

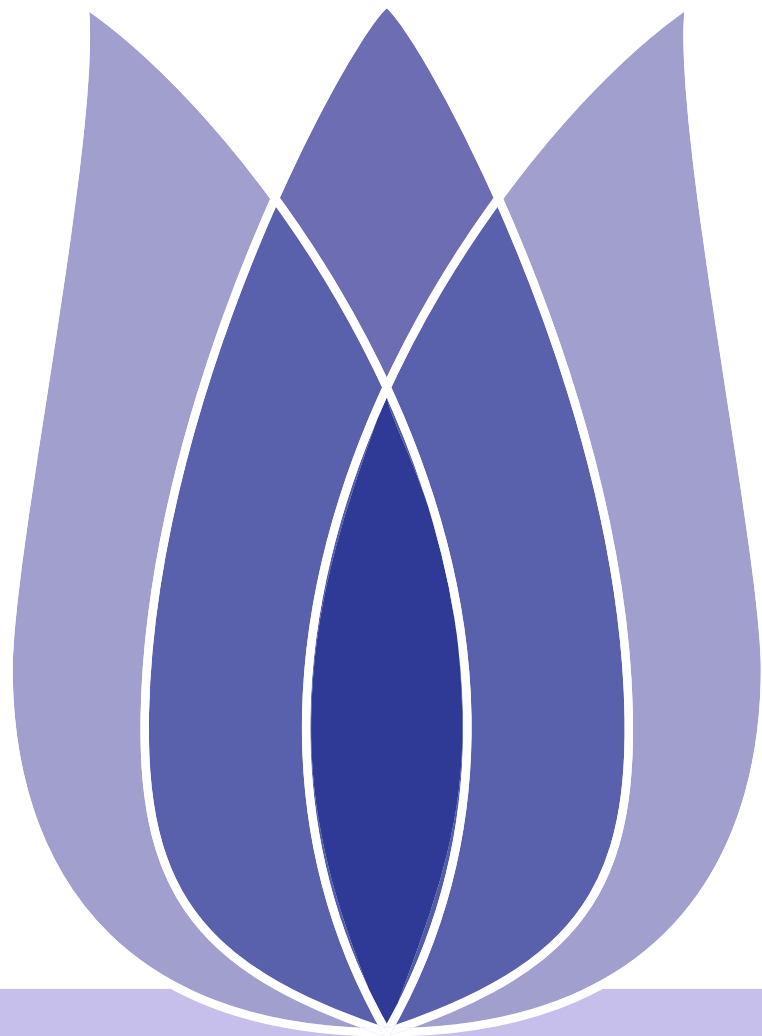


# Group Outlying Aspects Mining

Shaoni Wang, Haiyang Xia, Gang Li, Jianlong Tan

Xi'an Shiyou University  
Deakin University  
Chinese Academy of Sciences

(None)





# Overview

- [Problem Definition](#)
- [Related Work and Challenges](#)
- [GOAM Algorithm](#)
- [Evaluation Results](#)
- [Conclusion](#)

## Problem Definition

- Outlying Aspects Mining
- Group Outlying Aspects Mining

## Related Work and Challenges

- Related Work - Outlying Aspects Mining
- Challenges (1)

## GOAM Algorithm

- Step One - Group Feature Extraction
- Step Two - Outlying Degree Scoring
- Step Three - Outlying Aspects Identification

## Evaluation Results

- Synthetic Dataset
- NBA Dataset

## Conclusion



Problem Definition

Outlying Aspects Mining

Group Outlying Aspects Mining

Related Work and Challenges

GOAM Algorithm

Evaluation Results

Conclusion

# Problem Definition



- Problem Definition
- Outlying Aspects Mining
- Group Outlying Aspects Mining
- Related Work and Challenges
- GOAM Algorithm
- Evaluation Results
- Conclusion

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

- Problem Definition
- Outlying Aspects Mining
- Group Outlying Aspects Mining
- Related Work and Challenges
- GOAM Algorithm
- Evaluation Results
- Conclusion

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

- Problem Definition
- Outlying Aspects Mining
- Group Outlying Aspects Mining
- Related Work and Challenges
- GOAM Algorithm
- Evaluation Results
- 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
Related Work and Challenges
GOAM Algorithm
Evaluation Results
Conclusion

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
- GOAM Algorithm
- Evaluation Results
- Conclusion

## ■ 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





- Problem Definition
- Outlying Aspects Mining
- Group Outlying Aspects Mining
- Related Work and Challenges
- GOAM Algorithm
- Evaluation Results
- Conclusion

- 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



- Problem Definition
- Outlying Aspects Mining
- Group Outlying Aspects Mining
- Related Work and Challenges
- GOAM Algorithm
- Evaluation Results
- Conclusion

- 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



- [Problem Definition](#)
- [Related Work and Challenges](#)**
- [Related Work - Outlying Aspects Mining](#)
- [Challenges \(1\)](#)
- [GOAM Algorithm](#)
- [Evaluation Results](#)
- [Conclusion](#)

# Related Work and Challenges



# Related Work - Outlying Aspects Mining

[Problem Definition](#)

[Related Work and Challenges](#)

[Related Work - Outlying Aspects Mining](#)

[Challenges \(1\)](#)

[GOAM Algorithm](#)

[Evaluation Results](#)

[Conclusion](#)

## ■ 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.



**TULIP**

*Team for Universal Learning and Intelligent Processing*



# Related Work - Outlying Aspects Mining

Problem Definition

Related Work and Challenges

Related Work - Outlying Aspects Mining

Challenges (1)

GOAM Algorithm

Evaluation Results

Conclusion

## ■ 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.



**TULIP**

Team for Universal Learning and Intelligent Processing



- Problem Definition
- Related Work and Challenges
- Related Work - Outlying Aspects Mining
- Challenges (1)
- GOAM Algorithm
- Evaluation Results
- Conclusion

## Group Outlying Aspects Mining

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

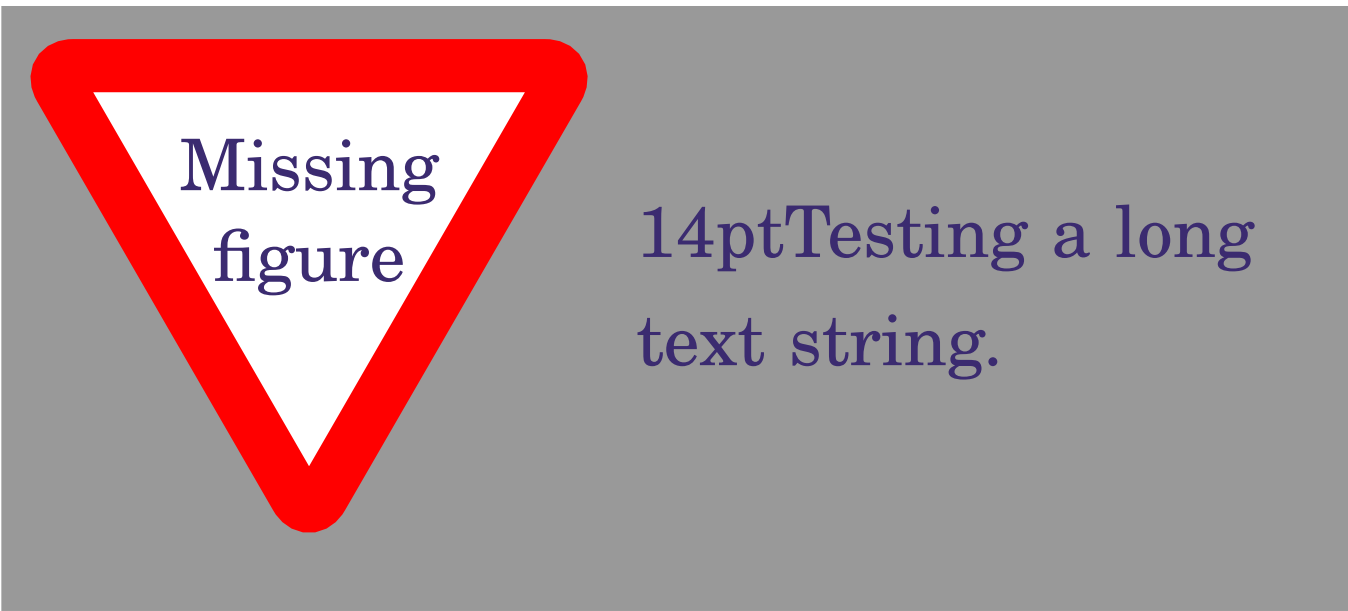


Figure 3: Group Outlying Aspects Target

## Outlying Aspects Mining

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

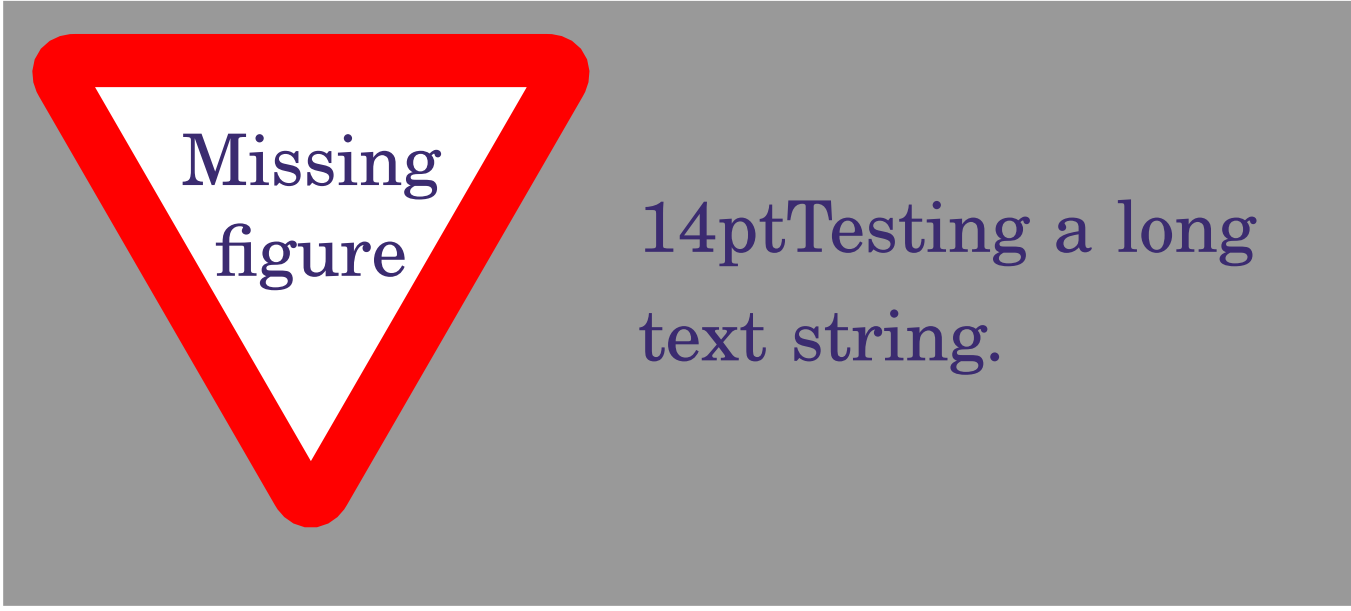


Figure 4: Outlying Aspects Target





# Challenges (1)

[Problem Definition](#)

[Related Work and Challenges](#)

[Related Work - Outlying Aspects](#)

[Mining](#)

[Challenges \(1\)](#)

[GOAM Algorithm](#)

[Evaluation Results](#)

[Conclusion](#)

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



**TULIP**

*Team for Universal Learning and Intelligent Processing*





## Challenges (2)

[Problem Definition](#)

[Related Work and Challenges](#)

[Related Work - Outlying Aspects](#)

[Mining](#)

[Challenges \(1\)](#)

[GOAM Algorithm](#)

[Evaluation Results](#)

[Conclusion](#)

- 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.



**TULIP**

*Team for Universal Learning and Intelligent Processing*



# Challenges (3)

<a href="#">Problem Definition</a>
<a href="#">Related Work and Challenges</a>
<a href="#">Related Work - Outlying Aspects</a>
<a href="#">Mining</a>
<b><a href="#">Challenges (1)</a></b>
<a href="#">GOAM Algorithm</a>
<a href="#">Evaluation Results</a>
<a href="#">Conclusion</a>

- 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.





[Problem Definition](#)

[Related Work and Challenges](#)

**[GOAM Algorithm](#)**

[Step One - Group Feature Extraction](#)

[Step Two - Outlying Degree Scoring](#)

[Step Three - Outlying Aspects  
Identification](#)

[Evaluation Results](#)

[Conclusion](#)

# GOAM Algorithm



- [Problem Definition](#)
- [Related Work and Challenges](#)
- [GOAM Algorithm](#)
  - [Step One - Group Feature Extraction](#)
  - [Step Two - Outlying Degree Scoring](#)
  - [Step Three - Outlying Aspects Identification](#)
- [Evaluation Results](#)
- [Conclusion](#)

# Framework of GOAM algorithm:

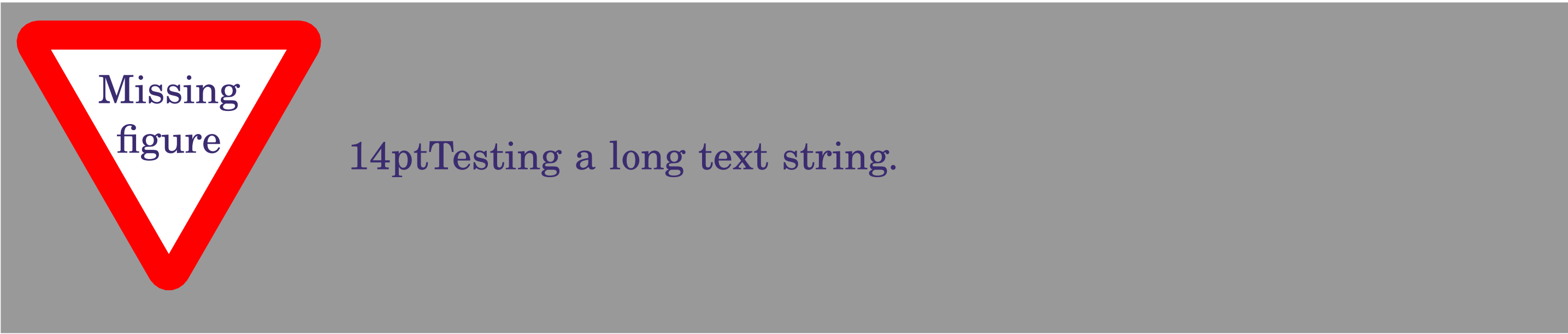


Figure 5: Framework of GOAM Algorithm



# Step One - Group Feature Extraction

- Problem Definition
- Related Work and Challenges
- GOAM Algorithm
- Step One - Group Feature Extraction**
- Step Two - Outlying Degree Scoring
- Step Three - Outlying Aspects Identification
- Evaluation Results
- Conclusion

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

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

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

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

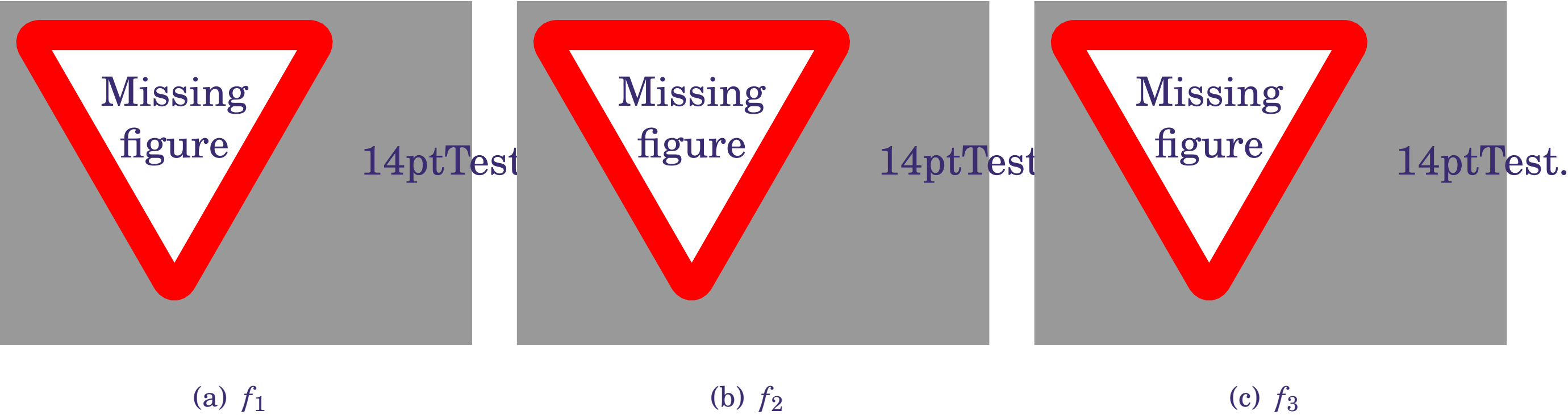


Figure 6: Histogram of  $G_q$  on three features

## Step Two - Outlying Degree Scoring

Problem Definition

Related Work and Challenges

GOAM Algorithm

Step One - Group Feature Extraction

Step Two - Outlying Degree Scoring

Step Three - Outlying Aspects

Identification

Evaluation Results

Conclusion

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

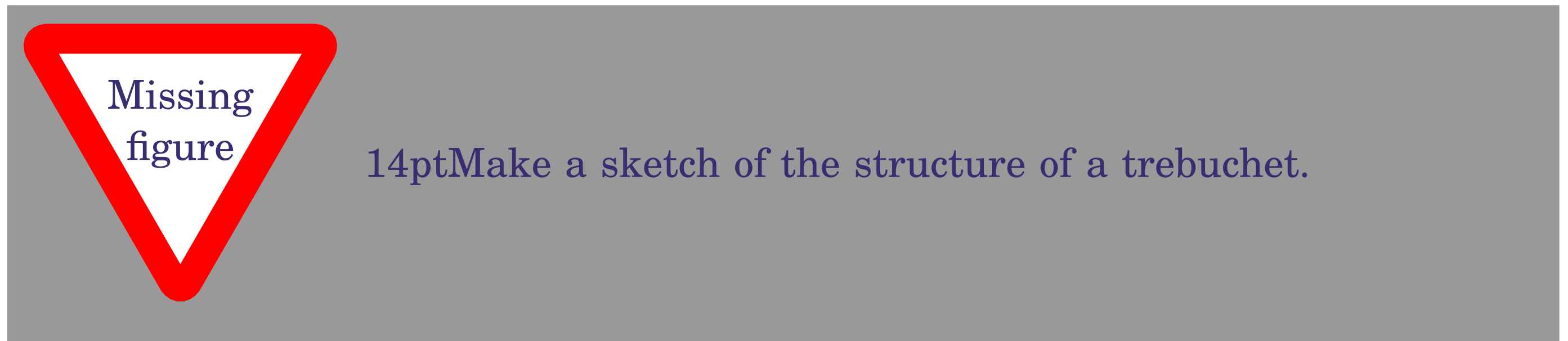


Figure 7: EMD of one feature



**TULIP**

Team for Universal Learning and Intelligent Processing



# Step Two - Outlying Degree Scoring

Problem Definition
Related Work and Challenges
GOAM Algorithm
Step One - Group Feature Extraction
<b>Step Two - Outlying Degree Scoring</b>
Step Three - Outlying Aspects Identification
Evaluation Results
Conclusion

## ■ 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

- [Problem Definition](#)
- [Related Work and Challenges](#)
- [GOAM Algorithm](#)
  - [Step One - Group Feature Extraction](#)
  - [Step Two - Outlying Degree Scoring](#)
  - [Step Three - Outlying Aspects Identification](#)
- [Evaluation Results](#)
- [Conclusion](#)

- 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

[Problem Definition](#)

[Related Work and Challenges](#)

[GOAM Algorithm](#)

[Step One - Group Feature Extraction](#)

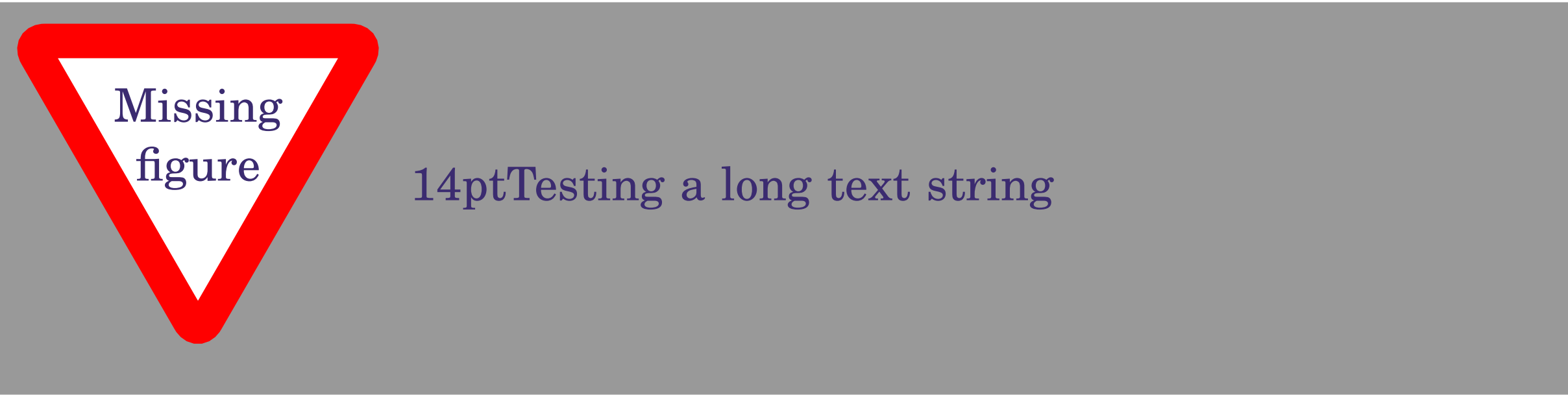
[Step Two - Outlying Degree Scoring](#)

[Step Three - Outlying Aspects Identification](#)

[Evaluation Results](#)

[Conclusion](#)

## ■ Pseudo code of GOAM algorithm





# Illustration

- Problem Definition
- Related Work and Challenges
- GOAM Algorithm
  - Step One - Group Feature Extraction
  - Step Two - Outlying Degree Scoring
  - Step Three - Outlying Aspects Identification
- Evaluation Results
- Conclusion

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



- Problem Definition
- Related Work and Challenges
- GOAM Algorithm
  - Step One - Group Feature Extraction
  - Step Two - Outlying Degree Scoring
  - Step Three - Outlying Aspects Identification
- Evaluation Results
- Conclusion

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

<a href="#">Problem Definition</a>
<a href="#">Related Work and Challenges</a>
<a href="#">GOAM Algorithm</a>
<a href="#">Step One - Group Feature Extraction</a>
<a href="#">Step Two - Outlying Degree Scoring</a>
<a href="#">Step Three - Outlying Aspects Identification</a>
<a href="#">Evaluation Results</a>
<a href="#">Conclusion</a>

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





[Problem Definition](#)

[Related Work and Challenges](#)

[GOAM Algorithm](#)

**[Evaluation Results](#)**

[Synthetic Dataset](#)

[NBA Dataset](#)

[Conclusion](#)

# Evaluation Results



# Evaluation

- [Problem Definition](#)
- [Related Work and Challenges](#)
- [GOAM Algorithm](#)
- [Evaluation Results](#)
  - [Synthetic Dataset](#)
  - [NBA Dataset](#)
- [Conclusion](#)

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





- Problem Definition
- Related Work and Challenges
- GOAM Algorithm
- Evaluation Results
- Synthetic Dataset
- NBA Dataset
- Conclusion

## ■ Synthetic Dataset and Ground Truth

Table 5: Synthetic Dataset and Ground Truth

Query group	$\mathbf{F_1}$	$\mathbf{F_2}$	$F_3$	$\mathbf{F_4}$	$F_5$	$F_6$	$F_7$	$F_8$
$i_1$	<b>10</b>	<b>8</b>	9	<b>7</b>	7	6	6	8
$i_2$	<b>9</b>	<b>9</b>	7	<b>8</b>	9	9	8	9
$i_3$	<b>8</b>	<b>10</b>	8	<b>9</b>	6	8	7	8
$i_4$	<b>8</b>	<b>8</b>	6	<b>7</b>	8	8	6	7
$i_5$	<b>9</b>	<b>9</b>	9	<b>7</b>	7	7	8	8
$i_6$	<b>8</b>	<b>10</b>	8	<b>8</b>	6	6	8	7
$i_7$	<b>9</b>	<b>9</b>	7	<b>9</b>	8	8	8	7
$i_8$	<b>10</b>	<b>9</b>	10	<b>7</b>	7	7	7	7
$i_9$	<b>9</b>	<b>10</b>	8	<b>8</b>	7	6	7	7
$i_{10}$	<b>9</b>	<b>9</b>	7	<b>7</b>	7	8	8	8





- [Problem Definition](#)
- [Related Work and Challenges](#)
- [GOAM Algorithm](#)
- [Evaluation Results](#)
- [Synthetic Dataset](#)
- [NBA Dataset](#)
- [Conclusion](#)

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%





- [Problem Definition](#)
- [Related Work and Challenges](#)
- [GOAM Algorithm](#)
- [Evaluation Results](#)
- [Synthetic Dataset](#)
- [NBA Dataset](#)
- [Conclusion](#)

## 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*).



- Problem Definition
- Related Work and Challenges
- GOAM Algorithm
- Evaluation Results
- Synthetic Dataset
- NBA Dataset
- Conclusion

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



- Problem Definition
- Related Work and Challenges
- GOAM Algorithm
- Evaluation Results
- Synthetic Dataset
- NBA Dataset**
- Conclusion

## ■ 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,+∞]



- [Problem Definition](#)
- [Related Work and Challenges](#)
- [GOAM Algorithm](#)
- [Evaluation Results](#)
- [Synthetic Dataset](#)
- [NBA Dataset](#)
- [Conclusion](#)

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}



- [Problem Definition](#)
- [Related Work and Challenges](#)
- [GOAM Algorithm](#)
- [Evaluation Results](#)
- [Conclusion](#)

# Conclusion



# Conclusion

[Problem Definition](#)

[Related Work and Challenges](#)

[GOAM Algorithm](#)

[Evaluation Results](#)

[Conclusion](#)

- 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.



**TULIP**

*Team for Universal Learning and Intelligent Processing*



# Questions?

- [Problem Definition](#)
- [Related Work and Challenges](#)
- [GOAM Algorithm](#)
- [Evaluation Results](#)
- [Conclusion](#)





# Contact Information

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



[GANGLI@TULIP.ORG.AU](mailto:GANGLI@TULIP.ORG.AU)



[TEAM FOR UNIVERSAL LEARNING AND INTELLIGENT PROCESSING](#)

