

# Package ‘fcmfd’

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**Type** Package

**Title** Fuzzy C-Means for Fuzzy Data

**Version** 0.1.2

**Description** Implements a fuzzy clustering approach for ordinal Likert-type data using triangular fuzzy numbers (TFNs). The package extends the classical fuzzy C-means algorithm to better handle uncertainty in ordinal scales and includes automatic selection of the number of clusters using the Xie-Beni validity index. References: Coppi, R., D'Urso, P., and Giordani, P. (2012), ``Fuzzy and possibilistic clustering for fuzzy data", <doi:10.1016/j.csda.2010.09.013>. Xie, X. L. and Beni, G. (1991), ``A validity measure for fuzzy clustering", <doi:10.1109/34.85677>.

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**Encoding** UTF-8

**LazyData** true

**Depends** R (>= 3.5)

**Imports** stats, graphics

**Suggests** knitr, rmarkdown, testthat (>= 3.0.0)

**VignetteBuilder** knitr

**Config/testthat/edition** 3

**RoxygenNote** 7.3.3

**NeedsCompilation** no

**Author** José Ortigas [aut, cre]

**Maintainer** José Ortigas <jose.ortigas@unmsm.edu.pe>

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cluster_assignment	<i>Hard Cluster Assignment</i>
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### Description

Assigns each observation to the cluster with the highest membership value.

### Usage

```
cluster_assignment(object)
```

### Arguments

object            An object of class "fcmTFN".

### Value

A factor indicating cluster labels.

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cluster_size	<i>Cluster Sizes</i>
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### Description

Computes the size of each cluster using both hard assignments and fuzzy memberships.

### Usage

```
cluster_size(object)
```

### Arguments

object            An object of class "fcmTFN".

**Details**

Hard size is obtained by assigning each observation to the cluster with the highest membership degree.

Fuzzy size is computed as the sum of membership degrees for each cluster.

**Value**

A data.frame containing:

**Cluster** Cluster label.

**Hard\_Size** Number of observations assigned to the cluster.

**Fuzzy\_Size** Sum of membership degrees.

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 fcmTFN

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*Fuzzy C-Means Clustering for Triangular Fuzzy Numbers*


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**Description**

Performs fuzzy clustering on ordinal Likert-type data represented as triangular fuzzy numbers (TFNs).

**Usage**

```
fcmTFN(
  data,
  type = "symmetric",
  option = "B",
  dictionary = NULL,
  k_values = 2:6,
  m = 2,
  epsilon = 1e-06,
  max_iter = 1000,
  verbose = TRUE
)
```

**Arguments**

data	A data.frame or matrix containing ordinal Likert-type responses. Rows represent observations (respondents) and columns represent variables (items or dimensions). All values must be integers within the range defined by the selected scale option.
type	A character string specifying the type of fuzzy dictionary to use. Must be one of "symmetric" for predefined symmetric triangular fuzzy numbers, or "asymmetric" for a user-defined custom dictionary. Defaults to "symmetric".

option	A character string indicating the Likert scale option. Must be one of "A" (5-point scale, 1–5), "B" (7-point scale, 1–7), "C" (10-point scale, 1–10), or "D" (11-point scale, 0–10). Defaults to "B".
dictionary	An optional numeric matrix with 3 columns (l, c, r) representing the lower bound, modal value, and upper bound of each triangular fuzzy number. Required when type = "asymmetric"; ignored when type = "symmetric". Defaults to NULL.
k_values	A numeric vector specifying the candidate numbers of clusters to evaluate. The algorithm runs independently for each value of k. Defaults to 2:6.
m	Fuzzifier parameter ( $m > 1$ ) specifying the fuzzifier parameter, which controls the degree of membership overlap between clusters. Higher values produce softer partitions. Defaults to 2.
epsilon	A positive numeric value specifying the convergence tolerance. The algorithm stops when the change in the objective function between iterations falls below this threshold. Defaults to 1e-06.
max_iter	A positive integer specifying the maximum number of iterations allowed per run. If convergence is not reached within this limit, a warning is issued. Defaults to 1000.
verbose	A logical value. If TRUE, progress messages are printed to the console during execution, including iteration count and convergence status for each value of k. Defaults to TRUE.

### Details

The function automatically determines the optimal number of clusters based on the Xie-Beni validity index.

### Value

An object of class `"fcmTFN"` and `"fcm"`.

### References

- Coppi, R., D'Urso, P., & Giordani, P. (2012). Fuzzy and possibilistic clustering for fuzzy data. <doi:10.1016/j.csda.2010.09.013>
- Xie, X. L., & Beni, G. (1991). A validity measure for fuzzy clustering. <doi:10.1109/34.85677>

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membership

*Extract Membership Matrix*

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### Description

Returns the fuzzy membership matrix obtained from the Fuzzy C-Means clustering process.

**Usage**

```
membership(object)
```

**Arguments**

object            An object of class "fcmTFN".

**Value**

A matrix where rows represent observations and columns represent clusters.

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membership_quality	<i>Membership Quality Assessment</i>
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**Description**

Evaluates the quality of fuzzy assignments for each cluster using membership-based measures.

**Usage**

```
membership_quality(object)
```

**Arguments**

object            An object of class "fcmTFN".

**Details**

This function computes both cluster-specific metrics based on hardened assignments (maximum membership rule) and global partition criteria to evaluate how well-defined the fuzzy boundaries are.

**Value**

A list containing:

**cluster\_summary** Data frame with one row per cluster containing:

- **Hard\_Size**: number of observations primarily assigned to the cluster.
- **Avg\_Membership**: average membership of those observations.
- **Avg\_Margin**: average difference between the largest and second-largest memberships, indicating the clarity of assignment.

**partition\_coefficient** Global partition coefficient (PC).

**partition\_entropy** Global partition entropy (PE).

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plot_dictionary	<i>Plot Fuzzy Dictionary</i>
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**Description**

Plots the triangular fuzzy numbers defining the Likert-scale dictionary.

**Usage**

```
plot_dictionary(object, show_title = TRUE, ...)
```

**Arguments**

object	An object of class "fcmTFN".
show_title	Logical. If TRUE (default), displays the plot title.
...	Additional graphical parameters.

**Value**

Invisibly returns NULL.

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plot_prototypes	<i>Plot Cluster Prototypes</i>
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**Description**

Visualizes cluster prototypes as interval plots using triangular fuzzy numbers (l, c, r).

**Usage**

```
plot_prototypes(
  object,
  cluster = 1,
  view = c("single", "global"),
  use_var_names = FALSE,
  var_names = NULL,
  show_title = TRUE,
  ...
)
```

**Arguments**

object	An object of class "fcmTFN".
cluster	Integer cluster to plot when view = "single".
view	Character string indicating the visualization mode. Either "single" or "global".
use_var_names	Logical.
var_names	Optional character vector of variable names.
show_title	Logical. If TRUE (default), displays the plot title.
...	Additional graphical parameters.

**Value**

Invisibly returns NULL.

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plot_xb	<i>Plot Xie-Beni Index</i>
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**Description**

Plots the Xie-Beni validity index across candidate numbers of clusters.

**Usage**

```
plot_xb(object, mark_optimal = TRUE, type = "b", show_title = TRUE, ...)
```

**Arguments**

object	An object of class "fcmTFN".
mark_optimal	Logical. Whether to highlight the optimal k.
type	Character string indicating the plotting style (default = "b").
show_title	Logical. If TRUE (default), displays the plot title.
...	Additional graphical parameters.

**Value**

Invisibly returns NULL.

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print_fcmTFN	<i>Print Method for fcmTFN Objects</i>
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**Description**

Displays a concise summary of a fitted fuzzy C-means model using triangular fuzzy numbers.

**Usage**

```
print_fcmTFN(x, ...)
```

**Arguments**

x	An object of class "fcmTFN".
...	Additional arguments (not used).

**Value**

The input object (invisibly).

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prototype_results	<i>Prototype Results</i>
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**Description**

Returns cluster prototypes either as a flat matrix or as a list of tables containing l, c, r values for each variable.

**Usage**

```
prototype_results(
  object,
  use_var_names = FALSE,
  var_names = NULL,
  format = c("flat", "table")
)
```

**Arguments**

object	An object of class "fcmTFN".
use_var_names	Logical.
var_names	Optional variable names.
format	Character string indicating the output format: "flat" (default) returns the original matrix representation, while "table" returns one table per cluster.

**Value**

If format = "flat", a data.frame containing prototype values.

If format = "table", a named list of data.frames, one for each cluster.

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`sim_likert7`*Simulated Likert 1–7 Survey Dataset*

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**Description**

A simulated Likert-type dataset with three well-separated clusters, specifically designed for testing fuzzy clustering of ordinal data.

**Usage**

```
sim_likert7
```

**Format**

A data frame with 300 rows and 12 variables:

- Q1** Simulated survey response measured on a 1–7 Likert scale.
- Q10** Simulated survey response measured on a 1–7 Likert scale.
- Q11** Simulated survey response measured on a 1–7 Likert scale.
- Q12** Simulated survey response measured on a 1–7 Likert scale.
- Q2** Simulated survey response measured on a 1–7 Likert scale.
- Q3** Simulated survey response measured on a 1–7 Likert scale.
- Q4** Simulated survey response measured on a 1–7 Likert scale.
- Q5** Simulated survey response measured on a 1–7 Likert scale.
- Q6** Simulated survey response measured on a 1–7 Likert scale.
- Q7** Simulated survey response measured on a 1–7 Likert scale.
- Q8** Simulated survey response measured on a 1–7 Likert scale.
- Q9** Simulated survey response measured on a 1–7 Likert scale.

**Details**

The dataset contains 300 observations divided into three distinct clusters of 100 observations each. Data generation was based on three latent profiles centered approximately at:

- **Low agreement:**  $\approx 2$
- **Moderate agreement:**  $\approx 4$
- **High agreement:**  $\approx 6$

**Source**

Simulated data generated for package examples.

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students\_wellbeing      *Student Wellbeing During COVID-19*

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**Description**

Survey data on subjective well-being, optimism, gratitude, emotional closeness, worry, and depression, collected from university students.

**Usage**

students\_wellbeing

**Format**

A data frame with 651 rows and 9 variables:

- Q13.1 Satisfaction with life overall.
- Q13.2 Satisfaction with life at the present moment.
- Q13.3 Satisfaction with oneself.
- Q13.4 Satisfaction with physical appearance.
- Q13.5 Satisfaction with ability to communicate with others.
- Q13.6 Satisfaction with overall health.
- Q13.7 Satisfaction with achievements in life so far.
- Q13.8 Satisfaction with the college.
- Q13.9 Satisfaction with college classmates.

**Details**

All variables are measured on an 11-point ordinal scale ranging from 0 to 10, where higher values indicate greater satisfaction.

**Source**

Martinez, L., Valencia, I., Trofimoff, V., & Valenzuela, L. S. (2020). Students wellbeing during COVID-19. <doi:10.17632/w9brygpwg7.2>

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summary.fcmTFN      *Summary for fcmTFN Objects*

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**Description**

Displays a summary of the Fuzzy C-Means clustering results for triangular fuzzy numbers.

**Usage**

```
## S3 method for class 'fcmTFN'  
summary(object, ...)
```

**Arguments**

object	An object of class "fcmTFN".
...	Additional arguments (not used).

**Value**

Prints a formatted summary of the clustering result.

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