Projekt MinCover
Algorithmen für die minimale Überdeckung von funktionalen Abhängigkeiten

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Zusammenfassung

Die Definitionen und Algorithmen dienen zur Berechnung der minimalen Überdeckung von funktionalen Abhängigkeiten und ähnlichen Anwendungen. Der erste Abschnitt führt mit einen kurzen Überblick über die wichtigsten Definition in die Thematik der funktionalen Abhängigkeiten ein. Der zweite und dritte Abschnitt beschäftigt mit der verwendete Datenstruktur und Algorithmen, die Definitionen der Algorithmen erfolgt in Pseudocode und beschreibt die grundlegenden Ideen, die hinter ihnen stecken. Die Datenstrukturen und Algorithmen wurden dann in C# implementiert und als Anwendung, die im vieren Abschnitt beschreiben wird, veröffentlicht. Das entsprechende Projekt finden Sie unter http://www.netpage-germany.de/projects/mincover oder unter SourceForge.Net, es steht unter der GNU Library oder „Lesser“ General Public License (LGPL).

Das Projekt „MinCover“ ist ein akademisches Framework (Bibliothek) für funktionale Abhängigkeiten (FA) mit Algorithmen zur Berechnung der minimalen Überdeckung, kompletten Überdeckung und ähnlicher Überdeckung. Das Framework implementiert das volle Spektrum der funktionalen Abhängigkeiten mit Attributen, Attributlisten und Listen von funktionalen Abhängigkeiten. Als Programmiersprache wurde C# verwendet. Die Beispielanwendung „MinCover“ zeigt die Anwendung dieser Algorithmen und nutzt zur graphischen Visualisierung der Ergebnisse die ”Netron Graph Bibliothek”(auch Projekt bei SF.Net).

Vorabversion zur Framework Version 2.0.2006.0809

1 Definitionen

Grundlegende Definitionen über die minimale Überdeckung von funktionalen Abhängigkeiten. [1]

1.1 Was sind funktionale Abhängigkeiten?

Funktionale Abhängigkeiten (Abk. *FA* , englisch functional dependency , FD) sind die Grundlage für die Normalisierung von Relationenschemata in der Datenbankwelt. Sie bilden somit die Grundvoraussetzung für die Analyse und Verbesserung von gegeben Schemata.

Eine Relation wird durch *Attribute* definiert. Einige dieser Attribute können nun andere Attribute eindeutig bestimmen, diese Beziehung nennt man funktionale Abhängigkeit. So kann man sich zum Beispiel vorstellen das in einer Kundendatenbank, eine Kundennummer genau zu einem Kundenname führt. Dies würde man wie folgt aufschreiben:

$$[\ \text{Kundennummer} -> \text{Kundenname}\ ]\ ^{2}$$

Weiter kann man sich nun aber auch überlegen, das z.B. der Straßename und der Ort die Kundennummer eindeutig bestimmen. Dies lässt aber nun auch die Folgerung zu, das der Straßenname und der Ort den Kundennamen eindeutig bestimmen. In diesem Fall hängen der Straßename und der Ort zusammen, so spricht von einem *zusammengesetzten Attribut* oder *Attributmenge* . Diese funktionale Abhängigkeit schreibt man wie folgt auf:

$$[\ \text{Straßenname Ort} -> \text{Kundennummer}\ ]$$
$$[\ \text{Straßenname Ort} -> \text{Kundenname}\ ]$$

oder zusammengeschrieben[3]:

$$[\ \text{Straßenname Ort} -> \text{Kundennummer Kundenname}\ ]$$

Bestimmen nun einige Attribute einer Relation eindeutig die Werte aller Attribute der Relation, so spricht man von einem Superschlüssel , d.h. jedes einzelne Attribut der gesamten Relation ist durch diese Attribute eindeutig bestimmt. (2) Einen minimalen Superschlüssel nennt man Schlüsselkandidat , wenn er eine minimale Attributmenge ist, von der alle Attribute der Relation funktional abhängig sind. (1)

Beispiel 1.1 *Gegeben sei folgenden Relation R:*

R	*A*	*B*	*C*
	1	*1*	*3*
	1	*1*	*3*
	1	*2*	*4*

[1] Im weiteren Verlauf sind funktionale Abhängigkeiten und Funktionalabhängigkeiten äquivalent und wird abgekürzt mit FA.

[2] Notation in Anlehnung in die spätere Anwendung des Frameworks

[3] weitere Regeln für FA im Satz 1.1 Axiome von Armstrong

In diesem Beispiel ist C funktional abhängig von A und B, geschrieben:

$$[\ A\ B\ ->\ C\ ]$$

Der Pfeil kann somit gelesen werden als „bestimmt eindeutig". Aber C ist nicht funktional abhängig von A allein.

Es gelten auch die funktionalen Abhängigkeiten (und sonst keine weiteren mehr):

$$[\ C\ ->\ A\ ]$$
$$[\ B\ ->\ A\ ]$$
$$[\ B\ ->\ C\ ]$$

Definition 1.1 (Formale Definition einer funktionalen Abhängigkeit) *Sei $r(R)$[4] eine Relation mit Schemata R und seien α und β Teilmengen von Attributen aus dem Schemata von R. Sei $t \in r(R)$ ein Tupel aus der Relation R. Dann ist $t.\alpha$ die Einschränkung (Projektion) des Tupels t auf die Attribute aus α. Die funktionale Abhängigkeit $[\alpha -> \beta]$ (β ist funktional abhängig von α) gilt auf R, wenn für jedes Tupel aus $r(R)$ gilt:*

$$\forall t_1, t_2 \in r(R) : t_1.\alpha = t_2.\alpha \Rightarrow t_1.\beta = t_2.\beta$$

Das heißt, für alle $t_1, t_2 \in r(R)$ mit gleichen α-Attributen gilt auch, dass ihre β-Attribute über einstimmen. Die Werte der Attribute aus der Attributmenge α bestimmen somit die Werte aus der Attributmenge β eindeutig. β heißt nun voll funktional abhängig von α, wenn aus α kein Attribut mehr entfernt werden kann, so dass die Bedingung immer noch gilt.

Satz 1.1 (Axiome von Armstrong) *Mit Hilfe der Axiome von Armstrong (auch Armstrong Axiome) lassen sich aus einer Menge von funktionalen Abhängigkeiten, die auf einer Relation gelten, weitere funktionale Abhängigkeiten ableiten. Die folgenden drei Regeln reichen aus, um alle funktionalen Abhängigkeiten herzuleiten:*

1. *Eine Menge von Attributen bestimmt eindeutig die Werte einer Teilmenge dieser Attribute (triviale Abhängigkeit), d.h. $\beta \subseteq \alpha \Rightarrow \alpha \rightarrow \beta$ (Reflexivitätsregel).*
2. *Gilt $\alpha \rightarrow \beta$, so gilt auch $\alpha\gamma \rightarrow \beta\gamma$ für jede Menge von Attributen γ (Erweiterungsregel, Verstärkung).*
3. *Gilt $\alpha \rightarrow \beta$ und $\beta \rightarrow \gamma$, so auch $\alpha \rightarrow \gamma$ (Transitivitätsregel).*

Die Armstrong-Axiome sind korrekt und vollständig [5], d.h. sie beschreiben nur semantisch gültige Implikationen und mit ihnen sind alle semantisch gültigen Implikationen herleitbar.

Auch sind folgende Herleitungsregeln oft nützlich, sie folgen bereits aus den Armstrong-Axiomen:

4. *Gelten $\alpha \rightarrow \beta$ und $\alpha \rightarrow \gamma$, so gilt auch $\alpha \rightarrow \beta\gamma$ (Vereingungsregel).*
5. *Gilt $\alpha \rightarrow \beta\gamma$, so gelten auch $\alpha \rightarrow \beta$ und $\alpha \rightarrow \gamma$ (Dekompositions-/Zerlegungsregel).*
6. *Gilt $\alpha \rightarrow \beta$ und $\gamma\beta \rightarrow \delta$, so auch $\alpha\gamma \rightarrow \delta$ (Pseudotransitivitätsregel).*

[4] $r(R)$ ist die Ausprägung (bzw. Zustand) der Relation mit dem Schemata $R =< A_1, \ldots, A_n >$, wobei $A_1, \ldots A_n$ Attribute sind.

[5] siehe (1)

1.2 Abschluss, Hülle und Transitivität

Um nun die minimale Überdeckung berechnen zu können, müssen wir noch ein paar Eigenschaften definieren, die wir im Zusammenhang mit Mengen von funktionalen Abhängigen brauchen. Diese Eigenschaften sind ziemlich grundlegend und werden von vielen weiteren Algorithm genutzt.

Definition 1.2 (Abschluss bzgl. einer Attributmenge) *X^+ ist der Abschluss einer Attributmenge X bezüglich einer Menge von funktionalen Abhängigkeiten F. Sie umfasst die Menge aller Attribute Y, für die gilt $X \rightarrow Y$ in $F^+(X)$ bzw. F^*.*

Sei die Attributmenge U gegeben durch alle Attribute, die in F vorkommen, so wird der Abschluss bzgl. der Attributmenge $X \subseteq U$ wie folgt definiert:

$$X^+ := \{Y \in U | [X \rightarrow Y] \in F^+(X)\}$$

Definition 1.3 (Hülle bzgl. einer Attributmenge) *$F^+(X)$ ist die Hülle einer Menge von funktionalen Abhängigkeiten F bezüglich einer Attributmenge X. Sie erweitert die vorhandenen funktionalen Abhängigkeiten F mit funktionalen Abhängigkeiten, die sich transitiv (nach Regel 3 aus Satz 1.1) aus F berechnen lassen und auf der linken Seite der funktional Abhängigkeiten die Attributmenge X enthält.*

Somit erhält man einen rekursiven Aufbau der gesuchten Menge $F^+(X)$:

$$\begin{aligned} F^+(X) \quad := \quad & \{F\} \\ & \cup \{[X \rightarrow Y_1] | [X \rightarrow Y_0] \in F \wedge [Y_0 \rightarrow Y_1] \in F\} \\ & \dots \\ & \cup \{[X \rightarrow Y_n] | [X \rightarrow Y_0] \in F \wedge \dots \wedge [Y_0 \rightarrow Y_n] \in F\} \end{aligned}$$

Definition 1.4 (Transitive Hülle) *...*

1.3 Äquivalenz von FA-Mengen

Um nun noch Überdeckungen zu vergleichen, brauchen wir folgende Definition:

Definition 1.5 (Äquivalenz) *Seien F und G zwei Mengen von funktionalen Abhängigkeiten mit gleichen Attributmengen. F und G sind äquivalent, wenn $F^+ = G^+$, d.h. wenn ihre Hüllen gleich sind. F heißt auch **Überdeckung** von G und umgekehrt.*

Anschaulich ausgedrückt, beide Mengen müssen die gleichen Abhängigkeiten enthalten, entweder direkt oder durch die transitive Hülle.

1.4 Determinanten

...

1.5 Minimale Überdeckung

Die minimale Überdeckung lässt sich nun wie folgt definieren:

Definition 1.6 (Minimale Überdeckung) *Eine Menge von funktionalen Abhängigkeiten F* ***ist minimal****, wenn gilt:*

1. *Jede rechte Seite von einer FA in F besteht aus einem Attribut (Kanonisierung).*
2. *Es gibt kein* $[X \rightarrow A]$ *in F, so dass die Menge* $F - [X \rightarrow A]$ *äquivalent zu F ist.*
3. *Es gibt kein* $X \rightarrow A$ *in F und keine echte Untermenge Z von X, so dass* $F - \{X \rightarrow A\} \cup \{Z \rightarrow A\}$ *äquivalent zu F ist.*

2 Datenstruktur

In diesem Abschnitt werde ich die grundlegenden Datenstruktur und -typen des Framework definieren. Die Struktur wird in UML angeben und die Definition der Datentypen erfolgt in Pseudo-Code, angelehnt an die Microsoft C# Notation.

2.1 Objekt-Modell

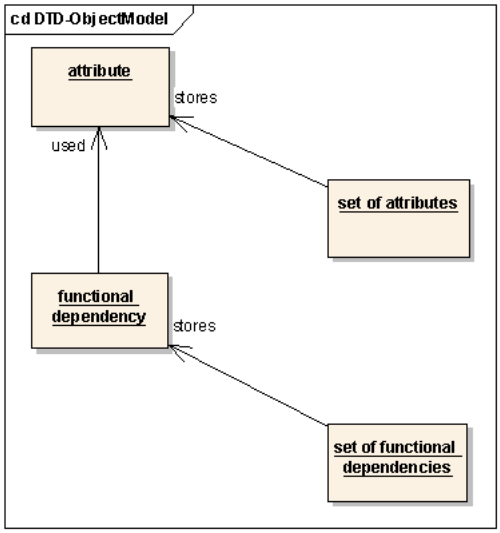

Abbildung 2.1: Objekt-Modell

Wie in Abbildung 2.1 zu sehen ist, gibt es vier grundlegende Datentypen: Attribute (attribute), Menge von Attributen (set (list) of attribute), funktionale Abhängigkeiten (functional dependency) und Menge von funktionalen Abhängigkeiten (set (list) of functional dependencies).

Wie auch in der Abbildung 2.1 zu sehen ist, besteht ein enger Zusammenhang zwischen diesen Datentypen. Ein Attribut ist so zu sagen der Grundbaustein, da alle anderen Datentypen ihn verwenden. Ein Attribut kann sich aus einem einzelnen Element, z.B. A, oder einer Menge von Elementen zusammensetzen, z.B. A B C ... .

Auf diesen Datentyp Attribut baut nun die Menge (oder auch Liste) von Attributen auf. Der Begriff Menge kann hier im mathematischen Sinne auf gefasst werden, da die Reihenfolge der Attribute keine Rolle spielt und doppelte Attribute ignoriert werden. Die Menge von Attributen enthält, wie der Name schon sagt, einzelne Elemente vom Datentyp Attribut.

Der Datentyp funktionale Abhängigkeit realisiert nun mit dem Datentyp Attribut eine funktionale Abhängigkeit wie man sie kennt. Sie setzt sich aus einer linken und rechten Seite zusammen, die jeweils durch ein Attribut repräsentiert wird.

Zum Schluss gibt es noch den Datentyp Menge von funktionalen Abhängigkeiten, der das Gegenstück zu dem Datentyp Menge von Attributen ist. Die Menge von funktionalen Abhängigkeiten unterstützt die meisten Operationen und ist daher für die Berechnung von großer Bedeutung.

2.2 Attribute und ihre Mengen

Datentyp Attribute

Wie in Abbildung 2.2 zu sehen ist, definiert das Interface IAttribute die notwendigen Schnittstellen für das Objekt Attribute. Die Klasse Attribute ist dann die konkrete Implementierung des Interface.

Ein Attribut wird eindeutig über seinen Namen identifiziert. Ein Attribut kann einfach, d.h. nur einen Namen haben, oder zusammengesetzt sein, d.h. mehrere Namen haben, z.B. A B C ... . Das Attribut speichert seine Namen alphabetisch.

Datentypdefinition 2.1

Interface: IAttribute
Class: Attribute
Namespace: NetPage_Germany.MinCover.Framework
Sichtbarkeit: Public

public void Add(String name);

public void Add(String[] names);

public void Remove(String name);

public void Remove(String[] names);

public Boolean Equals(IAttribute attribute);

public Boolean Contains(IAttribute attribute);

public String GetAttributeName();

public String[] GetAttributeNames();

public IAttribute GetCopyOf();

public Boolean IsJoinedAttribute();

public int Size
{
get;
}

public String ToString();

Datentyp AttributeList

Wie in Abbildung 2.2 zu sehen ist, definiert das Interface IAttributeList die notwendigen Schnittstellen für das Objekt Menge von Attributen. Die Klasse AttributeList ist dann die konkrete Implementierung des Interface.

Die Menge von Attributen kann Attribute aufnehmen und diese dann auch wieder entfernen. Die Attribute werden in alphabetischer Reihenfolge gespeichert, man kann abfragen, ob ein Attribut in der Liste enthalten ist oder nicht.

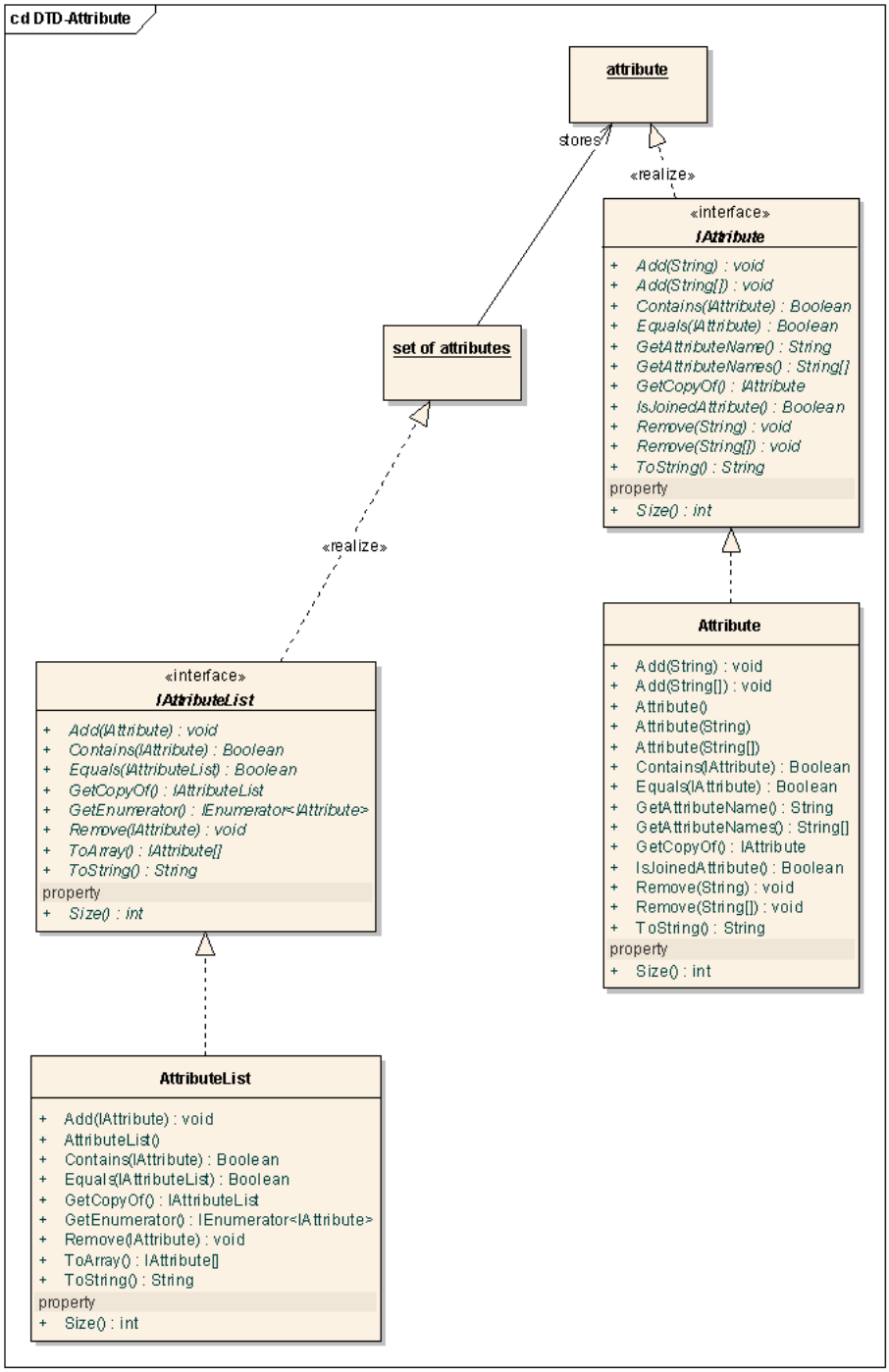

Abbildung 2.2: Attribut und Menge von Attributen

Datentypdefinition 2.2

Interface: IAttributeList
Class: AttributeList
Namespace: NetPage_Germany.MinCover.Framework
Sichtbarkeit: Public

public void Add(IAttribute attribute);

public void Remove(IAttribute attribute);

public void Boolean Contains(IAttribute attribute);

public Boolean Equals(IAttributeList attributeList);

public IEnumerator<IAttribute> GetEnumerator();

public IAttributeList GetCopyOf();

public int Size
{
get;
}

public IAttribute[] ToArray();

public String ToString();

2.3 Funktionale Abhängigkeiten und ihre Mengen

Datentyp FunctionalDep

Wie in Abbildung 2.3 zu sehen ist, definiert das Interface IFunctionalDep die notwendigen Schnittstellen für das Objekt funktionale Abhängigkeit. Die Klasse FunctionalDep ist dann die konkrete Implementierung des Interface.

Die funktionale Abhängigkeit verhält sich ganz wie erwahrtet. Die Attribute der linken bzw. rechten Seite sind nach ihrem Namen alphabetisch geordnet.

Datentypdefinition 2.3

Interface: IFunctionalDep
Class: FunctionalDep
Namespace: NetPage_Germany.MinCover.Framework
Sichtbarkeit: Public

public Boolean Equals(IFunctionalDep FA);

public IAttribute LeftSide
{
get;
}

public IAttribute RightSide
{

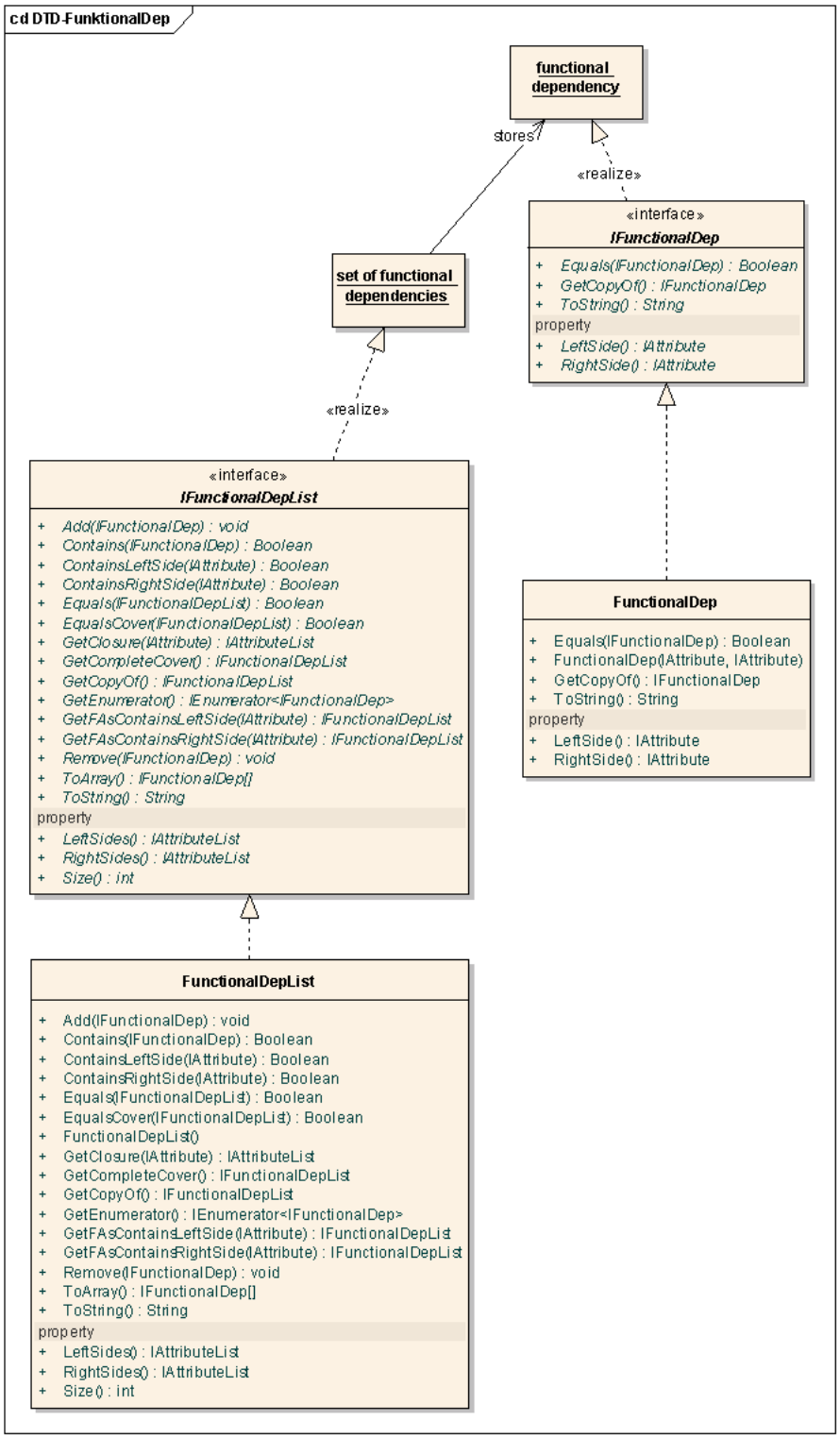

Abbildung 2.3: Attribut und Menge von Attributen

get;
}

public IFunctionalDep GetCopyOf();

public String ToString();

Datentyp FunctionalDepList

Wie in Abbildung 2.3 zu sehen ist, definiert das Interface IFunctionalDepList die notwendigen Schnittstellen für das Objekt Menge von funktionale Abhängigkeit. Die Klasse FunctionalDepList ist dann die konkrete Implementierung des Interface.

Dieser Datentyp ist wichtigste Datentyp, um Berechnungen auf funktionalen Abhängigkeiten durchzuführen. Er wird später von den Algorithmen in Abschnitt 3 verwendet. Grundsätzlich speichert er die einzelnen Abhängigkeiten, doppelte FAen werden ignoriert. Die FAen werden in alphabetischer Reihenfolge gespeichert. Man kann prüfen, ob eine FA enthalten ist, den Abschluss bzgl. eines Attributes berechnen, gleiche Überdeckung ...

Datentypdefinition 2.4
Interface: IFunctionalDepList
Class: FunctionalDepList
Namespace: NetPage_Germany.MinCover.Framework
Sichtbarkeit: Public

public void Add(IFunctionalDep FA);

public void Remove(IFunctionalDep FA);

public Boolean Contains(IFunctionalDep FA);

public Boolean ContainsRightSide(IAttribute attribute);

public Boolean ContainsLeftSide(IAttribute attribute);

public Boolean Equals(IFunctionalDepList FAList);

public Boolean EqualsCover(IFunctionalDepList FAList);

public int Size
{
get;
}

public IEnumerator<IFunctionalDep> GetEnumerator();

public IFunctionalDepList GetFAsContainsLeftSide(IAttribute attribute);

public IFunctionalDepList GetFAsContainsRightSide(IAttribute attribute);

public IAttributeList LeftSides
{
get;
}

public IAttributeList RightSides
{

```
  get;
 }
public IFunctionalDepList GetCopyOf();
public IFunctionalDepList GetCompleteCover();
public IAttributeList GetClosure(IAttribute attribute);
public IFunctionalDep[] ToArray();
public String ToString();
```

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3 Algorithmen

Die Definition der Algorithmen erfolgt in Pseudo-Code, angelehnt an die Microsoft C# Notation. Auf die Definition der Datenstruktur wurde bereits in Abschnitt 2 eingegangen.

Allgemeine Variablen und ihre Bedeutung[6]*:*

Variable	Bedeutung
X, Y, Z	Variable für Attribute (können auch zusammengesetzte Attribute sein), siehe Datentyp 2.2 Attribut
FA	eine funktionale Abhängigkeit mit den Attributen X und Y, siehe Datentyp 2.3 funktionale Abhängigkeit
$X \rightarrow Y$	
F, G	Variablen für die Mengen von funktional Abhängigkeiten, siehe Datentyp 2.3 Menge von funktionalen Abhängigkeiten

Bemerkung 3.1 *Die Datenstrukturen für die Listen von Attributen und FAs ignorieren mehrfach gleiche Einträge, z.B.* $F = (\{X \rightarrow Y\}) \Rightarrow F \leftarrow F \cup \{X \rightarrow Y\} \Rightarrow F = (\{X \rightarrow Y\})$*, genauso bei Attributlisten.*

3.1 Algorithmus Closure (Abschluss)

Ein einfacher Algorithmus zur Bestimmung von X^+(Abschluss von F bzgl. einer Attributmenge X). Der Algorithmus baut iterativ eine Kette der von X erreichbaren Attribute auf. Er liefert eine Liste der Attribute zurück.

Algorithm 3.1 CLOSURE

Eingabe: Ein Attributen X (auch zusammengesetzte) und eine Menge von FA F
Ausgabe: X^+ (eine Menge von Attributen (auch zusammengesetzte)) bzgl. F

```
1:  OLDDEP ← ()
2:  NEWDEP ← () ∪ X
3:  while NEWDEP ≠ OLDDEP do
4:     OLDDEP ← NEWDEP
5:     for all FA Y → Z ∈ F do
6:        if Y ⊆ NEWDEP then
7:           NEWDEP ← NEWDEP ∪ Z
8:        end if
9:     end for
10: end while
11: return NEWDEP
```

Bemerkung 3.2 *Die Variablen OLDDEP und NEWDEP sind in dem Algorithmus 3.1 Mengen von Attributen.*

[6] wenn nichts anderes definiert ist

3.2 Algorithmus Member

Testen der Mitgliedschaft einer FA bzgl. F, d. h. es wird geprüft, ob die FA in F ist. Der Algorithmus prüft, ob die rechte einer FA: $X \rightarrow Y$ in dem Abschluss von X bzgl. F liegt.

Algorithm 3.2 MEMBER

Eingabe: FA $X \rightarrow Y$, F
Ausgabe: `TRUE`, wenn $F \models X \rightarrow Y$, sonst `FALSE`

```
1: if Y ⊆ CLOSURE(X, F) then
2:     return(TRUE)
3: else
4:     return(FALSE)
5: end if
```

Bemerkung 3.3 *Der Algorithmus verwendet den Algorithmus 3.1 Closure (Abschluss).*

3.3 Algorithmus Minimale Überdeckung (MinCover)

Für eine gegebene Menge von funktionalen Abhängigkeiten lässt sich eine äquivalente Menge von Funktionalrelationen mit jeweils einem Attribut auf der rechten Seite (kanonisierte FAs) finden. Dabei wird eine FA vorläufig entfernt und dann geprüft, ob die entfernte FA sich aus den noch vorhandenen FAs rekonstruieren lassen.

Algorithm 3.3 MINCOVER

Eingabe: eine Menge F von FAs (siehe Bemerkung 3.5)
Ausgabe: eine minimale Überdeckung für F

```
1: G ← F
2: for all FA {X → Y} ∈ F do
3:     if MEMBER({X → Y}, G − {X → Y}) then
4:         G ← G − {X → Y}
5:     end if
6: end for
7: return G
```

Bemerkung 3.4 *Dieser Algorithmus verwendet den Algorithmus 3.2 (MEMBER) und implizit auch der Algorithmus 3.1 (CLOSURE).*

Bemerkung 3.5 *Die Eingabemenge sollte bereits voroptimiert sein, dann liefert der Algorithmus bessere minimale Überdeckungen, siehe dazu die Algorithmen zur Optimierung der Eingabemenge.*

Bemerkung 3.6 *Zeile 2: Bei MEMBER($\{X \rightarrow Y\}$, $G - \{X \rightarrow Y\}$) soll (und darf!) die Menge G nicht verändert werden.*

3.4 Algorithmus Gleiche Überdeckung (SAMECOVER)

Berechnet von zwei Mengen von FAs F und G, ob sie die gleiche Überdeckung erzeugen. Dabei werden zunächst alle möglichen Determinaten der beiden Menge erzeugt und verglichen. Voraussetzung für diese Verfahren ist, das die Eingabemengen kanonisch (siehe

Algorithmus 3.5 (KANONIZE)) und vorkorrigiert (siehe Algorithmus 3.8 (DETCREATION)) sind, damit die Mengen möglichst einfach sind.

Algorithm 3.4 SAMECOVER

Eingabe: zwei Mengen F und G von FAs
Ausgabe: `TRUE`, wenn die Überdeckung gleich ist, sonst `FALSE`

```
1:  F' ← DETCREATION(F)
2:  G' ← DETCREATION(G)
3:  b ← TRUE
    {F' < G' Testet, welche Menge größer ist.}
4:  if F' < G' then
5:     for all FA X → Y ∈ F' do
6:        b ← FA ⊆ G'
7:     end for
8:  else
9:     for all FA X → Y ∈ G' do
10:       b ← FA ⊆ F'
11:    end for
12: end if
13: return b
```

3.5 Algorithmen zur Optimierung von funktionalen Abhängigkeitsmengen

Algorithmen zur Kanonisierung bzw. zur Dekanonisierung

Kanonisierung bzw. Dekanonisierung einer Menge von funktionalen Abhängigkeiten. Nach der Kanonisierung darf auf der rechten Seite einer FA nur noch ein Attribut stehen, bei FA, die mehr als ein Attribut auf der rechten Seite haben, wird die FA auf mehrere FAs aufteilt. Bei der Dekanonisierung wird dieser Prozess wieder rückgängig gemacht, d. h. bei gleichen linke Seiten, sofern vorhanden, werden die rechten Seiten wieder zusammengefasst.

Algorithm 3.5 KANONIZE

Eingabe: Menge F von FAs
Ausgabe: kanonisierte Menge von FAs

```
1:  G ← ()
2:  for all FA X → Y ∈ F do
3:     if zusammengesetztes_Attribut(Y) then
4:        for all Z ∈ Y do
5:           G ← G ∪ {X → Z}
6:        end for
7:     else
8:        G ← G ∪ {X → Y}
9:     end if
10: end for
11: return G
```

Bemerkung 3.7 *Der Algorithmus 3.5 (KANONIZE) sollte immer im Vorfeld der Berechnung der minimale Überdeckung ausgeführt werden. Dies reduziert die Komplexität der Algorithmen*

3.3 (MINCOVER), man muss nicht darauf achten, ob die rechte Seite ein zusammengesetztes Attribut ist.

Algorithm 3.6 DEKANONIZE

Eingabe: Menge F von FAs
Ausgabe: dekanonisierte Menge von FAs

```
1:  G ← ()
2:  for all FA X → Y ∈ F do
3:     for all FA X' → Y' ∈ F do
4:        if X = X' then
5:           Y ← Y ∪ Y'
6:        end if
7:     end for
8:     G ← {X → Y}
9:  end for
10: return G
```

Bemerkung 3.8 *Der Algorithmus 3.6 (DEKANONIZE) dient nur zur besseren Darstellung der Ergebnismenge von FAs. Er hat keine weitere Bedeutung in der Berechnung der minimalen Überdeckung der funktionalen Abhängigkeiten.*

Algorithmen zur Optimierung der Menge von FAs

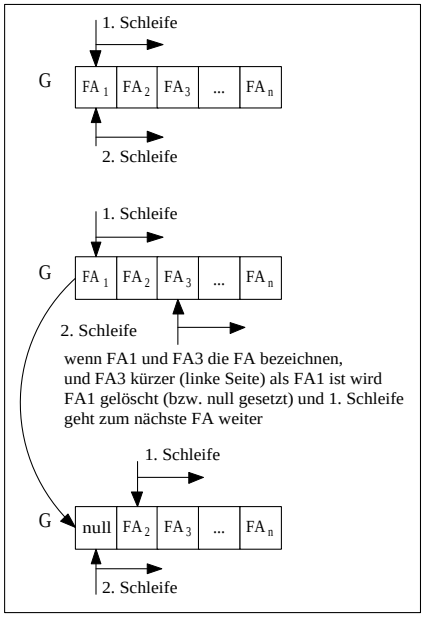
Verschiedene Algorithmen zur Optimierung der Eingabemenge von FAs.

Algorithmus CORRECTION Der Algorithmus 3.7 (CORRECTION) reduziert die Eingabeliste für den Algorithmus 3.3 (MINCOVER), indem er unnötige FA streicht. Dies hat zur folge das nach der Korrektur nur noch notwendige FAs existieren und die linken Seiten so kurz wie möglich sind. Im Vorfeld der Korrektur, muss der Algorithmus 3.5 (KANONIZE) und 3.8 (DETCORRECTION) ausgeführt werden, weil die Korrektur bei der rechten Seite nicht auf zusammengesetzte Attribute achtet und nicht die rechte Seite weiter ableitet.
Allgemeine Arbeitsweise des Algorithmus (siehe auch Abbildung):

1. wähle die erste FA aus
2. prüfe ob es zu dieser FA eine kürze FA in F gibt, die die selbe Funktionalabhängigkeit beschreibt
3. wenn dies der Fall ist lösche diese gewählte FA und wähle die nächste FA aus F und gehe zu Schritt 2, dies wird solange aus geführt, bis die Liste der FAs abgearbeitet ist.

Beispiel 3.1 (Beispiel für Algorithmus CORRECTION)

$$F = (\{A \to D\}, \{AB \to D\}, \{ABC \to D\}) \Rightarrow F' = (\{A \to D\})$$



Algorithm 3.7 CORRECTION

Eingabe: eine Menge F von FAs (kanonisiert)
Ausgabe: eine reduzierte Menge G von FAs ohne unnötige FAs

```
1:  G ← F
2:  for all FA1 X → Y ∈ G do
3:     for all FA2 X' → Y' ∈ G do
4:        if FA1 ≠ FA2 and Y = Y' and X' ⊆ X then
5:           G ← G − {X → Y}
6:           break
7:        end if
8:     end for
9:  end for
10: return G
```

Algorithmus DETCREATION Der Algorithmus 3.8 erzeugt alle Determinanten einer Menge von FAs, d.h. es werden zu jedem Attribut X einer FA $X \rightarrow Y$ alle FA hinzugefügt, die von X aus erreicht werden können. Die Arbeitsweise von DETCREATION ist relativ simpel, es wird zu jeder FA $X \rightarrow Y$ mit Hilfe des Algorithmus 3.1 CLOSURE(X,F) der Abschluss berechnet. Mit Hilfe der so bestimmten Menge von (erreichbaren) Attributen aus dem Abschluss, lässt sich jetzt zu jeder FA $X \rightarrow Y$ alle rechten Seiten, die von X erreichbar sind, herstellen.
Führe für jede FA $X \rightarrow Y$ in F folgende Schritte durch:

1. bestimme den Abschluss von X bzgl. F
2. dann werden neue FAs erzeugt, in der Form FA $X \rightarrow Y'$ für alle $Y' \in$ CLOSURE(X,F)

Bemerkung 3.9 *Die Variable A sei in dem Algorithmus 3.8 eine Menge von Attributen.*

[6] Arbeitsweise des Algorithmus KORRECTION

Algorithm 3.8 DETCREATION

Eingabe: Menge F von FAs
Ausgabe: Menge aller Determinaten der Eingabemenge

```
1: A ← ()
2: G ← ()
3: for all FA X ← Y ∈ F do
4:    A ← CLOSURE(X,F)
5:    for all Y' ∈ A and Y' ≠ X do
6:       G ← G ∪ {X → Y'}
7:    end for
8: end for
9: ...ERWEITERUNG...
10: return G
```

4 Programm

4.1 Verwendete Frameworks - Netron Graph Library Version 2.2

Siehe dazu die Netron Graph Libray

Summary of essential features - Solid open source C# code, totally free - Fully CLS compliant, can be used in any .Net language - Easy to use - Visual Studio toolbox controls - Drag-drop support - Extensive code comments, tutorials, complete applications and documentation online - Integrates into the Netron framework (NAF) but can be used outside it too - Programming interface to handle graphs, node and connections - Interactive editing and context menu's - Plugable and extensible model (uses .Net reflection) of shapes, connections and shape libraries - Layout algorithms - Support for visual data flow programming paradigm and development environments - Support for GraphML - Zoom in and out of the canvas - Continuously improved and used in our own applications - Fully supports the CLR and 100% managed code, no extra assemblies required - Full interactive access to traditional graph algorithms (Dijkstra, Floy, Prim,...) - Ships with advanced applications showing in detail how to use in real-world applications

Solid open source code The source code was written and architectured with care and contains a lot of coding comments in case you want to tweak the library or simply understand the mechanics. You can find extensive help, tutorials and other stuff online on the Netron site. Support is available via the forums on the Netron site, we would be glad to hear from you and receive some feedback to improve the library.

Layout algorithms Layout algorithms try to organize graphs in a visually pleasing way. The Netron graph control contains the spring embedder algorithm and the tree or rectangular algorithm. In future version more algorithms will be supplied and more graph mathematics will be fused into the graph control.

What's in the box? If you start up the Visual Studio solution under the 'GraphApplications' directory, you will see the following list of projects. See also the Setup topic below. the AutomataShapes library is a collection of graph shapes for the Automatron application the Automatron application shows some advanced custom shapes the BasiShapes library is a collection of general purpose graph shapes the Biotron application (aka Visual Logo) shows how to implement the visual programming paradigm with the graph library the BiotronCore library contains the essential classes and interface of the Biotron application the BiotronShapes library is a collection of graph shapes to give life to the bionts of the Biotron application the GenericGraphApplication application is a simple demonstration of the graph library accessing some of its most basic properties and features the GraphAnalysis application shows how you can benefit from the graph library and the data structures library to do some traditional graph analysis the GrooglerII application is an example of how you can use the graph layout algorithm to represent and lay out knowledge graphs the NetronDataStructures library is a collection of well-known data structures (queue, graph, stack, linked list and so on) the NetronGraphLib library is the actual graph assembly with the graph control and other elements related to it the NetronMaths library is a collection of classes related to mathematical operations

What can I do with it? This application is in the first place a drawing application with which you can create basic diagrams and flowcharts (similar to Microsoft Visio). It is fairly easy to extend the shipped drawing shapes with your own, see the online tutorial ' How to implement and use automata shapes' for details. Some advanced features like the data flow and the layout algorithm are not used by this application, if you wish to try these out see (respectively) the Biotron application above and the Groogler application below.

This application shows how to use the various traditional graph algorithms from the new Netron data structures library and how the results can be shown interactively using the graph library.

The Netron graph library can be used for doing traditional graph analysis, i.e. testing graph-like structures for:

shortest path

connectedness

cyclic property

Hamiltonian property

and so on. Since the graph data structure (as well as other) is widely used and emphasis was put on data flow aspects of the graph library, the graph analysis part was taken to a separate assembly called the 'NetronDataStructures'. The graph analysis application shows you how you can combine the aforementioned library and the graph control to explore graphs and their mathematical properties.

This application and the algorithms behind require some mathematical background though the basic ideas are simple to grasp. It would require a textbook to explain all the machinery behind and the current assemblies are by no means complete since the field of graph theory is really a world on its own. Despite this, this current version should allow a wider audience of users to use the graph control and to implement more refined layout algorithms since these algorithms often depend on the precise mathematical form of graphs.

Recently a lot of research is going on in graph theory and random networks in particular. The so-called small-world phenomenon, also called six degrees of freedom, pervades both technology and natures: the way our brain is connected, the way the internet hangs together, the social relationships of people...it seems to underly a lot of systems. In this graph analysis demo you can experiment with various random graph algorithm, among which the Watts-Strogatz small-world algorithm.

The Netron data structures contains a lot of structures, among which the 'graph' class and the 'algorithms' class. First, a random graph is generated corresponding to a random adjacency matrix. This matrix is used to feed the graph class and the algorithm class, containing the various graph algorithms. Once, these class have outputted their calculations, a loop is going over the newly created adjacency matrix to draw the directed graph. In this way, both libraries (the graph library and the data structures) are independent and can be used independently of each other.

How the algorithms work and the theory behind it lies outside the scope of this document but you will find more information on the Netron site.

Index

Literatur

[1] Lipeck, Prof. Dr. Udo: *Datenbanksysteme IIa Wintersemester 2005/06*. Vorlesung Datenbanksysteme, 2005/06.

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A Project Summary

The project „MinCover“ is an academic framework for functional dependencies (FD) with algorithms for the computation of the minimum cover, complete cover and equal cover. The framework implements the full spectrum of functional dependencies with attributes, lists on attributes and lists on functional dependencies.

As programming language Microsoft C# was used. The application of examples „MinCover“ shows the application of these algorithms and uses for the graphic visualization of the results the „Netron Graph Library“ (see project Netron Reloaded on SF.Net).

The project is under GNU Library or „Lesser“ General Public License (LGPL).

B GNU Lesser General Public License

Version 2.1, February 1999

[This is the first released version of the Lesser GPL. It also counts as the successor of the GNU Library Public License, version 2, hence the version number 2.1.]

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