A Network Clustering based Software Attribute Selection for Identifying Fault-Prone Modules

ICITCS 15’

Software fault prediction

How to measure the software quality?

- Static code analysis

How to detect the software fault?

- Poor design
- Structural problems

Complexity measures

Module-based software complexity measures

McCabe

- Graph-theoretic complexity
- The more complicated software → error-prone

Halstead

- Based on the number of operators and operands
- The software is harder to read or understand → error-prone

Complexity measures

Feature	Description
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design complexity	Design complexity (the number of paths which calls s omething in the control flow)
design density	Design density (design complexity divided by cyclom atic complexity)
normalized cyclomatic complexity	Normalized cyclomatic complexity
formal parameters	The number of formal parameters

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Need to select some highly correlated features with the software defect

&

Remove some redundant features

Dataset

PROMISE Software Engineering Repository data set

- SoftLab data - a Turkish white-goods manufacturer Embedded software implemented in C
- Measured by McCabe & Halstead metrics

- 428 modules(observation), 29 features(predictor)
- Binary response - defective(1) / defect-free(0)

Feature network

To measure the correlation between features

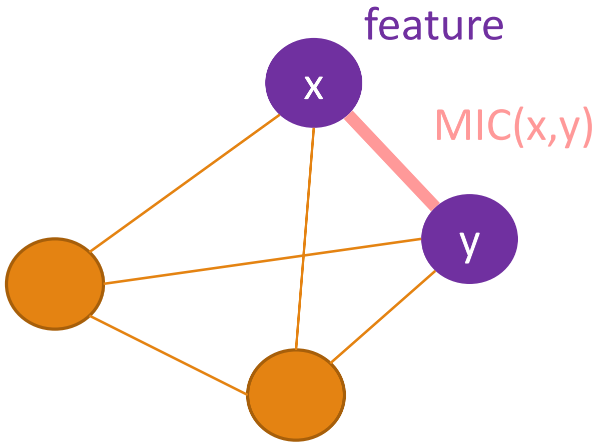
MIC(Maximal Information Coefficient) feature network construction

- A measure of the strength of the linear or non-linear association between two variables *X* and *Y*
- Binning scheme - apply mutual information on continuous random variables
- Mutual information between x and y

$$I(x, y) = H(x) + H(y) - H(x, y)$$

- Try all the possible binnings and pick the maximum

$$MIC(x, y) = max\left(\frac{I(x, y)}{log_2 min(n_x, n_y)}\right)$$



Feature selection

F-score(Fisher score) based feature selection

- Fisher score of i-th feature

$$F(i) = \frac{\left(\overline{x_i}^{(+)} - \overline{x_i}\right)^2 + \left(\overline{x_i}^{(-)} - \overline{x_i}\right)^2}{\frac{1}{n_+ - 1}\sum_{k=1}^{n_+}\left(x_{k,i}^{(+)} - \overline{x_i}^{(+)}\right)^2 + \frac{1}{n_- - 1}\sum_{k=1}^{n_-}\left(x_{k,i}^{(-)} - \overline{x_i}^{(-)}\right)^2}$$

n_+ , n_- : the positive and negative instances, $\overline{x_i}, \overline{x_i}^{(+)}, \overline{x_i}^{(-)}$: the average of the *i*-th feature of the whole, positive, and negative data sets, $x_{k,i}^{(+)}$, $x_{k,i}^{(-)}$: the *i*-th feature of the *k*-th positive/negative instance.

- Measures the discrimination of the feature
- Automatically finds the feature subset with high discrimination
- Don’t reveal the mutual information between features

Feature selection

k-means clustering

- Given the p-by-n data matrix (p predictors, n modules),
- Select k mutually exclusive clusters from p predictors
- The standard k-means algorithm, Lloyd’s algorithm &
  k-means++ algorithm for the centroid initialization

Feature selection

Spectral clustering

- Standard graph cut algorithm
- Uses the spectrum(eigenvalues) of the graph for dimensionality reduction before clustering
- The normalized cuts algorithm
- The affinity matrix

$$W = e^{\left(-\frac{G}{2*\sigma^2}\right)}$$

σ: scaling parameter

- The graph is clustered using eigenvectors with the second smallest eigenvalue solving the symmetric normalized laplacian matrix

$$D^{-\frac{1}{2}}(D - W)D^{-\frac{1}{2}}x = \lambda x$$

x: eigenvectors, λ: eigenvalue

Feature selection

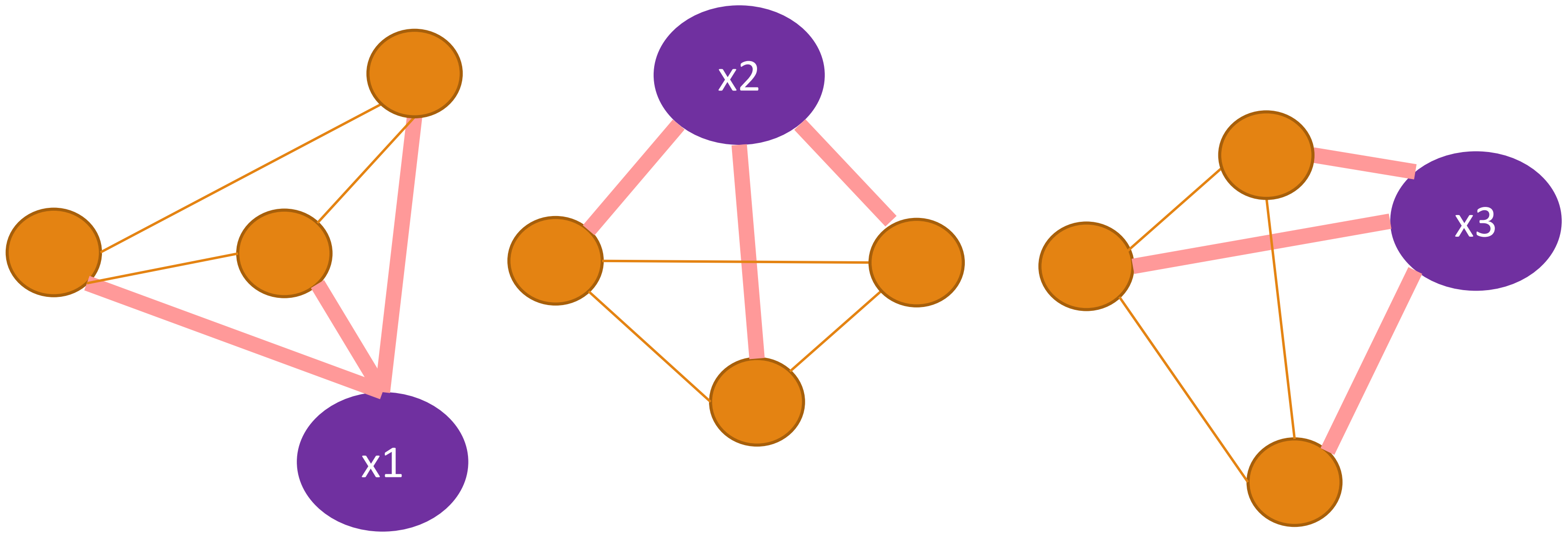
Hierarchical clustering

- Construct clusters from the agglomerative hierarchical cluster tree
- To encode the hierarchical cluster tree, linkage methods are used
  - average = centroid = weighted average > Ward's method
- *k* clusters are obtained by cutting off the hierarchical tree at the smallest height

Feature selection

Given network or data matrix,

- Cluster into 3 feature groups,
- Select 3 features which have the highest value of averaged edge weights within each cluster



Fault classification

SVM classification

- The prediction model is trained with the selected features
- Kernel : linear > polynomial, RBF, sigmoid

Defect prediction on validation set

- Perform 5-fold cross validation
  - determine optimal parameter, avoid over-fitting to the training data
- 80% (≈ 342) for training, 20% (≈ 85) for test
- Evaluate the performance with the averaged 5-fold cross validation accuracy

Results

Averaged 5-fold cross validation accuracy comparison

Method	Cross Validation Accuracy
Whole	78.27%
FFS	86.21%
K-means	85.75%
Spectral	87.85%
Hierarchical	86.68%

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F-score based feature selection

K-means clustering

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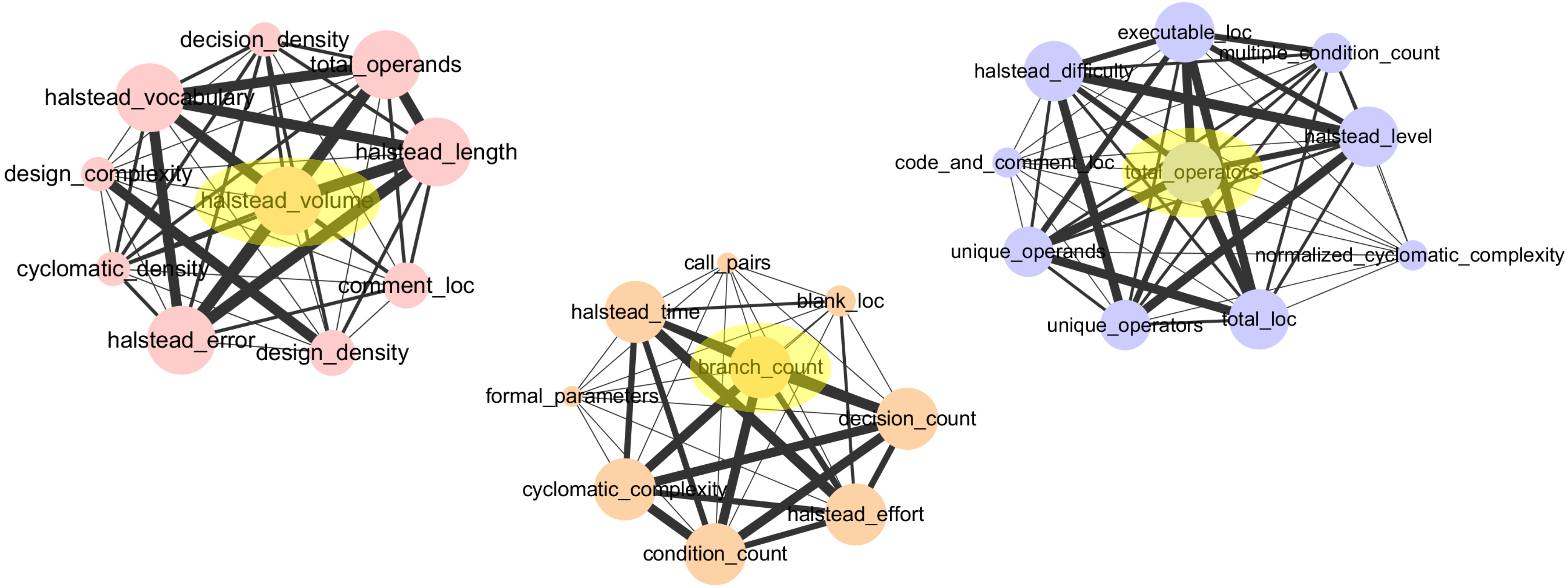
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total_operands
halstead_vocabulary
halstead_length
design_complexity
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cyclomatic_density
comment_loc
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executable_loc
multiple_condition_count
halstead_difficulty
halstead_level
code_and_comment_loc
total_operators
unique_operands
normalized_cyclomatic_complexity
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halstead_effort
condition_count

Thanks !

Q & A