Relationen-Algebra und Persistenz

Implementierungskonzepte und Anforderungen an Attributdatentypen

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Inhalt

- Datentypen und Operationen der RelationAlgebra
- DBArrays und FLOBs
- Attributsdatentypen
- Tupel
- Referenzzähler
- Komplexere Type-Mappings
- Tipps zum Debugging

Grundlegende Datentypen

- Kinds: IDENT, DATA, TUPLE, REL
- Typkonstruktoren: *rel* und *tuple*

```
             Name: tuple
        Signature: (ident x DATA)+ -> TUPLE
Example Type List: (tuple((name string)(age int)))
         List Rep: (<attr1> ... <attrn>)
     Example List: ("Myers" 53)

             Name: rel
        Signature: TUPLE -> REL
Example Type List: (rel(tuple((name string)(age int))))
         List Rep: (<tuple>*)where
                    <tuple> is (<attr1> ... <attrn>)
     Example List: (("Myers" 53)("Smith" 21))
```

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  Example: query cities feed consume

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     Name: filter
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   Syntax: _ filter [ fun ]
  Meaning: Only tuples, fulfilling a certain condition are
           passed on to the output stream.
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     Name: attr
Signature: ((tuple ((x1 t1)...(xn tn))) xi)  -> ti)
   Syntax: attr ( _ , _ )
  Meaning: Returns the value of an attribute at a given position.
  Remarks: not for use with sos-syntax
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Mit diesen Operationen kann die Selektion im folgenden Beispiel realisiert werden:

Grundlegende Operationen

```
Secondo =>
   query cities feed filter[.population > 500000] consume;
```

Grundlegende Operationen

```
Secondo =>
   query cities feed filter[.population > 500000] consume;
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Übersetzung der Query in die Listendarstellung

Grundlegende Operationen

```
Secondo =>
   query cities feed filter[.population > 500000] consume;

(query
    (consume
        (filter
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                (tuple1 TUPLE)
                (>
                    (attr tuple1 population)
                    500000)))))
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.spec-File:
Benutzung von Argumentfunktionen mit
impliziten Parametern und des Typabbildungsoperators **TUPLE**:

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.spec-File:
Benutzung von Argumentfunktionen mit impliziten Parametern und des Typabbildungsoperators **TUPLE**:

```
operator filter alias FILTER
   pattern _ op [ fun ]
   implicit parameter tuple type TUPLE
```

Grundlegende Operationen

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```
Type mapping for operator filter:
RelationAlgebra: filter (algId=3, opId=5) accepted!
IN: ((stream (tuple ((name string) (population int))))
     (map (tuple((name string) (population int))) bool))
OUT: (stream (tuple ((name string) (population int))))
```

FLOB

- Datenstruktur zur Speicherung beliebiger Datenmengen
- Eingebauter Persistenzmechanismus
- Verwaltet "**unstrukturierte Speicherblöcke**" (wie `malloc`)
- Zugriff mittels spezieller Funktionen und eines "**offsets**"

```
class FLOB
{
    FLOB( size_t size );
    size_t Size() const;
    void Put( size_t offset, size_t length, const void *source );
    void Get( size_t offset, const char **target,
                    const bool paged = false ) const;
    void Resize( size_t size );
    void Clean();
    void Destroy();
}
```

FLOB

Achtung!

FLOBs werden direkt “en bloc” auf die Platte geschrieben.
Flobs werden an irgendeine Stelle in den Speicher eingelesen.

Verwenden Sie keine Zeiger in FLOBs, sondern **offsets**!

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DBArray

- **DBArray** ist eine Template-Klasse, die von **FLOB** abgeleitet ist.
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- Ein- und Auslagerung von Datenteilen muss daher (wie beim **FLOB**) nicht selbst programmiert werden!
- Wird ein **DBArray** sortiert abgespeichert, so ist eine effiziente externe binäre Suche möglich.

DBArray

```
template<class DBArrayElement> class DBArray : public FLOB
{
   DBArray( int n );
   int Size() const;
   void Resize( const int newSize );
   void Clear();
   void Put( int index, const DBArrayElement& elem );
   void Append( const DBArrayElement& elem );
   void Get( int index, DBArrayElement const*& elem ) const;
   void TrimToSize();
   void Sort( int (*cmp)( const void *a, const void *b) );
   bool Find( const void *key,
              int (*cmp)( const void *a, const void *b),
              int& result ) const
   void Destroy();
   [...]
}
```

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  - **Verwenden keine dynamischen Objekte/Zeiger!**

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Beispiel

Der Datentyp **`Polygon`** aus der Polygon Algebra stellt einen Datentyp dar, der

- als **Attribut** in Relationen verwendet werden kann und
- den Speicherverwaltungstyp **`DBArray`** verwendet:

Attributdatentypen (Bsp. Polygon)

```
class Polygon : public Attribute
  {
   public:
     Polygon() {}
     Polygon( const int n, const int *X = 0,
                                const int *Y = 0 );
     ~Polygon();

     int NumOfFLOBs() const;
     FLOB *GetFLOB(const int i);
     int Compare(const Attribute*) const;
       [...]
   private:
     DBArray<Vertex> vertices;
     PolygonState state;
};
```

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Klasse `Polygon` wird von Klasse `Attribute` abgeleitet

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Wichtig:

Bei Mehrfachvererbung darf keine Klasse mehrfach von derselben Klasse (z.B. `Attribute`) erben.

Sonst: Probleme bei der Typkonvertierung (cast).

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Standard-Konstruktor
Wird vom Persistenzmechanismus verwendet.
Darf das Objekt nicht verändern.

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Wichtig:
Vermeiden Sie die Nutzung des Standard-Konstruktors.
Diese führt häufig wegen uninitialisierter Werte zu Fehlern.
Initialisieren Sie Objekte mittels anderer Konstruktoren.

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Einziges **FLOB-Objekt** in Polygon

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Anzahl der FLOBs zurückgeben:

```
int
Polygon::NumOfFLOBs() const
{
  return 1;
}
```

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Den i-ten FLOB zurückgeben:

```
FLOB *Polygon::GetFLOB(const int i)
{
  assert( i >= 0 &&
          i < NumOfFLOBs() );
  return &vertices;
}
```

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     PolygonState state;
};
```

Attributdatentypen (Bsp. Polygon)

```
class Polyg
  {
   public:
     Polygon
     Polygon

     ~Polygo

     int Num
     FLOB *GetFLOB(const int i);
     int Compare(const Attribute*) const;
       [...]
   private:
     DBArray<Vertex> vertices;
     PolygonState state;
};
```

`int Compare(const Attribute* rhs) const;`

Falls beide Objekte definiert:

`*this < *rhs` ⟶ `-1`
`*this = *rhs` ⟶ `0`
`*this > *rhs` ⟶ `1`

Sonst:

`undef x def` ⟶ `-1: *this < *rhs`
`undef x undef` ⟶ `0: *this = *rhs`
`def x undef` ⟶ `1: *this > *rhs`

Attributdatentypen (Bsp. Polygon)

```
class Polygon : public Attribute
  {
   public:
     Polygon() {}
     Polygon( const int n, const int *X = 0,
                                const int *Y = 0 );
     ~Polygon();

     int NumOfFLOBs() const;
     FLOB *GetFLOB(const int i);
     int Compare(const Attribute*) const;
       [...]
   private:
     DBArray<Vertex> vertices;
     PolygonState state;
};
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     int Compare(const Attribute*) const;
       [...]
   private:
     DBArray<Vertex> vertices;
     PolygonState state;
};
```

Weitere zu überschreibende Funktionen:

```
bool Adjacent(const Attribute*) const;
Polygon *Clone() const;
bool IsDefined() const;
void SetDefined( bool defined );
size_t Sizeof() const;
```

Attributdatentypen (Bsp. Polygon)

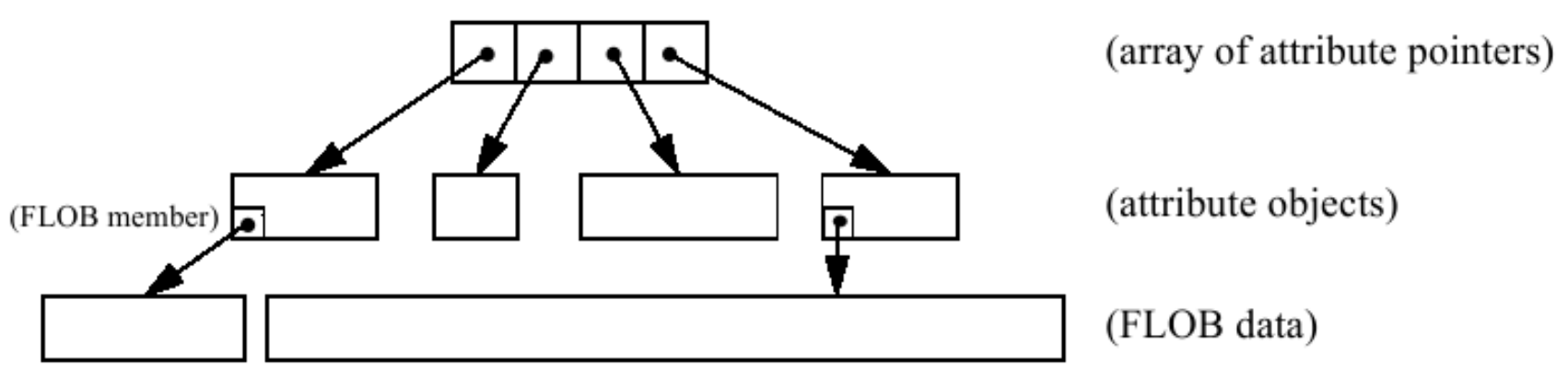
```
class Polygon : public Attribute
  {
   public:
     Polygon() {}
     int Compare(const Attribute*) const;
      [...]
   private:
     DBArray<Vertex> vertices;
     PolygonState state;
};
```

Wichtig:

Überschreibt man diese Funktionen nicht, z.B. weil man sich im Namen mit Groß- oder Kleinschreibung vertan hat, führt dies mitunter zu **Speicherfehlern**!

Tupel

- Ein Tupel wird (grob gesehen) dargestellt durch ein Array von Zeigern auf Attributdatentyp-Objekte:



- Konstruktoren

```
Tuple( TupleType* tupleType )
Tuple( ListExpr typeInfo )
```

- Zugriff auf Attribute mittels

```
Attribute* GetAttribute( int index )
void PutAttribute( int index, Attribute* attr )
void CopyAttribute(  int sourceIndex, Tuple source
                     int destIndex )
```

Referenzzähler

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- Ziel: Vermeidung teurer Kopien von Tupeln, Tupeltypen, und Attributen, z.B. in der Stromverarbeitung

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  `Clone`: Erzeugt eine Tiefenkopie (= 1. Referenz),

  `Copy`: Erzeugt eine weitere Referenz

  (max. 254 mal, dann `Clone`-Aufruf!)

  `DeleteIfAllowed`: Aufgabe einer Referenz

  (ggf. auch Löschen des Attributobjekts)

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- `CopyAttribute`: Aufruf von `Attributtyp::Copy` für ein Tupelattribut (automatische Verwaltung)
- **Tupel**: Manuelle Verwaltung (Beginn: Zähler = 0)
  `IncReference`: Zähler++,
  `DecReference`: Zähler--,
  `DeleteIfAllowed`: Löscht das Tupelobjekt, falls Zähler == 0.

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Der feed Operator

```
int
Feed(Word* args, Word& result, int message, Word& local, Supplier s)
{
  GenericRelation* r=0;
  GenericRelationIterator* rit=0;

  switch (message)
  {
    case OPEN :
      r = (GenericRelation*)args[0].addr;
      rit = r->MakeScan();

      local = SetWord(rit);
      return 0;

    case REQUEST :
      rit = (GenericRelationIterator*)local.addr;
      Tuple *t;
      if ((t = rit->GetNextTuple()) != 0)
      {
        result = SetWord(t);
        return YIELD;
      }
      else
      {
        return CANCEL;
      }

    case CLOSE :
      rit = (GenericRelationIterator*)local.addr;
      delete rit;
      return 0;
  }
  return 0;
}
```

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  5) `theTuple->DeleteIfAllowed;` Referenz ggf. löschen

Der consume Operator

```
int
Consume(Word* args, Word& result, int message, Word& local, Supplier s)
{
  Word actual;

  GenericRelation* rel = (Relation*)((qp->ResultStorage(s)).addr);
  if(rel->GetNoTuples() > 0)
  {
    rel->Clear();
  }

  qp->Open(args[0].addr);
  qp->Request(args[0].addr, actual);
  while (qp->Received(args[0].addr))
  {
    Tuple* tuple = (Tuple*)actual.addr;
    rel->AppendTuple(tuple);
    tuple->DeleteIfAllowed();
    qp->Request(args[0].addr, actual);
  }
  result = SetWord(rel);
  qp->Close(args[0].addr);
  return 0;
}
```

Komplexere Type-Mappings

- Manchmal ist es hilfreich bzw. notwendig, daß durch das Type-Mapping weitere (interne) Argumente angehangen werden können, die dem Value-Mapping dann zur Verfügung stehen.
- Dazu dient das Schlüsselwort APPEND. Wird im Type-mapping (APPEND (v_1 ... v_n) <t*ype-list*>) zurückgegeben, so werden die Werte v_i als zusätzliche Argumente weitergereicht.
- Die Werte v_i können auch selbst wieder Listen sein, dann muß im Value-Mapping mittels `qp->GetSupplier(...)` darauf zugegriffen werden, siehe z.B. Operator **project**.

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- Hier als Beispiel: Operator **attr**

Beispiel: Operator attr

```
ListExpr AttrTypeMap(ListExpr args)
{
  ListExpr first, second, attrtype;
  string  attrname, argstr;
  int j;

  nl->WriteToString(argstr, args);
  CHECK_COND(nl->ListLength(args) == 2,  "Operator attr expects a list of length two. But got " + argstr + "!");

  first = nl->First(args);
  nl->WriteToString(argstr, first);
  CHECK_COND( (nl->ListLength(first) == 2) && (TypeOfRelAlgSymbol(nl->First(first)) == tuple),
  "Operator attr expects as first argument a list with structure (tuple ((a1 t1)...(an tn)))\n"
  "Operator attr gets a list with structure '" + argstr + "'.");

  second  = nl->Second(args);
  nl->WriteToString(argstr, second);
  CHECK_COND( nl->IsAtom(second) &&
              nl->AtomType(second) == SymbolType,
  "Operator attr expects as second argument a symbol atom  (attributename).\n
  ”Operator attr gets '" + argstr + "'.");

  attrname = nl->SymbolValue(second);
  j = FindAttribute(nl->Second(first), attrname, attrtype);
  if (j)
    return nl->ThreeElemList(nl->SymbolAtom("APPEND"),
           nl->OneElemList(nl->IntAtom(j)), attrtype);
  else
  {
    nl->WriteToString( argstr, nl->Second(first) );
    ErrorReporter::ReportError(
    "Attribute name '" + attrname + "' is not known in the tuple.\n"
    "Known Attribute(s): " + argstr);

    return nl->SymbolAtom("typeerror");
  }
}
```

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    else
    {
      return nl->SymbolAtom("typeerror");
    }
  }
}
```

Beispiel: Operator attr

Type mapping for operator attr:

```
RelationAlgebra: attr (algId=3, opId=4) accepted!
IN: ((tuple ((name string) (population int))) population)
OUT: (APPEND (2) int)
```

Beispiel: Operator attr

Type mapping for operator attr:
RelationAlgebra: attr (algId=3, opId=4) accepted!
IN: ((tuple ((name string) (population int))) population)
OUT: **(APPEND (2) int)**

```
int Attr(Word* args, Word& result, int message,
                                    Word& local, Supplier s)
{
  Tuple* tupleptr = 0;
  int index = 0;

  tupleptr = (Tuple*)args[0].addr;
  // args[1] is not used since the attribute name is unimportant here.
  // Instead we need the attribute's index which was computed in the
  // operator's type map function.
  index = ((CcInt*)args[2].addr)->GetIntval();
  assert(1 <= index &&
         index <= tupleptr->GetNoAttributes() );
  result = SetWord(tupleptr->GetAttribute(index - 1));
  return 0;
}
```

Tipps zum Debugging

- In der TTY-Konsole können mit dem Kommando **debug {1|2|3}** detaillierte Informationen zur Analyse und Verarbeitung einer Query angezeigt werden.
- Bei der Implementierung von Stromoperatoren können schnell Speicherlöcher (ungenutzer Speicher wird nicht mehr frei gegeben) entstehen.
- Besonders schlimm ist es, wenn derselbe Zeiger versehentlich mehrfach gelöscht wird, da der Speicher mittlerweile schon anderweitig benutzt werden könnte.
- Das Setzen der Umgebungsvariablen **MALLOC_CHECK_=2** sorgt im obigen Fall für einen sofortigen Programmabbruch (Nur unter Linux möglich).

Noch Fragen ?!