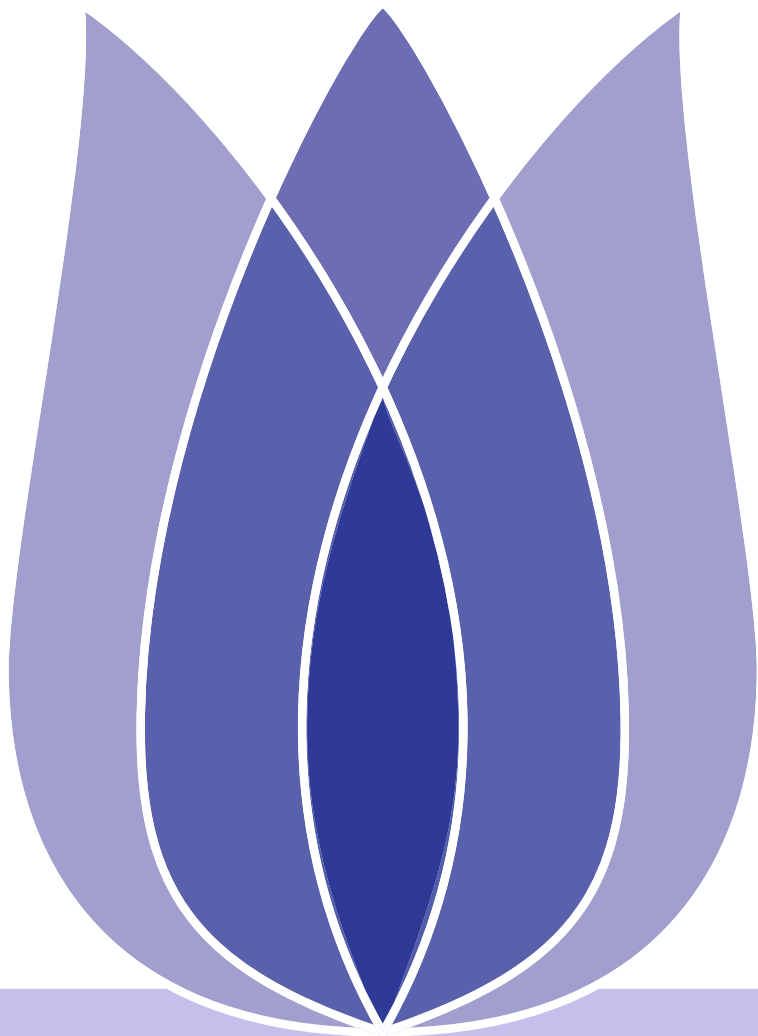


Group Outlying Aspects Mining

Shaoni Wang, Haiyang Xia, Gang Li, Jianlong Tan

Xi'an Shiyou University
Deakin University
Chinese Academy of Sciences

2023-10-22





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Problem Definition



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Defn

Outlying Aspects Mining aims to identify the outstanding features of the query object.

- A teacher may be interested in the **characteristics** that make **one student distinctive** from others.
- NBA coaches would prefer to find out the strengths and weaknesses of the player (a query object).

Player	3PT%	FTA	FT%	To
P_1	65	4	33	8
P_2	78	1	65	5
P_3	58	6	46	3
P_4	68	1.2	85	6.2
P_5	58	6.2	36	3.4



Outlying Aspects Mining vs Outlier Detection

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Player	3PT%	FTA	FT%	To
P_1	65	4	33	8
P_2	78	1	65	5
P_3	58	6	46	3
P_4	68	1.2	85	6.2
P_5	58	6.2	36	3.4

Outlying Aspects Mining

- Explain the distinctive **aspects** of the query object.
- The query object may (or may not) be an outlier.

Outlier Detection

- Find out **all** unusual **objects** in the whole dataset.
- **No** explanation on how they are different.



Group Outlying Aspects Mining

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- Group Outlying Aspects Mining
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- Conclusion

Defn

Group outlying aspects mining aims to identify the outstanding features of the group of query object.

- Doctors desire to identify the merits & demerits between a group of cancer patients and normal people.
- NBA coaches are passionate about exploring the obvious advantages & disadvantages of the team.



Figure 1: Medical



Figure 2: NBA-Team



Problem Formalization

Problem Definition
Outlying Aspects Mining
Group Outlying Aspects Mining
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Defn

Group outlying aspects mining aims to identify the top-k group outlying subspace $s \subseteq F$ in which the query group G_q is distinctive with other groups.

- $G = \{G_q, G_2, G_3, \dots, G_n\} \Leftrightarrow$ a set of groups.
- $G_q \Leftrightarrow$ the query group.
- Other groups \Leftrightarrow comparison groups.
- Each object in the group has d features $F = \{f_1, f_2, \dots, f_d\}$.



Term Definition

Problem Definition
Outlying Aspects Mining
Group Outlying Aspects Mining
Related Work and Challenges
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- Top-k group outlying subspaces
 - ◆ $\rho_s(\cdot) \Rightarrow$ outlying scoring function.
 - ◆ $\rho_s(\cdot)$ quantifies the outlying degree of the query group G_q in the subspace s .
 - ◆ Order by DESC using scoring function $\rho(\cdot)$ to identify top K group outlying subspaces.



(a) Original Feature Spaces



(b) Group Outlying Spaces



(c) Another Subspaces





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- Trivial Outlying Features
 - ◆ One-dimension subspaces.
 - ◆ G_q 's outlying degree $\rho(\cdot) > \alpha$.

Table 1: $\alpha = 4$

Feature	Outlying Degree
$\{F_1\}$	4.351
$\{F_3, F_4\}$	4.024
$\{F_2, F_4\}$	2.318
$\{F_2\}$	2.002
$\{F_3\}$	1.028



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- Non-Trivial Outlying Subspaces
 - ◆ Multi-dimension subspaces.
 - ◆ G_q 's outlying degree $\rho(\cdot) > \alpha$.

Table 2: $\alpha = 4$

Feature	Outlying Degree
$\{F_1\}$	4.351
$\{F_3, F_4\}$	4.024
$\{F_2, F_4\}$	2.318
$\{F_2\}$	2.002
$\{F_3\}$	1.028



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Related Work and Challenges



Related Work - Outlying Aspects Mining

Problem Definition

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Related Work - Outlying Aspects Mining

Challenges (1)

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■ Existing Methods - Feature selection

- ◆ To distinguish two classes: the query point (positive) & rest of data (negative)

Disadvantages

- ◆ Positive and negative classes are **Not** balanced.
- ◆ **Not** quantify the outlying degree accurately.
- ◆ **Not** identify group outlying aspects.

Advantages

- ◆ Easy to operate.
- ◆ Resolve dimensionality bias.



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Related Work - Outlying Aspects Mining

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■ Existing Methods - Score-and-search

- ◆ Define an outlying score function.
- ◆ Search subspaces.

Disadvantages

- ◆ Dimensionality bias.
- ◆ Search efficiency is **Not** high (dataset is large).
- ◆ **Not** identify group outlying aspects.

Advantages

- ◆ Quantify the outlying degree correctly.
- ◆ High Comprehensibility.



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Group Outlying Aspects Mining

- Focus on differences between **groups**.
- **Multiple** points.

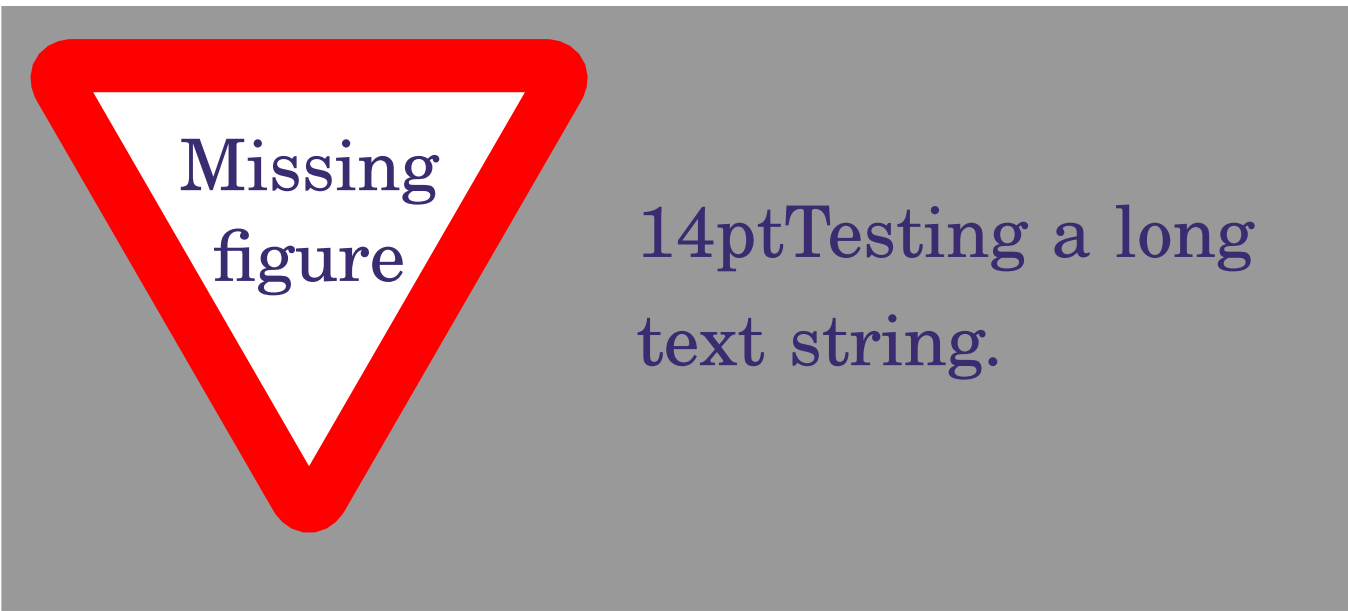


Figure 3: Group Outlying Aspects Target

Outlying Aspects Mining

- Concentrates on differences between **objects**.
- **One** point.

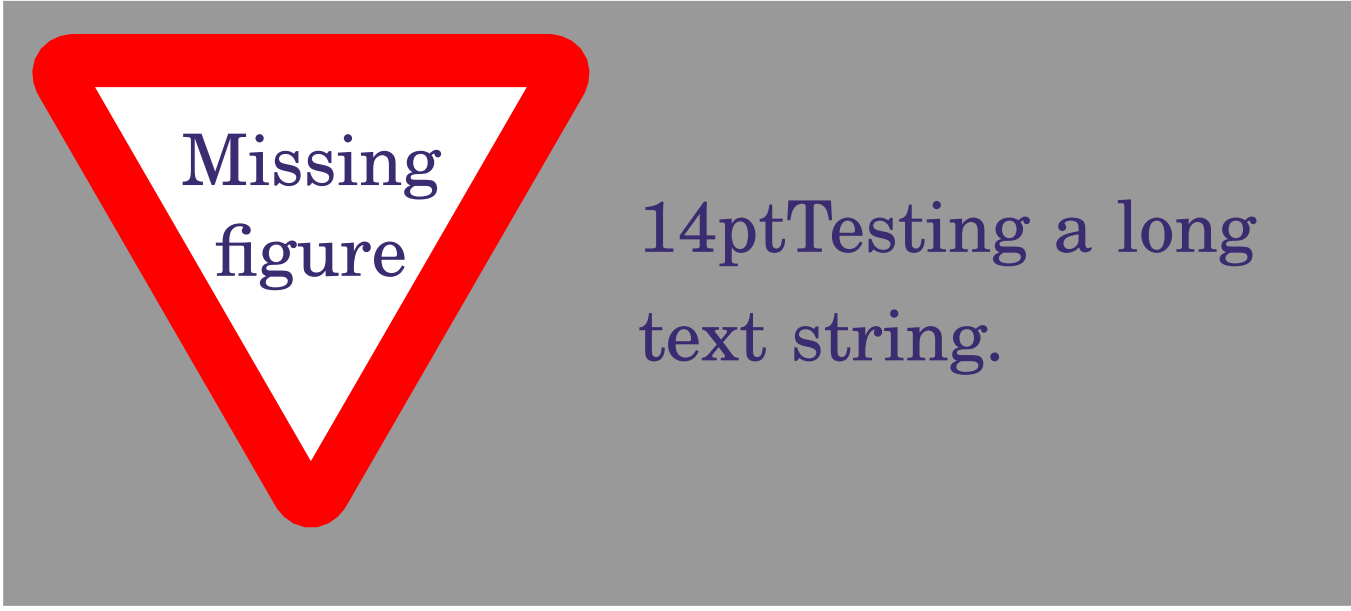


Figure 4: Outlying Aspects Target



Challenges (1)

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- How to **represent** the group features.
 - ◆ Can be affected by outlier values.
 - ◆ Can **Not** reflect the overall distribution of group features.



Challenges (2)

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- How to **evaluate** the outlying degree in different aspects.
 - ◆ Need design a scoring function when necessary.
 - ◆ Adopting an appropriate scoring function (without dimension bias) remains a problem.



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Challenges (3)

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- How to **improve** the efficiency.
 - ◆ When the dimension of the **data is high**, the candidate subspace grows exponentially.
 - ◆ It will easily go beyond the limits of the computation resources.



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GOAM Algorithm



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Framework of GOAM algorithm:

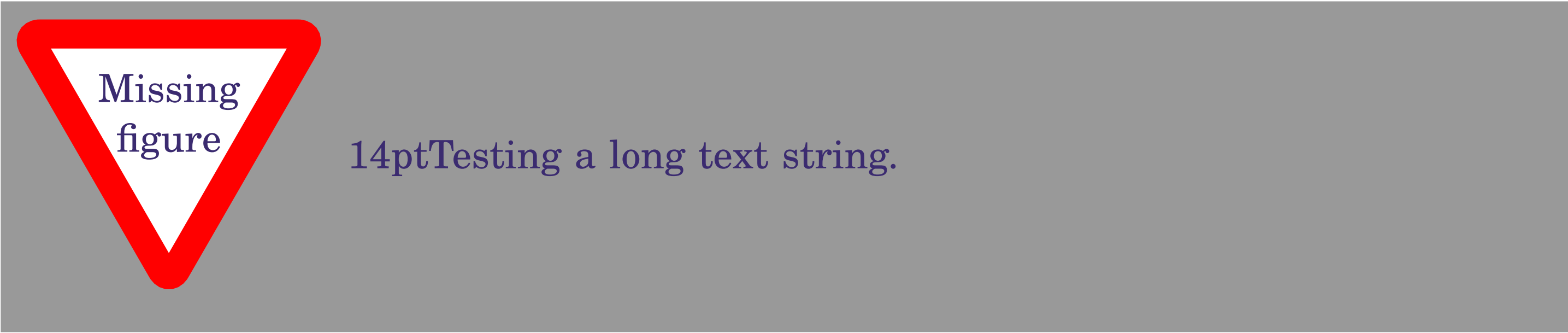


Figure 5: Framework of GOAM Algorithm



Step One - Group Feature Extraction

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■ Suppose f_1, f_2, f_3 are three features of G_q .

$$f_1: \{x_1, x_2, x_3, x_4, x_5, x_2, x_3, x_4, x_1, x_2\}$$

$$f_2: \{y_2, y_2, y_1, y_2, y_3, y_3, y_5, y_4, y_4, y_2\}$$

$$f_3: \{z_1, z_4, z_2, z_4, z_5, z_3, z_1, z_2, z_4, z_2\}$$

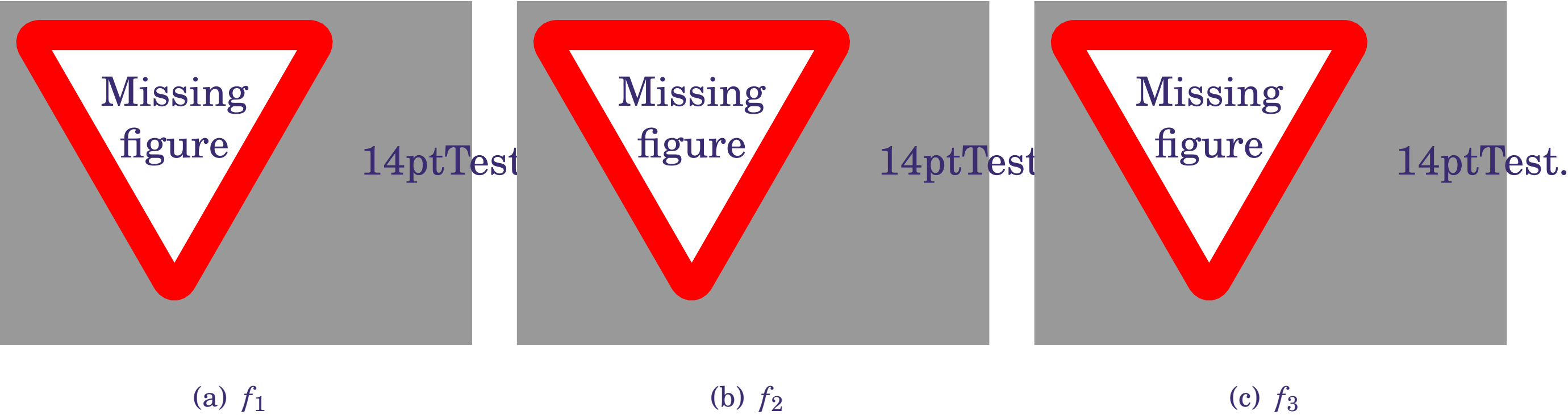


Figure 6: Histogram of G_q on three features



Step Two - Outlying Degree Scoring

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- Calculate Earth Mover Distance
 - ◆ Represent one feature among different groups
 - ◆ Purpose: calculate the minimum mean distance

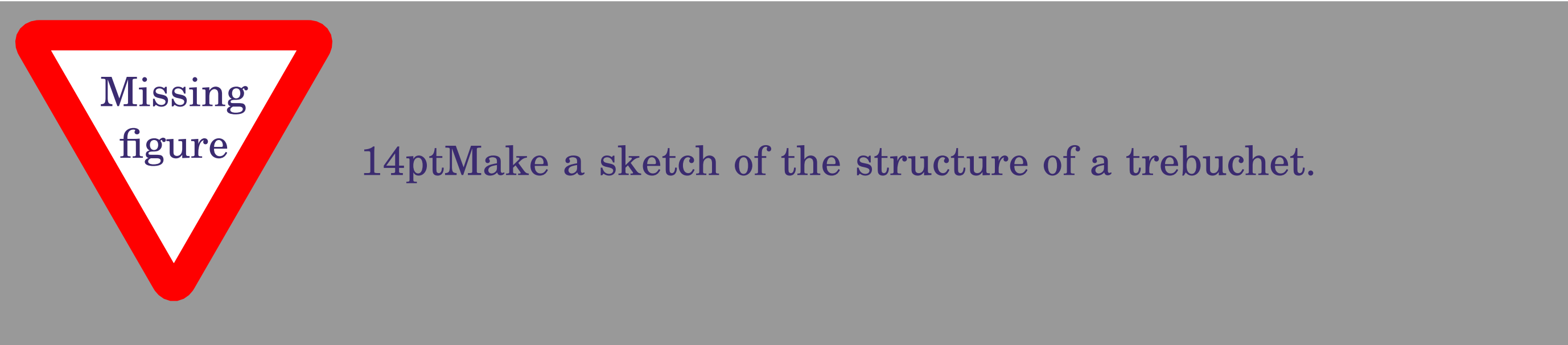


Figure 7: EMD of one feature



Step Two - Outlying Degree Scoring

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■ Calculate the outlying degree

$$OD(G_q) = \sum_1^n EDM(h_{q_s}, h_{k_s})$$

- ◆ $n \Leftrightarrow$ the number of contrast groups.
- ◆ $h_{k_s} \Leftrightarrow$ the histogram representation of G_k in the subspace s .





Step Three - Outlying Aspects Identification

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- Identify group outlying aspects mining based on the value of outlying degree.
- The greater the outlying degree is, the more likely it is group outlying aspect.



Pseudo code

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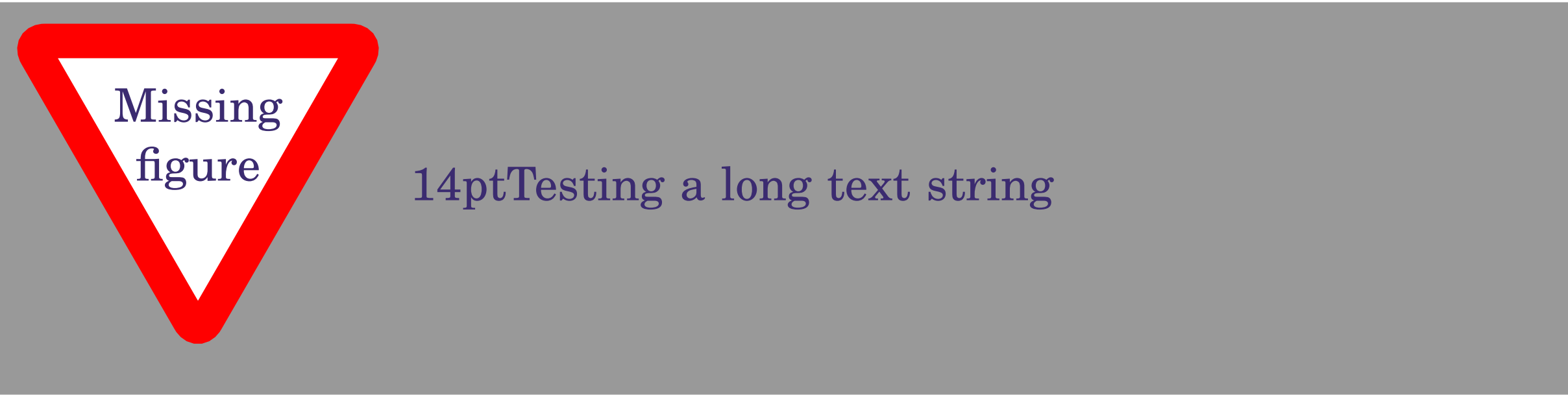
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■ Pseudo code of GOAM algorithm





Illustration

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Table 3: Original Dataset

G_1	F_1	F_2	F_3	F_4	G_2	F_1	F_2	F_3	F_4
	10	8	9	8		7	7	6	6
	9	9	7	9		8	9	9	8
	8	10	8	8		6	7	8	9
	8	8	6	7		7	7	7	8
	9	9	9	8		8	6	6	7
G_3	F_1	F_2	F_3	F_4	G_4	F_1	F_2	F_3	F_4
	8	10	8	8		9	8	8	8
	9	9	7	9		7	7	7	9
	10	9	10	7		8	6	6	8
	9	10	8	6		9	8	8	7
	9	9	7	9		8	7	9	8



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Table 4: outlying degree of each possible subspaces

Feature	Outlying Degree	Feature	Outlying Degree
$\{F_1\}$	4.351	$\{F_2, F_3\}$	4.023
$\{F_2\}$	2.012	$\{F_3, F_4\}$	4.324
$\{F_3\}$	1.392	$\{F_2, F_4\}$	2.018
$\{F_4\}$	2.207	$\{F_2, F_3, F_4\}$	2.012

■ Search process:

$OD(\{F_1\}) > \alpha$, save to T_1 .
 $OD(\{F_2\}) < \alpha$, save to C_1 .
 $OD(\{F_3\}) < \alpha$, save to C_2 .
 $OD(\{F_4\}) < \alpha$, save to C_3 .

$OD(\{F_2, F_3\}) > \alpha$, save to N_1 .
 $OD(\{F_3, F_4\}) > \alpha$, save to N_2 .
 $OD(\{F_2, F_4\}) < \alpha$, remove.
 $OD(\{F_2, F_3, F_4\}) < \alpha$, remove.



Strengths of GOAM Algorithm

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- **Reduction of Complexity**
 - ◆ Bottom-up search strategy.
 - ◆ Reduce the size of candidate subspaces.
- **Efficiency**
 - ◆ Before: $O(2^d)$
Now: $O(d * n^2)$





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- $Accuracy = \frac{P}{T}$
 - P: Identified outlying aspects
 - T: Real outlying aspects





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■ Synthetic Dataset and Ground Truth

Table 5: Synthetic Dataset and Ground Truth

Query group	\mathbf{F}_1	\mathbf{F}_2	F_3	\mathbf{F}_4	F_5	F_6	F_7	F_8
i_1	10	8	9	7	7	6	6	8
i_2	9	9	7	8	9	9	8	9
i_3	8	10	8	9	6	8	7	8
i_4	8	8	6	7	8	8	6	7
i_5	9	9	9	7	7	7	8	8
i_6	8	10	8	8	6	6	8	7
i_7	9	9	7	9	8	8	8	7
i_8	10	9	10	7	7	7	7	7
i_9	9	10	8	8	7	6	7	7
i_{10}	9	9	7	7	7	8	8	8



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Table 6: The experiment result on synthetic dataset

Method	Truth Outlying Aspects	Identified Aspects	Accuracy
GOAM	$\{F_1\}, \{F_2F_4\}$	$\{F_1\}, \{F_2F_4\}$	100%
Arithmetic Mean based OAM	$\{F_1\}, \{F_2F_4\}$	$\{F_4\}, \{F_2\}$	0%
Median based OAM	$\{F_1\}, \{F_2F_4\}$	$\{F_2\}, \{F_4\}$	0%



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Data Collection

Source

Yahoo Sports website (<http://sports.yahoo.com.cn/nba>)

Data

- Extract NBA teams’ data until March 30, 2018;
- 6 divisions;
- 12 features (eg: *Point Scored*).



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The detail features are as follows:

Table 7: Collected data of Brooklyn Nets Team

Pts	FGA	FG%	3FA	3PT%	FTA	FT%	Reb	Ass	To	Stl	Blk
18	12	42	2.00	50	7.00	100	0	4	3	0	0
15.7	14.07	41	5.45	32	3.05	75	3.98	5.1	2.98	0.69	0.36
14.5	11.1	47	0.82	26	4.87	78	6.82	2.4	1.74	0.92	0.66
13.5	10.8	42	5.37	37	3.38	77	6.66	2	1.38	0.83	0.42
12.7	10.59	39	5.36	33	3.37	82	3.24	6.6	1.56	0.89	0.31
12.6	10.93	40	6.94	37	1.70	84	4.27	1.5	1.06	0.61	0.44
12.2	10.39	44	3.42	35	2.70	72	3.79	4.1	2.15	1.12	0.32
10.6	7.85	49	4.51	41	1.35	83	3.34	1.6	1.15	0.45	0.24



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■ Data Preprocess

Table 8: The bins that used to discrete data of each feature

Labels	Pts	FGA	FG%	3FA	3PT%	FTA
low	[0,5]	[0,4]	[0,0.35]	[0,1.0]	[0,0.2]	[0,1.0]
medium	(5,10]	(4,7]	(0.35,0.45]	(1.0,2.5]	(0.2,0.3]	(1.0,1.5]
high	(10,15]	(7,10]	(0.45,0.5]	(2.5,3.5]	(0.3,0.35]	(1.5,2.5]
very high	(15,+∞]	(10,+∞]	(0.5,1]	(3.5,+∞]	(0.35,1]	(2.5,+∞]
Labels	FT%	Reb	Ass	To	Stl	Blk
low	[0,0.6]	[0,2.0]	[0,1.0]	[0,0.6]	[0,0.2]	[0,0.25]
medium	(0.6,0.65]	(2,5]	(1,2]	(0.6,0.9]	(0.2,0.5]	(0.25,0.5]
high	(0.65,0.75]	(5,6]	(2,4]	(0.9,1.7]	(0.6,0.75]	(0.5,0.7]
very high	(0.75,1]	(6,+∞]	(4,+∞]	(1.7,+∞]	(0.75,+∞]	(0.7,+∞]



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Table 9: The identified outlying aspects of groups

Teams	Trivial Outlying Aspects	NonTrivial Outlying Aspects
Cleveland Cavaliers	{3FA}	{FGA, FT%}, {FGA, FG%}
Orlando Magic	{Stl}	None
Milwaukee Bucks	{To}, {FTA}	{FGA, FTA}, {3FA, FTA}
Golden State Warriors	{FG%}	{FT%, Blk}, {FGA, 3PT%, FTA}
Utah Jazz	{Blk}	{3FA, 3PT%}
New Orleans Pelicans	{FT%}, {FTA}	{FTA, Stl}, {FTA, To}



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Conclusion

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- Formalize the problem of *Group Outlying Aspects Mining* by extending outlying aspects mining;
- Propose a novel method **GOAM algorithm** to solve the *Group Outlying Aspects Mining* problem;
- Utilize the pruning strategies to reduce time complexity.



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Contact Information

Associate Professor Gang Li
School of Information Technology
Deakin University, Australia



GANGLI@TULIP.ORG.AU



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