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FACULTY OF COMPUTER SCIENCE

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СОДРЖИНА
CONTENT

LINQ TO OBJECTS SUPPORTED JOINING DATA

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Abstract: Joins have been studied as a key operations in multiple application domains. This paper focuses on the study of joins as a first-class LINQ operators and their implementation as integrated component of the query processing. The join methods provided in the LINQ perform inner join, left outer join, and cross join. Our goal is to provide join operations, similar to SQL statements in the databases. We describe an efficient implementation of the following join operators: inner join, left outer join, right inner join, full outer join, left excluding join, right excluding join, full outer excluding join, and cross join. A simple example is used to present the potentialities of LINQ technology to solve the problem with the object-relational mapping.

Keywords: LINQ query, inner join, outer join, cross join, C# programming language

19 Introduction

Concept of joining is a key concept of accessing data. From SQL and relational point of view, almost every query requires joining data. SQL languages have powerful join capabilities. They support different types of joins, including inner joins, outer joins, and cross joins [1].

Language Integrated Query (LINQ) is the technology that addresses the problems between programming languages and databases. LINQ provides a uniform, object-oriented way to access data from heterogeneous sources and simplifies the interaction between object-oriented programming and relational data.

In this paper, we implement the set of join operators in LINQ that use syntax similar to SQL [3,4]. The main contributions include the study of joins as a first-class LINQ operators and their implementation as integrated component of the LINQ query processing.

The rest of the paper is organized as follows. Section 2 discusses the background. Section 3 presents the different types of SQL-like joins and syntax using examples in C#. Section 4 presents the conclusions and directions for future research.

20 Background

LINQ is a programming model that introduces queries as a first-class concept into any Microsoft .NET Framework Language [5]. LINQ provides a uniform way to access and manage data in the program, keeping existing heterogeneous data structures, regardless of their physical representation – the data source might be a graph of objects in-memory, relational table or XML file [2]. The software developers use the same query syntax over all different data access models.

The LINQ architecture is shown in Figure 1. The different data sources are as follows: LINQ to Objects, LINQ to Datasets, LINQ to SQL, LINQ to Entities, and LINQ to XML.

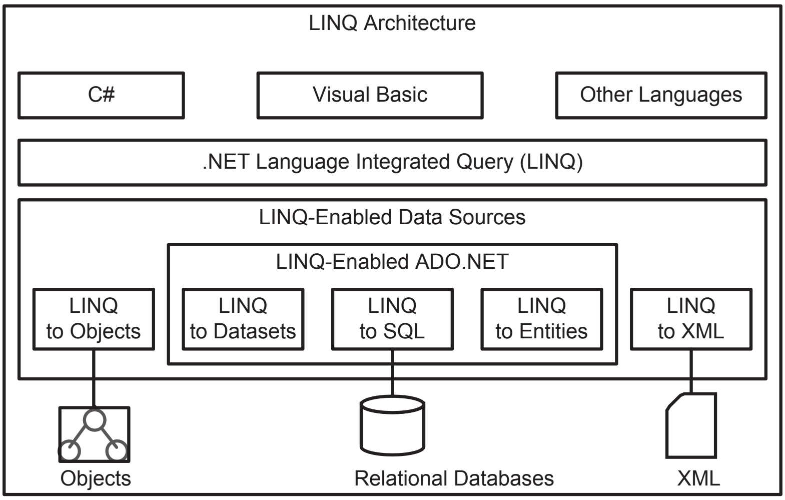


Figure 1 LINQ architecture

LINQ query is a set of operations on instances of some classes. The declarative description of operations on data using syntax very similar to SQL is the most important feature of LINQ because it enhances programmers' productivity.

21 Join operators

Joining data sets is the process of linking two data sources through a common attribute. Joining is an important operation in queries. It models a correlation between objects that is not implemented in the object-oriented programming.

7.3 Class model

In the example we will use a data structure that represents information about courses, with enrolls and students. Each course includes many enrolls. The class **Course** has information about **ID** number, **Title** and a reference to a set of **enroll**s. Class **Enroll** has information about **EnrollId**, **Grade** and faculty number **FN** of a student. Class **Student** has a faculty number **FN** and **Name**. The definitions of these types are represented in the Appendix. The data consists of a set of **courses**, each of which has enrolled **students**. The initialized instances are shown in the Appendix.

We assume we have two sets – **students** is on the left and **coursesEnrolls** is on the right. We can join these sets by their common **FN** attributes.

```
var coursesEnrolls =  from course in courses
                      from e in course.enroll
                        select e;
```

7.4 Inner join

The inner join is the most common join operator. It creates a result set of elements of the two sets (**students** and **coursesEnrolls**) that match in both sets. The inner join is implemented in the LINQ base library using the **Join** method.

SQL statement:
SELECT * FROM STUDENTS
INNER JOIN COURSESENROLLS
ON STUDENTS.FN=COURSESENROLLS.FN

Query expression syntax:	**Lambda expression syntax:**

var innerJoin =from x in students
  join y in coursesEnrolls
  on x.FN equals y.FN
  select new { X = x, Y = y };
	var innerJoin = students
	  .Join(coursesEnrolls,
	  x => x.FN, y => y.FN, (x, y) => new { x, y })
	  .Select(item => new { item.x, item.y });

Result:	**FN**	**Name**	**EnrollId**	**Grade**	**FN**
	222100	Petia Petrova	2	5	222100
	222101	Julian Emilov	4	6	222101
	222103	Neli Ivanova	6	6	222103
	222104	Ivan Georgiev	9	6	222104

FN values from **students** match with the **FN** from **coursesEnrolls**. The inner join only returns elements where the two sets intersect.

7.5 Left outer join

The left outer join creates a result set that includes all elements from the left set (**students**) with the matching elements from the right set (**coursesEnrolls**). The left outer join is implemented using the **GroupJoin** method on the left set and then using **from** operator to get the matching elements from the right set, if any exist. If there is not match the right side will contain null using the **DefaultIfEmpty** extension method.

SQL statement:
SELECT * FROM STUDENTS
LEFT OUTER JOIN COURSESENROLLS
ON STUDENTS.FN=COURSESENROLLS.FN

Query expression syntax:

```
var leftOuterJoin =
  from x in students
  join y in coursesEnrolls
  on x.FN equals y.FN into yG
  from y1 in yG.DefaultIfEmpty()
  select new { X = x,
                Y  =  y1  ==  null  ?
null : y1 };
```

Lambda expression syntax:

```
var leftOuterJoin =
  students
  .GroupJoin(coursesEnrolls,
  x => x.FN, y => y.FN, (x, g) => new {
x, g })
  .SelectMany(y                    =>
y.g.DefaultIfEmpty(),
     (item, y) => new { X=item.x, Y=y });
```

Result:	FN	Name	EnrollId	Grade	FN
	222100	Petia Petrova	2	5	222100
	222101	Julian Emilov	4	6	222101
	222102	Anely Borisova	0	0	-1
	222103	Neli Ivanova	6	6	222103
	222104	Ivan Georgiev	9	6	222104
	222105	Mila Ivanova	0	0	-1
	222107	Kristi Kirilova	0	0	-1
	222112	Anton Ivanov	0	0	-1

The result set contains all students but four students have no enrolls associated with them – the return objects by the **Enroll** class are null and the **NullReferenceException** is controlled.

7.6 Right outer join

The right outer join creates a result set that includes all elements from the right set (**coursesEnrolls**) with the matching elements from the left set (**students**). It closely likes to a left outer join with reversed sets.

SQL statement:

```
SELECT * FROM STUDENTS
RIGHT OUTER JOIN COURSESENROLLS
ON STUDENTS.FN=COURSESENROLLS.FN
```

Query expression syntax:

```
var rightOuterJoin =
  from y in coursesEnrolls
  join x in students
  on y.FN equals x.FN into xG
```

Lambda expression syntax:

```
var rightOuterJoin =
  coursesEnrolls
  .GroupJoin(students,
  from x1 in xG.DefaultIfEmpty()
  select new { X = x1==null ? null
: x1,
                Y = y };
```

```
  x => x.FN, y => y.FN, (x, g) => new {
x, g })
  .SelectMany(y                        =>
y.g.DefaultIfEmpty(),
  (y, item) => new { X = item, Y = y.x });
```

Result:	FN	Name	EnrollId	Grade	FN
	222100	Petia Petrova	2	5	222100
	-1	null	3	6	222201
	222101	Julian Emilov	4	6	222101
	222103	Neli Ivanova	6	6	222103
	-1	null	7	5	222200
	222104	Ivan Georgiev	9	6	222104
	-1	null	10	5	222110
	-1	null	11	4	222111

The result set contains all enrolls where four enrolls have no students associated with them – the return objects by the **StudentI** class are null and the **NullReferenceException** is controlled.

7.7 Full outer join

The full outer join creates a result set that includes all elements from the left set (**students**) and the right set (**coursesEnrolls**) with the matching elements from the both sets where available. If there is not match the missing left/right side will contain null.

SQL statement:

```
SELECT * FROM STUDENTS
FULL OUTER JOIN COURSESENROLLS
ON STUDENTS.FN=COURSESENROLLS.FN
```

Lambda expression syntax:

```
var fullOuterJoin = leftJoin.Union(rightJoin);
```

Result:	FN	Name	EnrollId	Grade	FN
	222100	Petia Petrova	2	5	222100
	222101	Julian Emilov	4	6	222101
	222102	Anely Borisova	0	0	-1
	222103	Neli Ivanova	6	6	222103

222104	Ivan Georgiev	9	6	222104
222105	Mila Ivanova	0	0	-1
222107	Kristi Kirilova	0	0	-1
222112	Anton Ivanov	0	0	-1
-1	null	3	6	222201
-1	null	7	5	222200
-1	null	10	5	222110
-1	null	11	4	222111

7.8 Left excluding join

The left excluding join creates a result set that includes only elements from the left set (**students**) that are not in the right set (**coursesEnrolls**). It performs the left outer join and then excludes the common elements from the right set.

SQL statement:

```
SELECT * FROM STUDENTS
LEFT OUTER JOIN COURSESENROLLS
ON STUDENTS.FN=COURSESENROLLS.FN
WHERE COURSESENROLLS.FN IS NULL
```

Query expression syntax:

```
var leftExcludingJoin = from x in students
   join y in coursesEnrolls
   on x.FN equals y.FN into yG
   from y1 in yG.DefaultIfEmpty()
   where y1 == null
   select new { X = x,
                Y = y1 == null ? nu
: y1 };
```

Lambda expression syntax:

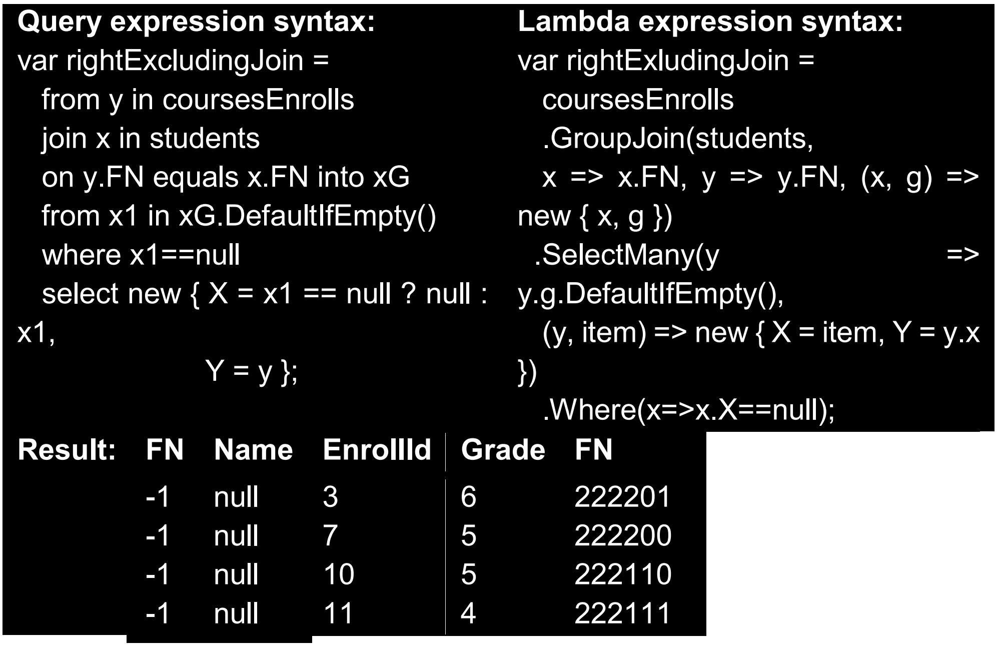
```
var leftExcludingJoinl = students
   .GroupJoin(coursesEnrolls,
   x => x.FN, y => y.FN, (x, g) => new {
x, g })

.SelectMany(y=>y.g.DefaultIfEmpty(),
   (item, y) => new { X = item.x, Y = y })
   .Where(y=>y.Y==null);
```

Result:	**FN**	**Name**	**EnrollId**	**Grade**	**FN**
	222102	Anely Borisova	0	0	-1
	222106	Mila Ivanova	0	0	-1
	222107	Kristi Kirilova	0	0	-1
	222112	Anton Ivanov	0	0	-1

7.9 Right excluding join

The right excluding join creates a result set that includes only elements from the right set (**coursesEnrolls**) that are not in left set (**students**). It closely likes to a left excluding join with reversed sets.

SQL statement:
SELECT * FROM STUDENTS
RIGHT OUTER JOIN COURSESENROLLS
ON STUDENTS.FN=COURSESENROLLS.FN
WHERE STUDENTS.FN IS NULL



Query expression syntax:

```
var rightExcludingJoin =
  from y in coursesEnrolls
  join x in students
  on y.FN equals x.FN into xG
  from x1 in xG.DefaultIfEmpty()
  where x1==null
  select new { X = x1 == null ? null :
x1,
              Y = y };
```

Lambda expression syntax:

```
var rightExludingJoin =
  coursesEnrolls
  .GroupJoin(students,
  x => x.FN, y => y.FN, (x, g) =>
new { x, g })
 .SelectMany(y                    =>
y.g.DefaultIfEmpty(),
  (y, item) => new { X = item, Y = y.x
})
  .Where(x=>x.X==null);
```

Result:	**FN**	**Name**	**EnrollId**	**Grade**	**FN**
	-1	null	3	6	222201
	-1	null	7	5	222200
	-1	null	10	5	222110
	-1	null	11	4	222111

7.10 Full outer excluding join

The full outer excluding join creates a result set that includes unique elements from the left set (**students**) and the right set (**coursesEnrolls**) that do not match. It performs the full outer join and then excludes the common elements from the both sets.

SQL statement:
SELECT * FROM STUDENTS
FULL OUTER JOIN COURSESENROLLS
ON STUDENTS.FN=COURSESENROLLS.FN
WHERE STUDENTS.FN IS NULL OR COURSESENROLLS.FN IS NULL
Lambda expression syntax:
var fullOuterExcludingJoin = leftExcludingJoin.Union(rightExcludingJoin);

Result:	FN	Name	EnrollId	Grade	FN
	222102	Anely Borisova	0	0	-1
	222105	Mila Ivanova	0	0	-1
	222107	Kristi Kirilova	0	0	-1
	222112	Anton Ivanov	0	0	-1
	-1	null	3	6	222201
	-1	null	7	5	222200
	-1	null	10	5	222110
	-1	null	11	4	222111

7.11 Cross join

The cross join or Cartesian product creates a result set that includes all possible ordered pairs whose first component is a member of the left set (**students**) and whose second component is a member of the right set (**coursesEnrolls**).

SQL statement:

```
SELECT * FROM STUDENTS
CROSS JOIN COURSESENROLLS
```

Query expression syntax:

```
var crossJoin =
  from x in students
  from y in coursesEnrolls
  select new { X = x, Y = y};
```

Lambda expression syntax:

```
var crossJoinl =
  students
  .SelectMany(x=>coursesEnrolls,
  (x,y)=>new { X=x, Y=y});
```

The result set contains 64 elements – all of the {student,enroll) pairs, even the combinations are not valid.

8 Conclusion and Future Work

We have proposed implementation of join operations using LINQ. These operations implement the behavior of the SQL join operations. We make attempt to solve the gap between the programming languages and the databases. These operations can be used for the purposes of analysis and visualization.

Plans for future work include the study and integration of join strategies as first-class LINQ operators in approaches that support SOA-based scientific data management.

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[4] Scott Mitchell (2009): *An Extensive Examination of LINQ: Grouping and Joining Data*, Last access: 10.11.2012, http://www.4guysfromrolla.com/articles/080509-1.aspx.

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Appendix

```
class Course
{
   public int ID { get; set; }
   public string Title { get; set;
}
   public Enroll[] enroll;
   public override string
ToString()
   {
      string r = ID + "\t" + Title
+ "\n";
      foreach (var e in enroll)
         r += e.ToString();
      return r;
   }
}

class Enroll
{
   public int? EnrollId { get;
set; }
   public int? Grade { get; set;
}
```

```
List<Course> courses = new List<Course>() {
   new Course { ID = 1, Title = "Distributed
Systems",
     enroll = new Enroll[] {
       new Enroll {EnrollId=2, Grade=5,
FN=222100},
       new Enroll {EnrollId=3, Grade=6,
FN=222201}}},
   new Course { ID = 2, Title = "Computer
Graphics",
      enroll = new Enroll[] {
       new Enroll {EnrollId=4, Grade=6,
FN=222101},
       new Enroll {EnrollId=6, Grade=6,
FN=222103},
       new Enroll {EnrollId=7, Grade=5,
FN=222200}}},
   new Course { ID = 3, Title = "Software
Engineering",
      enroll = new Enroll[] {
       new Enroll {EnrollId=9, Grade=6,
FN=222104},
   public int? FN { get; set; }
   public override string
ToString()
   {
      return
EnrollId+"\t"+Grade+
             "\t"+FN;
    }
}

class Student
{
   public int? FN { get; set; }
   public string Name { get;
set; }
   public override string
ToString()
   {
     return FN + "\t" + Name;
   }
}
```

```
        new Enroll {EnrollId=10, Grade=5,
FN=222110},
        new Enroll {EnrollId=11, Grade=4,
FN=222111}}}
};

List<Student> students = new List<Student>()
{
   new Student {FN=222100, Name="Petia
Petrova"},
   new Student {FN=222101, Name="Julian
Emilov"},
   new Student {FN=222102, Name="Anely
Borisova"},
   new Student {FN=222103, Name="Neli
Ivanova"},
   new Student { FN=222104, Name="Ivan
Georgiev"},
   new Student {FN=222105, Name="Mila
Ivanova"},
   new Student {FN=222107, Name="Kristi
Kirilova"},
   new Student {FN=222112, Name="Anton
Ivanov"}
};
```