DLV: Knowledge Representation and Industrial Applications of AI

Francesco Ricca

Department of Mathematics and Computer Science
University of Calabria

June 13, 2016
Outline

1. Introduction
2. The DLV System
3. Industrial Applications
4. Conclusion
5. References
Answer Set Programming (ASP)
- Declarative programming paradigm
- Non-monotonic reasoning and logic programming

Expressive KR Language
- Roots in Datalog
- Common Sense Reasoning
- Nonmonotonic Logic
- Database and Combinatorial problems
Example (3-col)

**Problem:** Given a map assign one color out of 3 colors to each nation such that two adjacent nations have always different colors.

**Input:** a Map is represented by `nation(_)` and `neighbor(_, _)`.

% Each nation X should be colored red or yellow or green.
\[(r) \quad col(X, red) \mid col(X, yellow) \mid col(X, green) \leftarrow nation(X).\]

% Adjacent nations cannot have the same color.
\[(c) \quad \leftarrow neighbor(X, Y), col(X, C), col(Y, C).\]
Answer Set Programming (ASP)

Idea:

1. Represent a computational problem by a Logic program
2. Answer sets correspond to problem solutions
3. Use an ASP solver to find these solutions
Answer Set Programming (ASP)

- Robust and efficient implementations
  - DLV \([\text{LPF}^+06]\), Clasp \([\text{GKNS}07]\),
  - CModels \([\text{LM}04]\), IDP \([\text{WMD}08]\), etc.

- Applications in several fields
  - Artificial Intelligence, Knowledge Representation & Reas.,
  - Information Integration, Data cleaning, Bioinformatics, ...
Answer Set Programming (ASP)

- Robust and efficient implementations
  - DLV [LPF⁺06], Clasp [GKNS07],
  - CModels [LM04], IDP [WMD08], etc.

- Applications in several fields
  - Artificial Intelligence, Knowledge Representation & Reas.,
  - Information Integration, Data cleaning, Bioinformatics, ... 
  - employed for developing industrial applications
The DLV System

- One of the most popular ASP systems
  *more than fifteen years of research and development*

- Research and Development
  - University of Calabria: Research and Extension
  - DLV System s.r.l.: Maintenance & Commercialization
    - Spin-Off of University of Calabria

- Widely used all over the world
  - in academia, for teaching [Bar03, GK14] and research [LGI+05, LR15]
  - in industry, for advanced applications [LR15]
The DLV System

- One of the most popular ASP systems...more than fifteen years of research and development

- Research and Development
  - University of Calabria: Research and Extension
  - DLV System s.r.l.: Maintenance & Commercialization
    - Spin-Off of University of Calabria

- Widely used all over the world
  → in academia, for teaching [Bar03, GK14] and research [LGI+05, LR15]
  → in industry, for advanced applications [LR15]!
The DLV System

- One of the most popular ASP systems
  ...more than fifteen years of research and development

- Research and Development
  - University of Calabria: Research and Extension
  - DLV System s.r.l.: Maintenance & Commercialization
    - Spin-Off of University of Calabria

- Widely used all over the world
  → in academia, for teaching [Bar03, GK14] and research [LGI+05, LR15]
  → in industry, for advanced applications [LR15]!
Routing and classification of call-center customers
- ZLog platform employed by Telecom Italia call-centers
  *(Telecom Italia is the largest Italian carrier)*

**Team Building in the Gioia-Tauro Seaport [RGA+12]**
- Team builder for ICO BLG in the Gioia Tauro seaport

**Automatic Diagnosis of Headache Disorders**
- The International Headache Society (IHS) Classification

**Intelligent Data Extraction**
- DIADEM Project (U. Oxford)
... and many others:

- Business Simulation Games
- Cleaning medical archives
- e-Tourism: Package search [RDG10], allotment [DLNR15], itinerary search
- Census Data Repair [FPL01]
- Detection of price manipulations
- Data Integration: the INFOMIX system [LGI05, MRT13]
- Deductive-database application at CERN
- Minimum cardinality diagnoses [FI08]
- E-learning [GPR06]
Routing and classification of call-center customers
Call center routing problem

- Call centers provide remote assistance to a variety of services
- Front-ends are flooded by a huge number of telephone calls every day
- Customers should be routed to the most appropriate service

**Goal:** Improve the quality of service
- Reduce the average call response times
- Quickly find solutions for customers
Customer profiling for routing phone calls
- Based on DLV
- Developed by Exeura s.r.l, a spin-off company of the University of Calabria
- In production on call centers of Telecom Italia

Key Ideas:
- Classify customer profiles
- Try to anticipate their actual needs
  → Exploit experience of customer care service
Customer classification

**Customer’s routing**

1. a customer calls the contact center
2. he/she is automatically assigned to a category (based on his/her profile)
3. then routed to an appropriate human operator or automatic responder

**Categories based on:**
- customer behavioral aspects
  - recent history of contacts, telephone calls to the contact center, messages sent to customer assistance, etc.
- basic customer demographics
  - age, residence, type of contract, etc.
Customer classification

Customer’s routing

1. a customer calls the contact center
2. he/she is automatically assigned to a category (based on his/her profile)
3. then routed to an appropriate human operator or automatic responder

Categories based on:
- customer behavioral aspects
  - recent history of contacts, telephone calls to the contact center, messages sent to customer assistance, etc.
- basic customer demographics
  - age, residence, type of contract, etc.
Customer classification

Contact center operators define categories

- Customer categories created with an user-friendly user interface
  - Added to the call routing system in real time
  - Automatically translated into ASP rules
  - Fed as input to DLV with the customer data DBs
  - DLV quickly computes the new class of customers

The customer call is routed

- Customer care of the appropriate branch is contacted
- The user is faced with an automatic responder
ZLog interface: Class Definition
ZLog Class Encoding

varTipoAbbonato(CLI) :- OR1(CLI).

OR1(CLI) :- AND1(CLI).  OR1(CLI) :- AND2(CLI).
OR1(CLI) :- Abbonati_on_line1(CLI).

AND1(CLI) :- Clienti_Linee(CLI, ...), not Abbonati_on_line2(CLI).
AND2(CLI) :- Clienti_Linee1(CLI), not Abbonati_on_line2(CLI).

Abbonati_on_line1(CLI) :-
  Abbonati_on_line(CLI, ..., ESITO_OPSC, ESITO_TGDS, ...),
  ESITO_OPSC = "2", ESITO_TGDS = "0".

Abbonati_on_line2(CLI) :-
  Abbonati_on_line(CLI, ..., ESITO_OPSC, ESITO_TGDS, ...),
  DatiOPSC(ESITO_OPSC).

DatiOPSC(codifica : "11"). DatiOPSC(codifica : "12").
DatiOPSC(codifica : "13").

Clienti_Linee1(CLI) :- Clienti_Linee(CLI, ..., TIPO_CLIENTE, STATO, ...),
  TIPO_CLIENTE = "ABB", STATO = "A".
The system is in production

- It runs in a production system at Telecom Italia
- It handles over one million telephone calls every day
  - Customer categories are detected in less than 100 ms
  - The system manages over 400 calls/sec.

Users Feedback

- “ZLog made possible huge time savings”
- “ZLog sensibly reduced the average call response times”
- “We improved our customer support quality”
Teambuilding in Gioia Tauro Seaport
Context and Motivation

- **The Gioia Tauro seaport**
  - the largest transshipment terminal of the Mediterranean Sea
  - main activity: container transhipment [Vacca et. al]
  - recently become an *automobile hub*

- **Automobile Logistics by ICO B.L.G.** (subsidiary of BLG Logistics Group)
  - several ships of different size shore the port every day,
  - transported vehicles are handled, warehoused, technically processed and then delivered to their final destination.

- **Management Goal:** promptly serve shoring boats!
  - **Crucial task:** arranging suitable teams of employees
    - teams are subject to many constraints
  - The impossibility of arranging teams
    → contract violations → pecuniary sanctions for B.L.G.
  - Thus, team building is a crucial management task!
The Gioia Tauro seaport
- the largest transshipment terminal of the Mediterranean Sea
- main activity: container transhipment [Vacca et. al]
- recently become an *automobile hub*

Automobile Logistics by ICO B.L.G. (subsidiary of BLG Logistics Group)
- several ships of different size shore the port every day,
- transported vehicles are handled, warehoused, technically processed and then delivered to their final destination.

Management Goal: promptly serve shoring boats!
- Crucial task: arranging suitable teams of employees
  - teams are subject to many constraints
- The impossibility of arranging teams
  → contract violations → pecuniary sanctions for B.L.G.
- Thus, **team building is a crucial management task!**
Manual team composition required several hours!
→ costly and risky management task

We developed a Team Builder System based on Answer Set Programming (ASP)

→ the user exploits a friendly User Interface
→ teams are automatically built in a few minutes!
→ full warranty of respecting all constraints!
Manual team composition required several hours!

→ costly and risky management task

We developed a Team Builder System based on Answer Set Programming (ASP)

→ the user exploits a friendly User Interface
→ teams are automatically built in a few minutes!
→ full warranty of respecting all constraints!
Team Building Process:

1. Data regarding shoring boats available one day in advance (arrival/departure date, number and kind of vehicles, etc.)
2. Manager determines requirement on skills (plans) (setting the number of required employees per skill per shift)
3. Available employees are assigned to shifts (respecting constraints)
Team Building Requirements:
- Shift requirements (e.g., number of workers per role)
- Employee contract (e.g. max 36 hours per week, etc.)
- Turnover of heavy/dangerous roles
- Fair distribution of workload
- and others (e.g. preserve crucial skills, etc.)
% Guess the assignment of available employees to shifts in appropriate roles

\[ (r) \text{ assign}(Em, Sh, Sk) \mid \text{nAssign}(Em, Sh, Sk) :\text{ canBeAssigned}(Em, Sh, Sk). \]

% Workers potentially allocable on the given shift.

\[ (r_{aux1}) \text{ canBeAssigned}(Em, Sh, Sk) :\text{ neededEmployees}(Sh, Sk, _), \]
\[ \text{hasSkill}(Em, Sk), \text{not exceedTimeLimit}(Em, Sh), \]
\[ \text{not absent}(Em, Sh), \text{not excluded}(Em, Sh), \]

% Workers not allocable due to contract constraints.

\[ (r_{aux2}) \text{ exceedTimeLimit}(Em, Sh) :\text{ shift}(Sh, _, Dur), \]
\[ \text{workedWeeklyHours}(Em, Wh), \text{not Dur + Wh} > 36. \]

% Similarly for daily hours (max 8h) and weekly overtime (max 12h).

\[ (r_{aux3}) \text{ exceedTimeLimit}(Em, Sh) :\text{ ..........} \]
\[ (r_{aux4}) \text{ exceedTimeLimit}(Em, Sh) :\text{ ..........} \]
# Introduction

The DLV System

# Industrial Applications

## Conclusion

F. Ricca

DLV: Knowledge Representation and Industrial Applications of AI
Conclusion

DLV

- Knowledge Representation & Reasoning
- Powerful reasoning engine
- Industrial Applications of AI

Key Points

- Declarative programming
- Fast Prototyping & Rapid development
- Flexibility & Extensibility
- Reduced maintenance costs
Thanks for your attention!
References


References (cont.)

