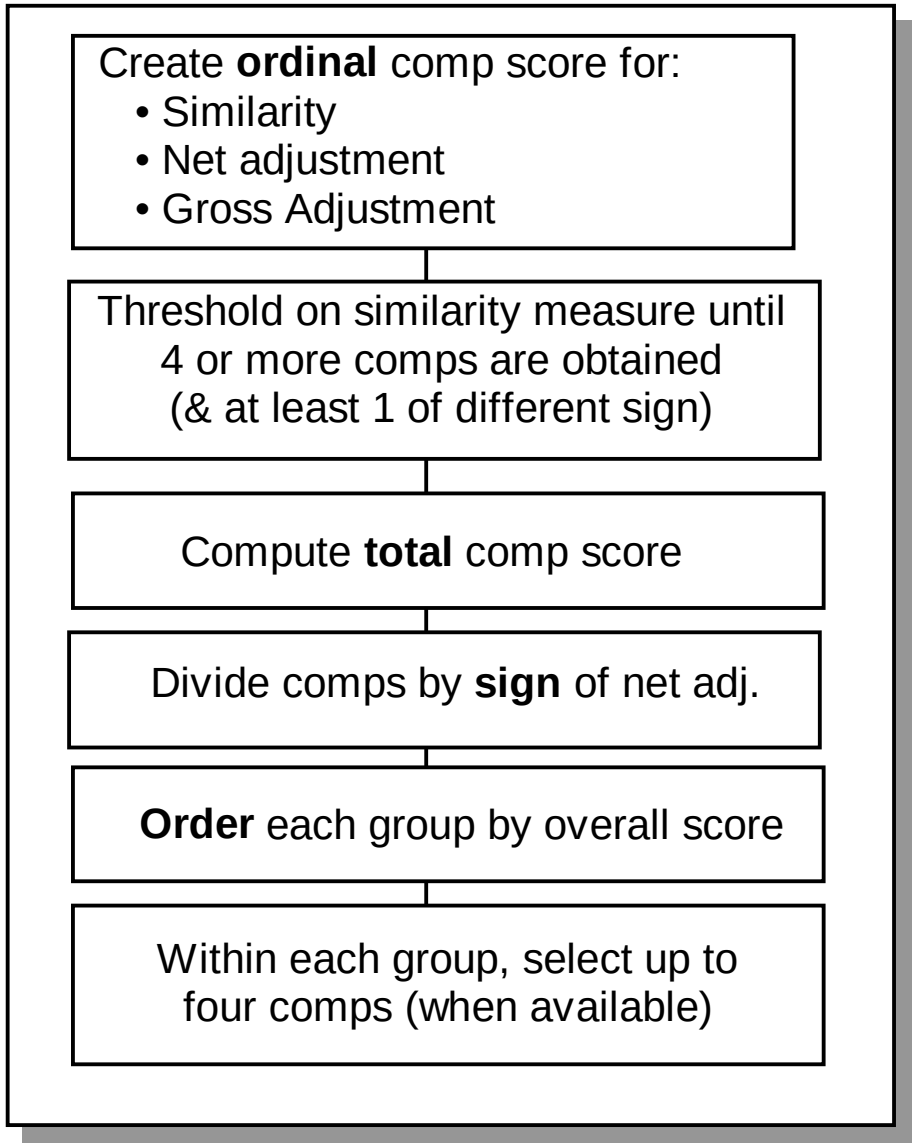
| Attribute | Subject | Comparable | Adjustment |
|---|---|---|---|
| SalePrice | ? | 175000 | 175000 |
| LivingArea | 2000 | 1800 | 5450 |
| LotArea | 20000 | 25000 | -5000 |
| TotalBaths | 2.5 | 2 | 2000 |
| Bedrooms | 3 | 3 | |
| Fireplaces | 1 | 0 | 2000 |
| EffYearBuilt | 93 | 89 | 2800 |
| Quality | Good | Average | 3500 |
| Condition | Average | Average | |
| Pool | Yes | No | 10000 |
| **Adjusted Price =** | | | **195750** |

# Comparable Filtering

**We would like the selected comparables to have the following properties:**

- No single adjustment should be larger (in absolute value) than 10% of sales price
- Net adjustment should not exceed 15% of sales price
- Gross adjustment should not exceed 25% of sales price
- The unit price for living area of the comparables should not vary more than 15% from each other and should bracket that of the subject
- Comparables should be as close as possible to the subject
- The value estimated for the subject should be bracketed by the sales price of the comparables

# Comparable Selection



# Example of Comparable Ranking

| Comparable | Score Value | Score Rank | Net Adjust Value | N. A. Rank | Gross Adjust Value | G. A. Rank | Total Rank |
|---|---|---|---|---|---|---|---|
| 113-012 | 0.95 | 1 | 1344 | 2 | 5924 | 4 | 7 |
| 306-018 | 0.88 | 2 | 3586 | 5 | 4186 | 1 | 8 |
| 093-011 | 0.78 | 3 | 5686 | 7 | 8191 | 7 | 17 |
| 305-006 | 0.67 | 4 | 6150 | 8 | 6160 | 6 | 18 |
| 685-046 | 0.64 | 5 | 3139 | 3 | 6099 | 5 | 13 |
| 847-984 | 0.58 | 6 | -948 | 1 | 5670 | 3 | 10 |
| 873-005 | 0.53 | 7 | -5261 | 6 | 9261 | 8 | 21 |
| 431-023 | 0.48 | 8 | 3546 | 4 | 4410 | 2 | 14 |
| 331-018 | 0.44 | 9 | 9310 | 9 | 11300 | 9 | 27 |

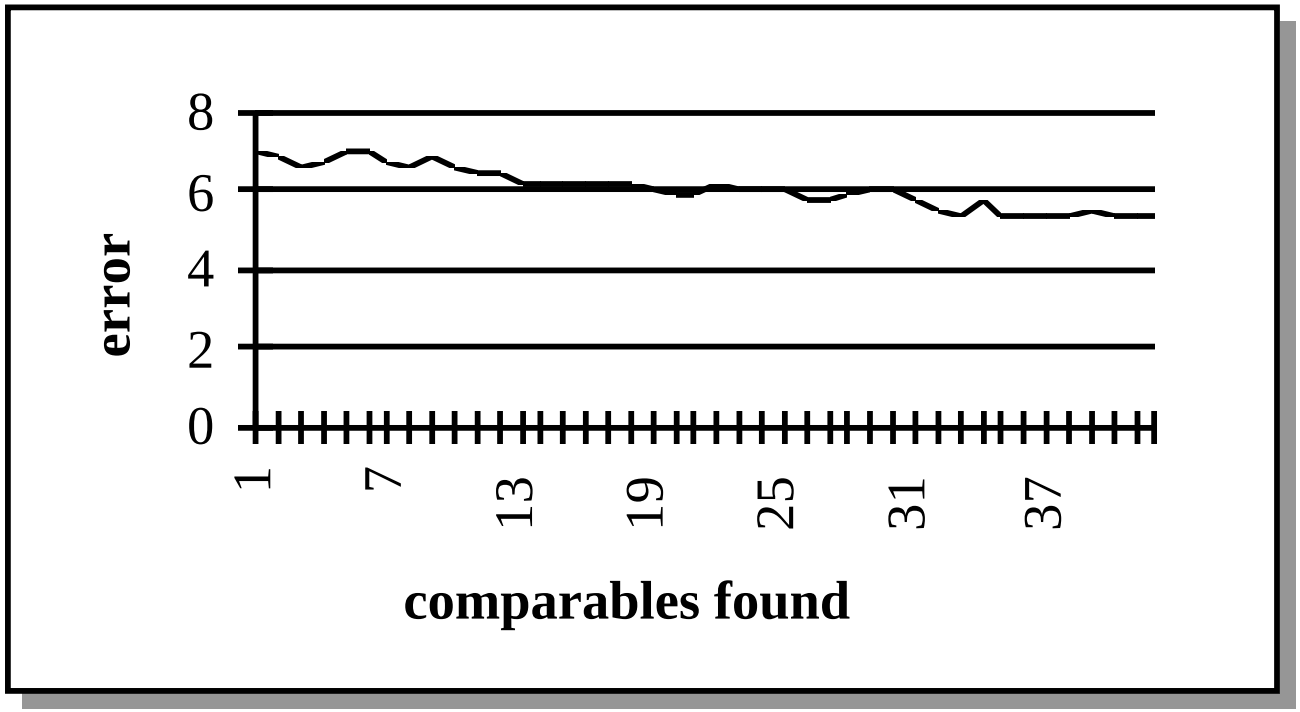
# Example of Final Aggregation

| Comparable | Adjusted Price | Score | Weighted Price |
|---|---|---|---|
| 113-012 | 197000 | 0.95 | 187150 |
| 306-008 | 202000 | 0.88 | 177760 |
| 093-011 | 196500 | 0.78 | 153270 |
| 685-046 | 192000 | 0.64 | 122880 |
| 847-984 | 201000 | 0.58 | 116580 |
| Total | | 3.83 | 757640 |
| **Final estimate = 757640/ 3.83 =** | | | **199900** |

# Validation Stage

- **System tested on 7,293 properties from Contra Costa county in California, USA.**
- **For each property, we computed:**
  - the predicted sales price of each property & compared it with its actual sales price to derive the estimate's error.
  - the percentage error and its five confidence characteristics
- **With these new data, we:**
  - analyzed the conditional distributions of the estimate's error, given each of its five confidence characteristics
  - used C4.5 to create rules predicting the error from the estimator's characteristics
  - validated these rules via data visualization
  - manually transformed the rules into the membership functions for confidence assessment

# Example of P(error |# comps found)

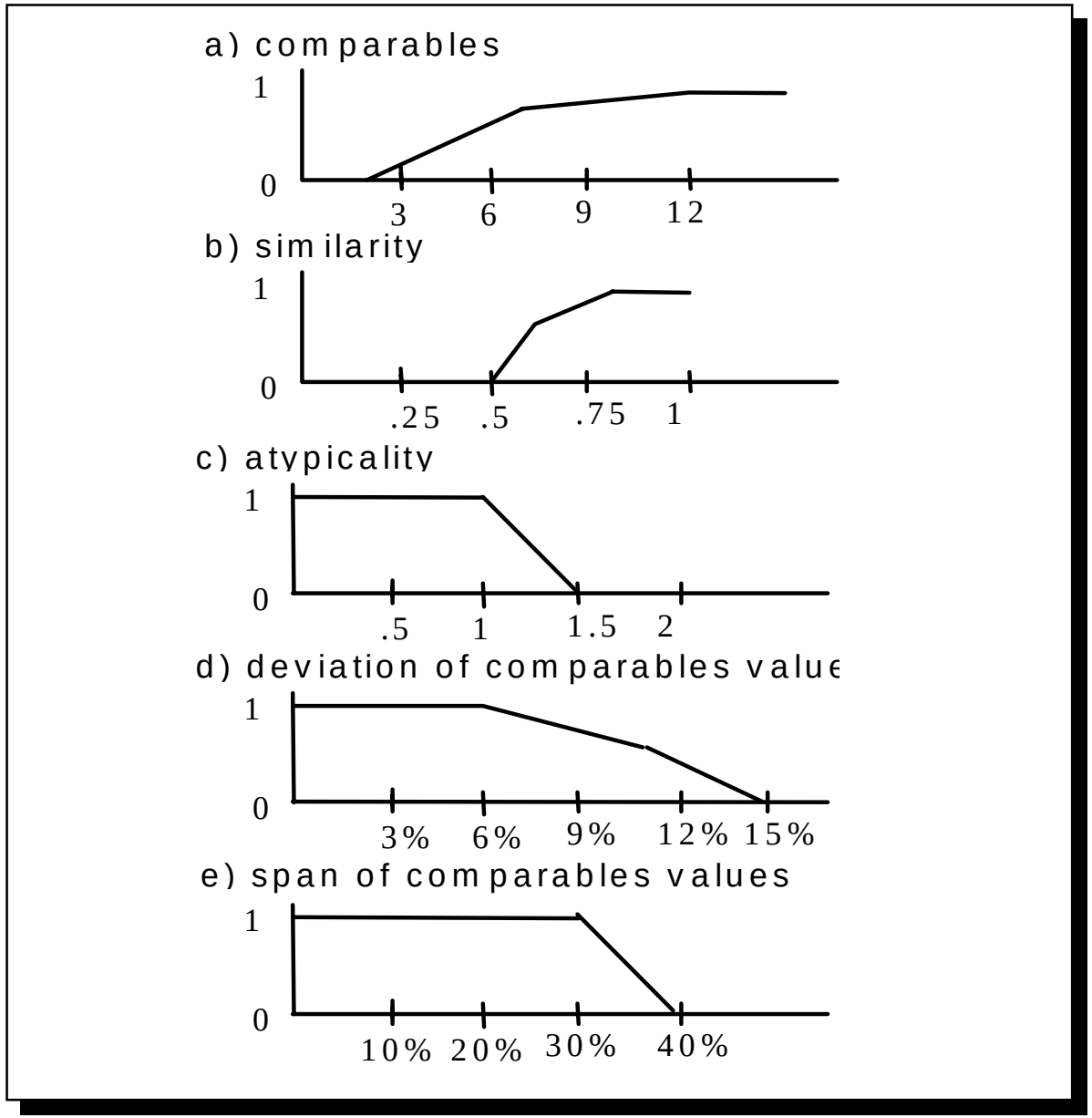



- For instance, the figure above shows that the estimate error (in percentage) decreases as the number of comparables found in the initial retrieval increases.
- Therefore, we can use this number as one of the filters to predict the expected error.

# Confidence Assessment

- The confidence value is obtained from the conjunctive evaluation of five soft constraints defined on the estimator's internal parameters:
- Number of cases found in the initial retrieval
  - Average of the similarity values for the best four cases
  - Typicality of problem with respect to the case-base (i.e. if the attributes of the subject fall within typical ranges for the subjects five digit zip code region)
  - Span of adjusted sales prices of highest confidence solutions
  - Distribution of adjusted sales prices of highest confidence solutions

# Membership Function for Confidence Assessment



# Random Sample of 10 of 7293 Validation Tests

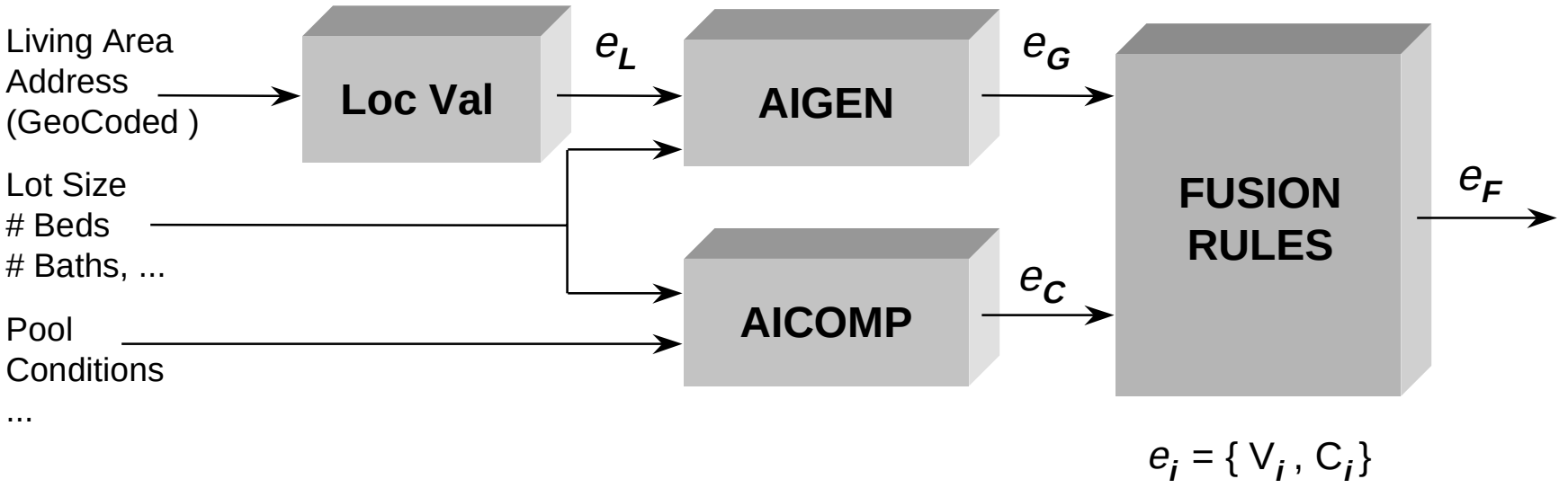
| Error | Comp Found | Simil. | Atyp. | Comp Dev. | Comp Span | Conf. Value | Verif. |
|---|---|---|---|---|---|---|---|
| -9.8 | 3 | 0.63 | 1.42 | 2.02 | 6.32 | **0.15** | ✓ |
| -2 | 35 | 0.94 | 0.38 | 2.24 | 8.57 | **1.00** | ✓ |
| 17.3 | 11 | 0.71 | 0.94 | 5.67 | 19 | **0.70** | |
| 0.5 | 24 | 0.85 | 0.66 | 2.05 | 7.24 | **1.00** | ✓ |
| -1.6 | 14 | 0.95 | 0.29 | 2.89 | 9.33 | **1.00** | ✓ |
| 5.2 | 15 | 0.90 | 0.73 | 3.24 | 12 | **1.00** | ✓ |
| 5.2 | 12 | 0.74 | 0.17 | 4.5 | 18 | **0.80** | ✓ |
| 3.1 | 19 | 0.74 | 0.81 | 2.83 | 8.11 | **0.80** | ✓ |
| -14 | 12 | 0.82 | 1.97 | 3.85 | 15 | **0.00** | ✓ |
| 7.8 | 11 | 0.77 | 1.34 | 4.24 | 13 | **0.32** | ✓ |

- Each row is a different property.
- Columns show the estimate's error, its five characteristics, and its confidence value (CV)
- CV is the conjunctive (minimum) evaluation of the membership functions used for confidence assessment

# Fusion of Reasoning Models

- **Develop Collection of Quasi-independent Models**
- **Each Model Generates:**
  - Output Value ($v_i$) - **Prediction**
  - Confidence parameter ($c_i$) derived from training stats**. - Introspection**
- **Intelligent Fusion Rules**
  - Consider discrepancies among Output values (v)
  - Consider dynamic confidence parameter (c) associated with each output

**Example of Fusion for Mortgage Collateral Evaluation**



# Fusion Rules

| HIGH Contention | | AIGEN Confidence Level | | |
|---|---|---|---|---|
| | | L | M | H |
| AICOMP Confidence Level | H | U | U | U |
| | M | U | U | U |
| | L | U | U | U |

| MEDIUM Contention | | AIGEN Confidence Level | | |
|---|---|---|---|---|
| | | L | M | H |
| AICOMP Confidence Level | H | I | I | I |
| | M | I | I | I |
| | L | U | I | I |

| LOW Contention | | AIGEN Confidence Level | | |
|---|---|---|---|---|
| | | L | M | H |
| AICOMP Confidence Level | H | I | E | E |
| | M | I | I | E |
| | L | U | I | I |

# Analysis of Results (cont.)

- The confidence value was subdivided into three groups (*good, fair, and poor* ) to identify the largest good set with the lowest error.
- Results of testing 7,293 properties:

| Label | Group Size [ % of Test size] | Median Absolute Relative Error |
|---|---|---|
| *Good (E)* | *63%* | *5.4%* |
| *Fair (I)* | *24%* | *7.7%* |
| *Poor (U)* | *13%* | *11.8%* |

# Conclusions

- Developed  a CBR system for residential property valuation, which generates an estimate and a confidence value
- The system uses Fuzzy Logic to translate current appraisers practices into:
  - Retrieval preference criteria
  - Similarity computation
  - Solution adaptation
  - Confidence value generation
- The confidence value determine the CBR estimate suitability for decision making.

# Conclusions (cont.)

- The system scalability was proven by thousands of transactions used in validation stage.
- The system can also be used to validate a property value provided by an external source.
  - The system identifies the best set of comparables to justify the given value and provides an associated confidence value.
- Possible Future work:
  - automatic case-base maintenance and update (determination of whether the selection or adaptation rules need to be changed, due to changing market conditions)
  - automatic generation of the new selection & adaptation rules.