动态模糊数据的分解模型及应用研究

Research on a Decomposition Model and it's Applications of Dynamic Fuzzy Data

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Abstract The data decomposition is an effective measure to reduce data complexity, but dynamic and fuzzy exist universally in our research object. In this paper, Based on the dynamic fuzzy sets and dynamic fuzzy graph, a decomposition model of dynamic fuzzy data is proposal. The model helps people to solve dynamic and fuzzy problem on the computer furnish evidence.

Keywords Dynamic fuzzy data, Decomposition model, Dynamic fuzzy sets, Dynamic fuzzy graph

一、引言

数据分解是降低数据复杂程度的有效途径，客观地讲，很多复杂的数据是由一些简单数据构成的，因此对数据进行分解可以降低系统的复杂度。特别是对越复杂的数据，就更是有分解的必要。然而当我们从事这方面的研究时，我们发现他们中具有“动态性”和“模糊性”的数据是普遍存在的，面对这些问题我们又不能不解决。为此，参照文[1～7]中的DF格结构，DF模运算、DF表现定理、DF分解定理、DF逻辑系统等基本理论，在其他作者已经形成的初步动态模糊系统理论基础上，针对文[2]中的DF数据模型作更进一步的研究工作，提出了动态模糊数据分解模型理论。

二、动态模糊数据分解模型

本节从两个方面来构造动态模糊数据的分解模型。一个方面是基于动态模糊集的思想来构造；另一方面是基于动态模糊图来构造。

下面分别进行讨论。

1. 基于DFS(Dynamic Fuzzy Sets)的DF数据分解模型

为了得到动态模糊数据分解模型，我们借助动态模糊集(1)的思想作如下规定。文中所有集合均指动态模糊数据集。于是有：

定义1 设$(\overleftarrow{A},\overrightarrow{A})\in D\mathscr{F}(\overleftarrow{x},\overrightarrow{x})$，记为D$\mathscr{F}$集合$(\overleftarrow{A},\overrightarrow{A})$的$\alpha$水平集。

称$(\overleftarrow{A},\overrightarrow{A})(\underset{\cdot}{\overleftarrow{\alpha}},\underset{\cdot}{\overrightarrow{\alpha}})=(\overleftarrow{A}\underset{\cdot}{\overleftarrow{\alpha}},\overrightarrow{A}\underset{\cdot}{\overrightarrow{\alpha}})=\{(\overleftarrow{x},\overrightarrow{x});(\overleftarrow{A},\overrightarrow{A})(\overleftarrow{x},\overrightarrow{x})\geqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})\}$，$(\overleftarrow{0},\overrightarrow{0})\leqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})<(\overleftarrow{1},\overrightarrow{1})$为D$\mathscr{F}$集合$(\overleftarrow{A},\overrightarrow{A})$的弱$\alpha$水平集。

称$(\overleftarrow{A}_{\overleftarrow{0}},\overrightarrow{A}_{\overrightarrow{0}})=\{(\overleftarrow{x},\overrightarrow{x});(\overleftarrow{A},\overrightarrow{A})(\overleftarrow{x},\overrightarrow{x})>(\overleftarrow{0},\overrightarrow{0})\}$ $=\mathrm{supp}(\overleftarrow{A},\overrightarrow{A})$为D$\mathscr{F}$集合$(\overleftarrow{A},\overrightarrow{A})$的支集。显然$(\overleftarrow{A}_{\overleftarrow{0}},\overrightarrow{A}_{\overrightarrow{0}})=(\overleftarrow{x},\overrightarrow{x})$，$(\overleftarrow{A}_{\overleftarrow{0}},\overrightarrow{A}_{\overrightarrow{0}})\subset(\overleftarrow{A}\overleftarrow{\alpha},\overrightarrow{A}\overrightarrow{\alpha})(\overleftarrow{\alpha},\overrightarrow{\alpha})<(\overleftarrow{1},\overrightarrow{1})$且$(\overleftarrow{\alpha},\overrightarrow{\alpha})<(\overleftarrow{\beta},\overrightarrow{\beta})$时有：

$$(\overleftarrow{A}_{\overleftarrow{\beta}},\overrightarrow{A}_{\overrightarrow{\beta}})\subset(\overleftarrow{A}\overleftarrow{\alpha},\overrightarrow{A}\overrightarrow{\alpha}),(\overleftarrow{A}_{\underset{\cdot}{\overleftarrow{\beta}}},\overrightarrow{A}_{\underset{\cdot}{\overrightarrow{\beta}}})\subset(\overleftarrow{A}\underset{\cdot}{\overleftarrow{\alpha}},\overrightarrow{A}\underset{\cdot}{\overrightarrow{\alpha}}),$$

$$(\overleftarrow{A}_{\overleftarrow{\beta}},\overrightarrow{A}_{\overrightarrow{\beta}})\subset(\overleftarrow{A}\underset{\cdot}{\overleftarrow{\alpha}},\overrightarrow{A}\underset{\cdot}{\overrightarrow{\alpha}})$$

由$(\overleftarrow{\alpha},\overrightarrow{\alpha})$水平集性质，易见$D\mathscr{F}$数据集$(\overleftarrow{A},\overrightarrow{A})$是一个没有确定边界范围的集合，我们只能在某个$(\overleftarrow{\alpha},\overrightarrow{\alpha})$水平带宽意义下，认为$(\overleftarrow{x},\overrightarrow{x})$属于$D\mathscr{F}$数据集合$(\overleftarrow{A},\overrightarrow{A})$，还是不属于$D\mathscr{F}$数据集合$(\overleftarrow{A},\overrightarrow{A})$。比如$(\overleftarrow{x},\overrightarrow{x})\in(\overleftarrow{A}_{\overleftarrow{\alpha}},\overrightarrow{A}_{\overrightarrow{\alpha}})$，我们称在$(\overleftarrow{\alpha},\overrightarrow{\alpha})$水平集下，$(\overleftarrow{x},\overrightarrow{x})$属于$D\mathscr{F}$集合$(\overleftarrow{A},\overrightarrow{A})$。若$(\overleftarrow{x},\overrightarrow{x})\notin(\overleftarrow{A}_{\overleftarrow{\alpha}},\overrightarrow{A}_{\overrightarrow{\alpha}})$，我们称在$(\overleftarrow{\alpha},\overrightarrow{\alpha})$水平集下，$(\overleftarrow{x},\overrightarrow{x})$不属于$D\mathscr{F}$数据集合$(\overleftarrow{A},\overrightarrow{A})$。因此，一个$D\mathscr{F}$数据集合可以称为一个具有游移边界带宽的不分明数据集合。

根据此定义，有如下定理。

定理1 $(\overleftarrow{\alpha},\overrightarrow{\alpha})$水平集和弱水平集具有以下性质：

$$(1)\ ((\overleftarrow{A},\overrightarrow{A})\cup(\overleftarrow{B},\overrightarrow{B}))_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}=((\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})})\cup((\overleftarrow{B},\overrightarrow{B})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})})$$

$$((\overleftarrow{A},\overrightarrow{A})\cap(\overleftarrow{B},\overrightarrow{B}))_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}=((\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})})\cap((\overleftarrow{B},\overrightarrow{B})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})})$$

$$(2)\ ((\overleftarrow{A},\overrightarrow{A})\cup(\overleftarrow{B},\overrightarrow{B}))_{(\underset{\cdot}{\overleftarrow{\alpha}},\underset{\cdot}{\overrightarrow{\alpha}})}=((\overleftarrow{A},\overrightarrow{A})_{(\underset{\cdot}{\overleftarrow{\alpha}},\underset{\cdot}{\overrightarrow{\alpha}})})\cup((\overleftarrow{B},\overrightarrow{B})_{(\underset{\cdot}{\overleftarrow{\alpha}},\underset{\cdot}{\overrightarrow{\alpha}})})$$

$$((\overleftarrow{A},\overrightarrow{A})\cap(\overleftarrow{B},\overrightarrow{B}))_{(\underset{\cdot}{\overleftarrow{\alpha}},\underset{\cdot}{\overrightarrow{\alpha}})}=((\overleftarrow{A},\overrightarrow{A})_{(\underset{\cdot}{\overleftarrow{\alpha}},\underset{\cdot}{\overrightarrow{\alpha}})})\cap((\overleftarrow{B},\overrightarrow{B})_{(\underset{\cdot}{\overleftarrow{\alpha}},\underset{\cdot}{\overrightarrow{\alpha}})})$$

证明：(1)因为$((\overleftarrow{A},\overrightarrow{A})\cup(\overleftarrow{B},\overrightarrow{B}))_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}$

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$=\{(\overleftarrow{x},\overrightarrow{x});((\overleftarrow{A},\overrightarrow{A})\cup(\overleftarrow{B},\overrightarrow{B}))_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})\}$

$=\{(\overleftarrow{x},\overrightarrow{x});(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}\cup(\overleftarrow{B},\overrightarrow{B})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})\}$

$=\{(\overleftarrow{x},\overrightarrow{x});(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})\}\cup\{(\overleftarrow{x},\overrightarrow{x});(\overleftarrow{B},\overrightarrow{B})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})\}$

$=(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}\cup(\overleftarrow{B},\overrightarrow{B})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}$

$((\overleftarrow{A},\overrightarrow{A})\cap(\overleftarrow{B},\overrightarrow{B}))_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}$

$=\{(\overleftarrow{x},\overrightarrow{x});((\overleftarrow{A},\overrightarrow{A})\cup(\overleftarrow{B},\overrightarrow{B}))_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})\}$

$=\{(\overleftarrow{x},\overrightarrow{x});(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}\cap(\overleftarrow{B},\overrightarrow{B})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})\}$

$=\{(\overleftarrow{x},\overrightarrow{x});(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})\}\cap\{(\overleftarrow{x},\overrightarrow{x});(\overleftarrow{B},\overrightarrow{B})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})\}$

$=(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}\cap(\overleftarrow{B},\overrightarrow{B})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}$

证毕。

(2)略。(类似(1)证)

例1 王丽和李娟现在是两个有理想、有抱负的好青年。则可表示为：

({王丽}∪{李娟})(有理想、有抱负、好青年)=({王丽})(有理想、有抱负、好青年)∪({李娟})(有理想、有抱负、好青年)

定理2 若$\{(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{t},\overrightarrow{t})};(\overleftarrow{t},\overrightarrow{t})\in T\}\subset D\mathscr{F}(\overleftarrow{x},\overrightarrow{x})$，则有以下性质：

(1)$(\bigcup_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}((\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{t},\overrightarrow{t})})\supset\bigcup_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}((\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{t},\overrightarrow{t})}))$

(2)$(\bigcap_{(\overleftarrow{t},\overrightarrow{t})\in T}((\overleftarrow{A}_{(\overleftarrow{t},\overrightarrow{t})},\overrightarrow{A}_{(\overleftarrow{t},\overrightarrow{t})}))=\bigcap_{(\overleftarrow{t},\overrightarrow{t})\in T}((\overleftarrow{A}_{(\overleftarrow{t},\overrightarrow{t})},\overrightarrow{A}_{(\overleftarrow{t},\overrightarrow{t})}))_{(\overleftarrow{\alpha},\overrightarrow{\alpha})})$

(3)$(\bigcup_{(\overleftarrow{t},\overrightarrow{t})\in T}((\overleftarrow{A}_{\overleftarrow{t}},\overrightarrow{A}_{\overrightarrow{t}})_{(\underset{\cdot}{\overleftarrow{\alpha}},\underset{\cdot}{\overrightarrow{\alpha}})})=\bigcup_{(\overleftarrow{t},\overrightarrow{t})\in T}((\overleftarrow{A}_{\overleftarrow{t}},\overrightarrow{A}_{\overrightarrow{t}}))_{(\underset{\cdot}{\overleftarrow{\alpha}},\underset{\cdot}{\overrightarrow{\alpha}})})$

(4)$(\bigcap_{(\overleftarrow{t},\overrightarrow{t})\in T}(\overleftarrow{A}_{\overleftarrow{t}},\overrightarrow{A}_{\overrightarrow{t}})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}=\bigcap_{(\overleftarrow{t},\overrightarrow{t})\in T}((\overleftarrow{A}_{\overleftarrow{t}},\overrightarrow{A}_{\overrightarrow{t}})_{(\underset{\cdot}{\overleftarrow{\alpha}},\underset{\cdot}{\overrightarrow{\alpha}})}))$

证明：若$(\overleftarrow{x},\overrightarrow{x})\in\bigcup_{(\overleftarrow{t},\overrightarrow{t})}((\overleftarrow{A}_{\overleftarrow{t}},\overrightarrow{A}_{\overrightarrow{t}})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})})$，

则存在$(\overleftarrow{t}_0,\overrightarrow{t}_0)\in T$使$(\overleftarrow{x},\overrightarrow{x})\in((\overleftarrow{A}_{\overleftarrow{t}_0},\overrightarrow{A}_{\overrightarrow{t}_0}))_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}$，于是$(\overleftarrow{A}_{\overleftarrow{t}_0},\overrightarrow{A}_{\overrightarrow{t}_0})(\overleftarrow{x},\overrightarrow{x})\geqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})$，

即得 $\mathop{Supp}_{(\overleftarrow{t},\overrightarrow{t})\in T}(\overleftarrow{A}_{\overleftarrow{t}},\overrightarrow{A}_{\overrightarrow{t}})(\overleftarrow{x},\overrightarrow{x})\geqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})$

故$(\overleftarrow{x},\overrightarrow{x})\in(\bigcup_{(\overleftarrow{t},\overrightarrow{t})\in T}((\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}))$

得证(1)。其余情形类似可证。

例2 在例1的基础上进行修改，10年后王丽可能发展得很好，李娟可能发展得不如王丽。

该数据可以表示为：({王丽})(10年后，发展好)({李娟})(10年后，发展不好)

定理3 设$(\overleftarrow{A},\overrightarrow{A})\in D\mathscr{F}(\overleftarrow{x},\overrightarrow{x})$，$(\overleftarrow{\alpha}_{\overleftarrow{t}},\overrightarrow{\alpha}_{\overrightarrow{t}});(\overleftarrow{t},\overrightarrow{t})\in T\}\subset[(\overleftarrow{0},\overrightarrow{0})(\overleftarrow{1},\overrightarrow{1})]$，则有：

(1)$(\overleftarrow{A}_{\overleftarrow{\alpha}},\overrightarrow{A}_{\overrightarrow{\alpha}})=\bigcap_{(\overleftarrow{t},\overrightarrow{t})\in T}(\overleftarrow{A}_{\overleftarrow{\alpha}_{\overleftarrow{t}}},\overrightarrow{A}_{\overrightarrow{\alpha}_{\overrightarrow{t}}}),(\overleftarrow{A}_{\overleftarrow{\beta}},\overrightarrow{A}_{\overrightarrow{\beta}})\supset\bigcup_{(\overleftarrow{t},\overrightarrow{t})\in T}(\overleftarrow{A}_{\overleftarrow{\alpha}_{\overleftarrow{t}}},\overrightarrow{A}_{\overrightarrow{\alpha}_{\overrightarrow{t}}})$

(2)$(\overleftarrow{A}_{\underset{\cdot}{\overleftarrow{\alpha}}},\overrightarrow{\alpha}_{\underset{\cdot}{\overrightarrow{\beta}}})\subset\bigcap_{(\overleftarrow{t},\overrightarrow{t})\in T}(\overleftarrow{A}_{\underset{\cdot}{\overleftarrow{\alpha}_{\overleftarrow{t}}}},\overrightarrow{A}_{\underset{\cdot}{\overrightarrow{\alpha}_{\overrightarrow{t}}}}),(\overleftarrow{A}_{\underset{\cdot}{\overleftarrow{\beta}}},\overrightarrow{\beta}_{\underset{\cdot}{\overrightarrow{\beta}}})=\bigcup_{(\overleftarrow{t},\overrightarrow{t})\in T}(\overleftarrow{A}_{\underset{\cdot}{\overleftarrow{\alpha}_{\overleftarrow{t}}}},\overrightarrow{A}_{\underset{\cdot}{\overrightarrow{\alpha}_{\overrightarrow{t}}}})$

其中$(\overleftarrow{\alpha},\overrightarrow{\alpha})=\bigvee_{(\overleftarrow{t},\overrightarrow{t})\in T}(\overleftarrow{\alpha}_{\overleftarrow{t}},\overrightarrow{\alpha}_{\overrightarrow{t}})$，$(\overleftarrow{\beta},\overrightarrow{\beta})=\bigwedge_{(\overleftarrow{t},\overrightarrow{t})\in T}(\overleftarrow{\alpha}_{\overleftarrow{t}},\overrightarrow{\alpha}_{\overrightarrow{t}})$

证明：

(1)由于$(\overleftarrow{A}_{\overleftarrow{\alpha}},\overrightarrow{A}_{\overrightarrow{\alpha}})=(\overleftarrow{x},\overrightarrow{x}):(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant\bigvee_{(\overleftarrow{t},\overrightarrow{t})\in T}(\overleftarrow{\alpha}_{\overleftarrow{t}},\overrightarrow{\alpha}_{\overrightarrow{t}})$

$=\bigcap_{(\overleftarrow{t},\overrightarrow{t})\in T}\{(\overleftarrow{x},\overrightarrow{x}):(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\alpha}_{\overleftarrow{t}},\overrightarrow{\alpha}_{\overrightarrow{t}})\}$

$=\bigcap_{(\overleftarrow{t},\overrightarrow{t})\in T}(\overleftarrow{A}_{\overleftarrow{\alpha}_{\overleftarrow{t}}},\overrightarrow{A}_{\overrightarrow{\alpha}_{\overrightarrow{t}}})$

又$(\overleftarrow{A}_{\overleftarrow{\beta}},\overrightarrow{A}_{\overrightarrow{\beta}})=(\overleftarrow{x},\overrightarrow{x}):(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant\bigwedge_{(\overleftarrow{t},\overrightarrow{t})\in T}(\overleftarrow{\alpha}_{\overleftarrow{t}},\overrightarrow{\alpha}_{\overrightarrow{t}})\supset\bigcup_{(\overleftarrow{t},\overrightarrow{t})\in T}\{(\overleftarrow{x},\overrightarrow{x}):(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\alpha}_{\overleftarrow{t}},\overrightarrow{\alpha}_{\overrightarrow{t}})\}=\bigcup_{(\overleftarrow{t},\overrightarrow{t})\in T}(\overleftarrow{A}_{\overleftarrow{\alpha}_{\overleftarrow{t}}},\overrightarrow{A}_{\overrightarrow{\alpha}_{\overrightarrow{t}}})$

[证毕]。

(2)类似可证。

定理4 对于任意$(\overleftarrow{A},\overrightarrow{A})\in D\mathscr{F}(\overleftarrow{x},\overrightarrow{x})$，有：

$(\overleftarrow{A}_{\overleftarrow{\alpha}},\overrightarrow{A}_{\overrightarrow{\alpha}})=\bigcap_{(\overleftarrow{\lambda},\overrightarrow{\lambda})<(\overleftarrow{\alpha},\overrightarrow{\alpha})}(\overleftarrow{A}_{\overleftarrow{\lambda}},\overrightarrow{A}_{\overrightarrow{\lambda}})$，

$(\overleftarrow{A}_{\underset{\cdot}{\overleftarrow{\alpha}}},\overrightarrow{A}_{\underset{\cdot}{\overrightarrow{\alpha}}})=\bigcup_{(\overleftarrow{\lambda},\overrightarrow{\lambda})>(\overleftarrow{\alpha},\overrightarrow{\alpha})}(\overleftarrow{A}_{\overleftarrow{\lambda}},\overrightarrow{A}_{\overrightarrow{\lambda}})$

证明：由于$(\overleftarrow{A}_{\overleftarrow{\alpha}},\overrightarrow{A}_{\overrightarrow{\alpha}})=\{(\overleftarrow{x},\overrightarrow{x}):(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\alpha},\overrightarrow{\alpha})\}$

$=\bigcap_{(\overleftarrow{\lambda},\overrightarrow{\lambda})<(\overleftarrow{\alpha},\overrightarrow{\alpha})}\{(\overleftarrow{x},\overrightarrow{x}):(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\lambda},\overrightarrow{\lambda})\}$

$=\bigcap_{(\overleftarrow{\lambda},\overrightarrow{\lambda})<(\overleftarrow{\alpha},\overrightarrow{\alpha})}(\overleftarrow{A}_{\overleftarrow{\lambda}},\overrightarrow{A}_{\overrightarrow{\lambda}})$

$(\overleftarrow{A}_{\underset{\cdot}{\overleftarrow{\alpha}}},\overrightarrow{A}_{\underset{\cdot}{\overrightarrow{\alpha}}})=\{(\overleftarrow{x},\overrightarrow{x}):(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}>(\overleftarrow{\alpha},\overrightarrow{\alpha})\}$

$=\bigcup_{(\overleftarrow{\lambda},\overrightarrow{\lambda})>(\overleftarrow{\alpha},\overrightarrow{\alpha})}\{(\overleftarrow{x},\overrightarrow{x}):(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}\geqslant(\overleftarrow{\lambda},\overrightarrow{\lambda})\}$

$=\bigcup_{(\overleftarrow{\lambda},\overrightarrow{\lambda})>(\overleftarrow{\alpha},\overrightarrow{\alpha})}(\overleftarrow{A}_{\overleftarrow{\lambda}},\overrightarrow{A}_{\overrightarrow{\lambda}})$

证毕。

定义2 设$(\overleftarrow{\alpha},\overrightarrow{\alpha})\in[(\overleftarrow{0},\overrightarrow{0}),(\overleftarrow{1},\overrightarrow{1})]$，$(\overleftarrow{A},\overrightarrow{A})\in D\mathscr{F}(\overleftarrow{x},\overrightarrow{x})$，则$(\overleftarrow{\alpha},\overrightarrow{\alpha})$与$(\overleftarrow{A},\overrightarrow{A})$的数积为：

$((\overleftarrow{\alpha},\overrightarrow{\alpha})(\overleftarrow{A},\overrightarrow{A}))_{(\overleftarrow{x},\overrightarrow{x})}=(\overleftarrow{\alpha},\overrightarrow{\alpha})\wedge(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{x},\overrightarrow{x})}$，现在就可以给出$DF$数据模型的分解模型了。

定理5 DF数据集合分解模型对任意$(\overleftarrow{A},\overrightarrow{A})\in D\mathscr{F}(\overleftarrow{x},\overrightarrow{x})$有：

$(\overleftarrow{A},\overrightarrow{A})=\bigcup_{(\overleftarrow{\alpha},\overrightarrow{\alpha})\in[(\overleftarrow{0},\overrightarrow{0}),(\overleftarrow{1},\overrightarrow{1})]}(\overleftarrow{\alpha},\overrightarrow{\alpha})(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}$，

$(\overleftarrow{A},\overrightarrow{A})=\bigcup_{(\overleftarrow{\alpha},\overrightarrow{\alpha})\in[(\overleftarrow{0},\overrightarrow{0}),(\overleftarrow{1},\overrightarrow{1})]}(\overleftarrow{\alpha},\overrightarrow{\alpha})(\overleftarrow{A},\overrightarrow{A})_{(\underset{\cdot}{\overleftarrow{\alpha}},\underset{\cdot}{\overrightarrow{\alpha}})}$

证明：因为 $(\overleftarrow{A},\overrightarrow{A})_{(\overleftarrow{\alpha},\overrightarrow{\alpha})}(\overleftarrow{x},\overrightarrow{x})=\begin{cases}(\overleftarrow{1},\overrightarrow{1})\,(\overleftarrow{x},\overrightarrow{x})\in(\overleftarrow{A}_{\overleftarrow{\alpha}},\overrightarrow{A}_{\overrightarrow{\alpha}})\\(\overleftarrow{0},\overrightarrow{0})\,(\overleftarrow{x},\overrightarrow{x})\notin(\overleftarrow{A}_{\overleftarrow{\alpha}},\overrightarrow{A}_{\overrightarrow{\alpha}})\end{cases}$

则有 $\left(\bigcup_{(\overleftarrow{\alpha},\overrightarrow{\alpha})\in[(\overleftarrow{0},\overrightarrow{0}),(\overleftarrow{1},\overrightarrow{1})]}(\overleftarrow{\alpha},\overrightarrow{\alpha})(\overleftarrow{A},\overrightarrow{A}_{(\overleftarrow{\alpha},\overrightarrow{\alpha})})(\overleftarrow{x},\overrightarrow{x})\right)=Sup(\overleftarrow{\alpha},\overrightarrow{\alpha})(\overleftarrow{A}_{\overleftarrow{\alpha}},\overrightarrow{A}_{\overrightarrow{\alpha}})(\overleftarrow{x},\overrightarrow{x})$

$=\underset{(\overleftarrow{x},\overrightarrow{x})\in(\overleftarrow{A}_{\overleftarrow{\alpha}},\overrightarrow{A}_{\overrightarrow{\alpha}})}{Sup}(\overleftarrow{\alpha},\overrightarrow{\alpha})=(\overleftarrow{A},\overrightarrow{A})(\overleftarrow{x},\overrightarrow{x})$

证毕。

例3 设 $U=\{(\overleftarrow{u}_1,\overrightarrow{u}_1),(\overleftarrow{u}_2,\overrightarrow{u}_2)(\overleftarrow{u}_3,\overrightarrow{u}_3)(\overleftarrow{u}_4,\overrightarrow{u}_4)(\overleftarrow{u}_5,\overrightarrow{u}_5)\}$

$$\begin{cases}\overrightarrow{A}=\dfrac{0.\overrightarrow{2}}{\overrightarrow{u}_1}+\dfrac{0.\overrightarrow{7}}{\overrightarrow{u}_2}+\dfrac{\overrightarrow{1}}{\overrightarrow{u}_3}+\dfrac{0.\overrightarrow{5}}{\overrightarrow{u}_5}\\ \overleftarrow{A}=\dfrac{0.\overleftarrow{2}}{\overleftarrow{u}_1}+\dfrac{0.\overleftarrow{7}}{\overleftarrow{u}_2}+\dfrac{\overleftarrow{1}}{\overleftarrow{u}_3}+\dfrac{0.\overleftarrow{5}}{\overleftarrow{u}_5}\end{cases},$$

$$\begin{cases}\overrightarrow{B}=\dfrac{0.\overrightarrow{5}}{\overrightarrow{u}_1}+\dfrac{0.\overrightarrow{3}}{\overrightarrow{u}_2}+\dfrac{0.\overrightarrow{1}}{\overrightarrow{u}_4}+\dfrac{0.\overrightarrow{3}}{\overrightarrow{u}_5}\\ \overleftarrow{B}=\dfrac{0.\overleftarrow{5}}{\overleftarrow{u}_1}+\dfrac{0.\overleftarrow{3}}{\overleftarrow{u}_2}+\dfrac{0.\overleftarrow{1}}{\overleftarrow{u}_4}+\dfrac{0.\overleftarrow{3}}{\overleftarrow{u}_5}\end{cases}$$

则 1) $\overrightarrow{A}\cup\overrightarrow{B}\triangleq\dfrac{0.\overrightarrow{2}\vee0.\overrightarrow{5}}{\overrightarrow{u}_1}+\dfrac{0.\overrightarrow{7}\vee0.\overrightarrow{3}}{\overrightarrow{u}_2}+\dfrac{\overrightarrow{1}\vee\overrightarrow{0}}{\overrightarrow{u}_3}+\dfrac{\overrightarrow{0}\vee0.\overrightarrow{1}}{\overrightarrow{u}_4}+\dfrac{0.\overrightarrow{5}\vee0.\overrightarrow{3}}{\overrightarrow{u}_5}$

$\triangleq\dfrac{0.\overrightarrow{5}}{\overrightarrow{u}_1}+\dfrac{0.\overrightarrow{7}}{\overrightarrow{u}_2}+\dfrac{\overrightarrow{1}}{\overrightarrow{u}_3}+\dfrac{0.\overrightarrow{1}}{\overrightarrow{u}_4}+\dfrac{0.\overrightarrow{5}}{\overrightarrow{u}_5}$

2) $\overleftarrow{A}\cup\overleftarrow{B}\triangleq\dfrac{0.\overleftarrow{2}}{\overleftarrow{u}_1}\vee\dfrac{0.\overleftarrow{5}}{\overleftarrow{u}_1}+\dfrac{0.\overleftarrow{7}}{\overleftarrow{u}_2}\vee\dfrac{0.\overleftarrow{3}}{\overleftarrow{u}_2}+\dfrac{\overleftarrow{1}}{\overleftarrow{u}_1}\vee\dfrac{\overleftarrow{0}}{\overleftarrow{u}_3}+\dfrac{\overleftarrow{0}}{\overleftarrow{u}_4}\vee\dfrac{0.\overleftarrow{1}}{\overleftarrow{u}_4}+\dfrac{0.\overleftarrow{5}}{\overleftarrow{u}_5}\vee\dfrac{0.\overleftarrow{3}}{\overleftarrow{u}_5}$

$\triangleq\dfrac{0.\overleftarrow{5}}{\overleftarrow{u}_1}+\dfrac{0.\overleftarrow{7}}{\overleftarrow{u}_2}+\dfrac{\overleftarrow{1}}{\overleftarrow{u}_3}+\dfrac{0.\overleftarrow{1}}{\overleftarrow{u}_4}+\dfrac{0.\overleftarrow{5}}{\overleftarrow{u}_5}$

2. 基于动态模糊图的动态模糊数据分解模型

先给出动态模糊图的有关概念。

1) *动态模糊图* 在一般图论中，一个图 G 被抽象地定义为二元组：G＝{V，E}其中，V＝{V_1，V_2，…，V_n}是一个结点的集合，E 是定义在 V 上的一个二元关系，表示联接结点的边的集合。一个动态模糊图除了要指明其包含的结点和边之外，还应给出它们各自的动态模糊程度。

定义3 设 V＝{V_1，V_2，…，V_n}是一个由 n 个结点构成的集合（称为论域），一个论域 V 上的动态模糊图 G 由一个三元组表示：$G=\{V,(\overleftarrow{V},\overrightarrow{V}),(\overleftarrow{E},\overrightarrow{E})\}$，其中$(\overleftarrow{V},\overrightarrow{V})$是论域 V 上的一个动态模糊集，其隶属函数为：$(\overleftarrow{V}_i(\overleftarrow{u}_i),\overrightarrow{V}_i(\overrightarrow{u}_i))$，$i=1,2,3,\cdots,n$ 它表示结点 V_i 的动态模糊度（或称动态存在度）。$(\overleftarrow{E},\overrightarrow{E})$是论域 V×V 上的一个动态模糊关系，可表示成如下矩阵：

$$(\overleftarrow{E},\overrightarrow{E})=\begin{bmatrix}(\overleftarrow{u}_{11},\overrightarrow{u}_{11}) & (\overleftarrow{u}_{12},\overrightarrow{u}_{12}) & \cdots & (\overleftarrow{u}_{1n},\overrightarrow{u}_{1n})\\(\overleftarrow{u}_{21},\overrightarrow{u}_{21}) & (\overleftarrow{u}_{22},\overrightarrow{u}_{22}) & \cdots & (\overleftarrow{u}_{2n},\overrightarrow{u}_{2n})\\ \cdots & \cdots & \cdots & \cdots\\(\overleftarrow{u}_{n1},\overrightarrow{u}_{n1}) & (\overleftarrow{u}_{n2},\overrightarrow{u}_{n2}) & \cdots & (\overleftarrow{u}_{nn},\overrightarrow{u}_{nn})\end{bmatrix}$$

其中$(\overleftarrow{u}_{ij},\overrightarrow{u}_{ij})(i=1,2,\cdots,n;j=1,2,\cdots,n)$，$(\overleftarrow{0},\overrightarrow{0})\leqslant(\overleftarrow{u}_{ij},\overrightarrow{u}_{ij})\leqslant(\overleftarrow{1},\overrightarrow{1})$。当$(\overleftarrow{u}_{ij},\overrightarrow{u}_{ij})\neq(\overleftarrow{0},\overrightarrow{0})$时表示从结点 V_i 到结点 V_j 之间存在一条连接边，$(\overleftarrow{u}_{ij},\overrightarrow{u}_{ij})$被称为从结点 V_i 到结点 V_j 连接强度，或称该边的动态模糊度。

如果对于任意的 i 和 j，均有 $\overleftarrow{u}_{ij}=\overrightarrow{u}_{ij}(i,j=1,2,\cdots,n)$，则该动态模糊图称为无向动态模糊图，否则称为有向动态模糊图。

若一个动态模糊图的一部分仍构成一个动态模糊图，且其中结点和边的动态模糊度都不大于原动态模糊图相应的动态模糊度，则称其为原图的一个动态模糊子图。

例4 无向动态模糊图 $G=\{V,(\overleftarrow{V},\overrightarrow{V}),(\overleftarrow{E},\overrightarrow{E})\}$（图1）的论域为 $V=\{V_1,V_2,V_3,V_4\}$，其动态模糊结点集为：$(\overleftarrow{V},\overrightarrow{V})=\{(0.\overleftarrow{9},0.\overrightarrow{9}),(0.\overleftarrow{9},0.\overrightarrow{9}),(0.\overleftarrow{6},0.\overrightarrow{6}),(0.\overleftarrow{7},0.\overrightarrow{7})\}$，其动态模糊矩阵为：

$$(\overleftarrow{E},\overrightarrow{E})=\begin{bmatrix}(\overleftarrow{0},\overrightarrow{0}) & (0.\overleftarrow{3},0.\overrightarrow{3}) & (0.\overleftarrow{2},0.\overrightarrow{2}) & (0.\overleftarrow{8},0.\overrightarrow{8})\\(0.\overleftarrow{3},0.\overrightarrow{3}) & (\overleftarrow{0},\overrightarrow{0}) & (\overleftarrow{0},\overrightarrow{0}) & (0.\overleftarrow{5},0.\overrightarrow{5})\\(0.\overleftarrow{2},0.\overrightarrow{2}) & (\overleftarrow{0},\overrightarrow{0}) & (0.\overleftarrow{3},0.\overrightarrow{3}) & (0.\overleftarrow{7},0.\overrightarrow{7})\\(0.\overleftarrow{8},0.\overrightarrow{8}) & (0.\overleftarrow{5},0.\overrightarrow{5}) & (0.\overleftarrow{7},0.\overrightarrow{7}) & (\overleftarrow{0},\overrightarrow{0})\end{bmatrix}$$

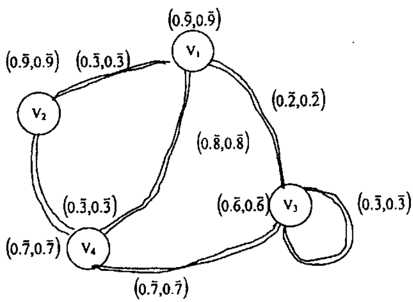

图1 无向动态模糊图

例5 有向动态模糊图 $G=\{V,(\overleftarrow{V},\overrightarrow{V}),(\overleftarrow{E},\overrightarrow{E})\}$（图2）的论域为 $V=\{V_1,V_2,V_3,V_4\}$，其动态模糊结点集为：$(\overleftarrow{V},\overrightarrow{V})=\{(0.\overleftarrow{9},0.\overrightarrow{9}),(0.\overleftarrow{7},0.\overrightarrow{7}),(0.\overleftarrow{8},0.$

$\overrightarrow{8}),(0.\overleftarrow{5},0.\overrightarrow{5}),(0.\overleftarrow{7},0.\overrightarrow{7})$，其动态模糊矩阵为：

$$(\overleftarrow{E},\overrightarrow{E})=\begin{bmatrix} (0.\overleftarrow{3},0.\overrightarrow{3}) & (0.\overleftarrow{7},0.\overrightarrow{7}) & (\overleftarrow{0},\overrightarrow{0}) & (\overleftarrow{0},\overrightarrow{0}) & (0.\overleftarrow{7},0.\overrightarrow{7}) \\ (0.\overleftarrow{6},0.\overrightarrow{6}) & (\overleftarrow{0},\overrightarrow{0}) & (\overleftarrow{0},\overrightarrow{0}) & (0.\overleftarrow{4},0.\overrightarrow{4}) & (\overleftarrow{0},\overrightarrow{0}) \\ (\overleftarrow{0},\overrightarrow{0}) & (0.\overleftarrow{6},0.\overrightarrow{6}) & (\overleftarrow{0},\overrightarrow{0}) & (\overleftarrow{0},\overrightarrow{0}) & (0.\overleftarrow{9},0.\overrightarrow{9}) \\ (0.\overleftarrow{8},0.\overrightarrow{8}) & (\overleftarrow{0},\overrightarrow{0}) & (0.\overleftarrow{9},0.\overrightarrow{9}) & (\overleftarrow{0},\overrightarrow{0}) & (\overleftarrow{0},\overrightarrow{0}) \\ (\overleftarrow{0},\overrightarrow{0}) & (\overleftarrow{0},\overrightarrow{0}) & (\overleftarrow{0},\overrightarrow{0}) & (0.\overleftarrow{2},0.\overrightarrow{2}) & (\overleftarrow{0},\overrightarrow{0}) \end{bmatrix}$$

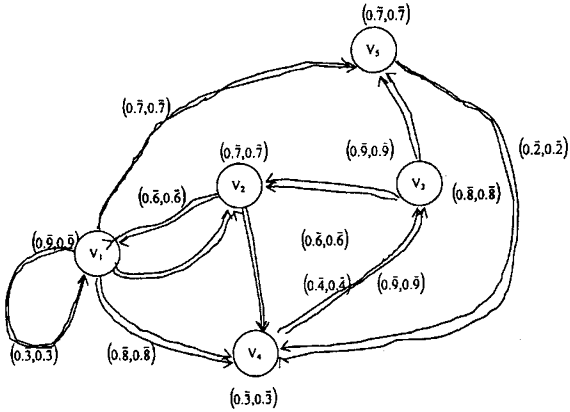

图2　有向动态模糊图

2）*多重动态模糊图*　如果允许任意两点间不多于 m 条边，这就是所谓多重（m 重）动态模糊图或多重（m 重）有向动态模糊图。

定义4　设 $V=\{V_1,V_2,\cdots,V_n\}$ 是一个由 n 个结点构成的集合（称为论域），一个论域 V 上的动态模糊图 G 由一个三元组表示：$G=\{V,(\overleftarrow{V},\overrightarrow{V}),(\overleftarrow{E},\overrightarrow{E})\}$，其中 $(\overleftarrow{V},\overrightarrow{V})$ 是论域 V 上的一个动态模糊集，其隶属函数为：$(\overleftarrow{V}_i(\overleftarrow{u_i}),\overrightarrow{V}_i(\overrightarrow{u_i}))$，$i=1,2,3,\cdots,n$ 它表示结点 V_i 的动态模糊度（或称动态存在度）。$(\overleftarrow{E},\overrightarrow{E})$ 是论域 $V\times V$ 上的一个动态模糊关系，可表示成如下矩阵：

$$(\overleftarrow{E},\overrightarrow{E})=\begin{bmatrix} (\overleftarrow{u}_{11},\overrightarrow{u}_{11}) & (\overleftarrow{u}_{12},\overrightarrow{u}_{12}) & \cdots & (\overleftarrow{u}_{1n},\overrightarrow{u}_{1n}) \\ (\overleftarrow{u}_{21},\overrightarrow{u}_{21}) & (\overleftarrow{u}_{22},\overrightarrow{u}_{22}) & \cdots & (\overleftarrow{u}_{2n},\overrightarrow{u}_{2n}) \\ \cdots & \cdots & \cdots & \cdots \\ (\overleftarrow{u}_{n1},\overrightarrow{u}_{n1}) & (\overleftarrow{u}_{n2},\overrightarrow{u}_{n2}) & \cdots & (\overleftarrow{u}_{nn},\overrightarrow{u}_{nn}) \end{bmatrix}$$

其中 $(\overleftarrow{u}_{ij},\overrightarrow{u}_{ij})(i=1,2,\cdots,n;j=1,2,\cdots,n)$ 是元素不超过 m 的隶属度集合；$(\overleftarrow{u}_{ij},\overrightarrow{u}_{ij})=\{(\overleftarrow{u}_{ij1},\overrightarrow{u}_{ij1}),(\overleftarrow{u}_{ij2},\overrightarrow{u}_{ij2}),\cdots,(\overleftarrow{u}_{ijm},\overrightarrow{u}_{ijm})\}$，$(\overleftarrow{0},\overrightarrow{0})\leqslant(\overleftarrow{u}_{ijk},\overrightarrow{u}_{ijk})\leqslant(\overleftarrow{1},\overrightarrow{1})$，$(k=1,2,\cdots,m)$，则称 $G=\{V,(\overleftarrow{V},\overrightarrow{V}),(\overleftarrow{E},\overrightarrow{E})\}$ 为一个论域 V 上的多重（m 重）动态模糊图或多重（m 重）有向动态模糊图。

例6　3重有向动态模糊图 $G=\{V,(\overleftarrow{V},\overrightarrow{V}),(\overleftarrow{E},\overrightarrow{E})\}$（图3）的论域为 $V=\{V_1,V_2,V_3,V_4\}$，其动态模糊结点集为：$(\overleftarrow{V},\overrightarrow{V})=\{(0.\overleftarrow{9},0.\overrightarrow{9}),(0.\overleftarrow{8},0.\overrightarrow{8}),(0.\overleftarrow{3},0.\overrightarrow{3}),(0.\overleftarrow{7},0.\overrightarrow{7})\}$，其动态模糊矩阵为：

$(\overleftarrow{E},\overrightarrow{E})=$

$$\begin{bmatrix} (0.\overleftarrow{1},0.\overrightarrow{1}) & ((0.\overleftarrow{3},0.\overrightarrow{3})(0.\overleftarrow{9},0.\overrightarrow{9})) & ((0.\overleftarrow{8},0.\overrightarrow{8})(0.\overleftarrow{4},0.\overrightarrow{4})) & (\overleftarrow{0},\overrightarrow{0}) \\ ((0.\overleftarrow{2},0.\overrightarrow{2})(0.\overleftarrow{4},0.\overrightarrow{4})) & (\overleftarrow{0},\overrightarrow{0}) & ((0.\overleftarrow{3},0.\overrightarrow{3})(0.\overleftarrow{7},0.\overrightarrow{7})(0.\overleftarrow{8},0.\overrightarrow{8})) & (\overleftarrow{0},\overrightarrow{0}) \\ (\overleftarrow{0},\overrightarrow{0}) & (\overleftarrow{0},\overrightarrow{0}) & (\overleftarrow{0},\overrightarrow{0}) & ((0.\overleftarrow{1},0.\overrightarrow{1})(0.\overleftarrow{9},0.\overrightarrow{9})(0.\overleftarrow{3},0.\overrightarrow{3})) \\ (0.\overleftarrow{8},0.\overrightarrow{8}) & (\overleftarrow{0},\overrightarrow{0}) & (\overleftarrow{0},\overrightarrow{0}) & (\overleftarrow{0},\overrightarrow{0}) \end{bmatrix}$$

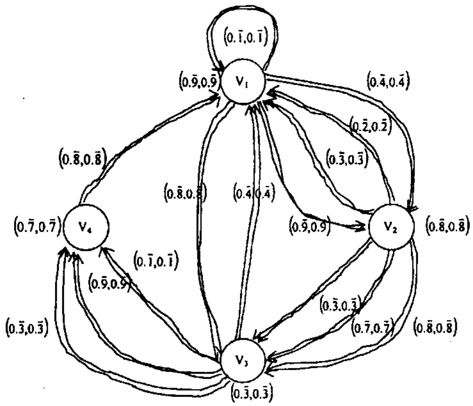

图3　3重有向动态模糊图

根据以上动态模糊图的概念，现在从图的角度给出动态模糊数据的分解理论。

定理6（基于 DF 图的 DF 数据分解模型）　任何一个非强连通有向 DF 图都是可分解的。

证明：对于任意有向 DF 图 G，如果 G 不可分解，既意味着 G 既不能分解为独立子图，也不能分解为单向连接的子图，前一个限制表明图至少是弱连通的，后一个限制表明 G 所分解的子图两两之间存在着有向的回路。任何存在回路连接的两个强连通有向子图都可以合并为一个强连通有向图，所以，G 不可分解，就推出 G 是强连通的。证毕。

结论　动态模糊数据是我们研究模拟人类系统的关键问题之一。目前关于这方面的研究工作还很少。基于此，本文作了初步的研究，从动态模糊集和动态模糊图两个角度出发，给出了动态模糊数据的分解模型。我们将在这些理论框架的基础上做更进一步的深入研究，且实现范例系统。

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