DLV: Knowledge Representation and Industrial Applications of AI

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Outline

Introduction

- **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

Classic Example

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) $col(X, red) \mid col(X, yellow) \mid col(X, green) \text{ :- } nation(X).$

% Adjacent nations cannot have the same color.

(c) $\text{ :- } neighbor(X, Y), col(X, C), col(Y, C).$

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 [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

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The DLV System (1)

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

  $\rightarrow$ in academia, for teaching [Bar03, GK14] and research [LGI+05, LR15]

  $\rightarrow$ in industry, for advanced applications [LR15]!

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Industrial Applications of DLV (1)

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)

Industrial Applications of DLV (2)

... and many others:

- Business Simulation Games
- Cleaning medical archives
- e-Tourism: Package search [RDG+10], allotment [DLNR15], itinerary search
- Census Data Repair [FPL+01]
- Detection of price manipulations
- Data Integration: the INFOMIX system [LGI+05, 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

The ZLog platform

- **Customer profiling for routing phone calls**
  - Based on DLV
  - Developed by Exeura s.r.l, a spin-off company of the University of Calabria
    `http://www.exeura.eu/en/archives/solution/customer-profiling`
  - In production on call centers of Telecom Italia
- **Key Ideas:**
  - Classify customer profiles
  - Try to anticipate their actual needs

    $\rightarrow$ 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.

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Customer classification

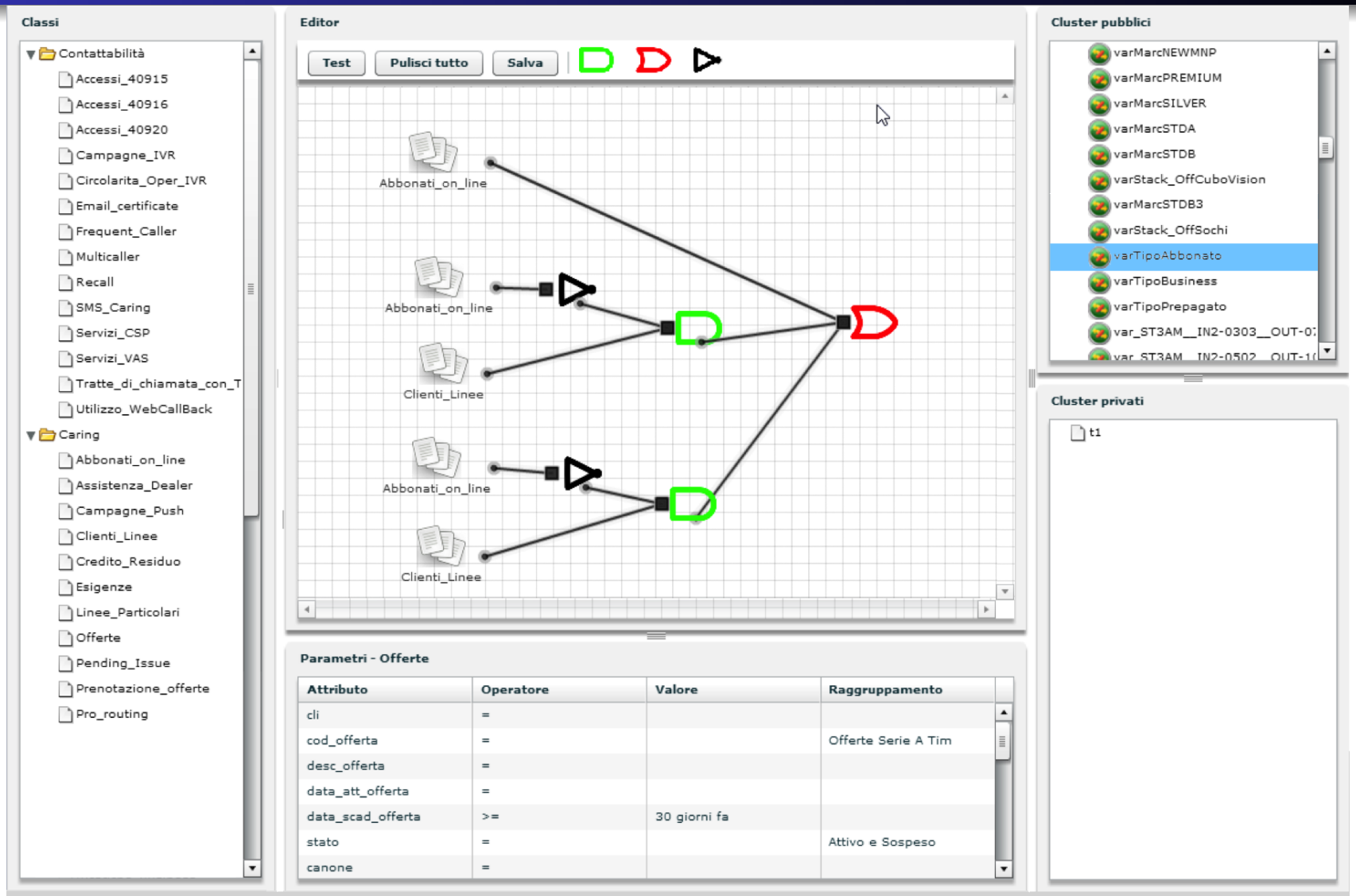
Contact center operators define categories

- 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

$$varTipoAbbonato(CLI) :\!- OR1(CLI).$$

$$OR1(CLI) :\!- AND1(CLI). \qquad OR1(CLI) :\!- AND2(CLI).$$
$$OR1(CLI) :\!- Abbonati\_on\_line1(CLI).$$

$$AND1(CLI) :\!- Clienti\_Linee(CLI, \ldots), \text{not } Abbonati\_on\_line2(CLI).$$
$$AND2(CLI) :\!- Clienti\_Linee1(CLI), \text{not } Abbonati\_on\_line2(CLI).$$

$$Abbonati\_on\_line1(CLI) :\!-$$
$$Abbonati\_on\_line(CLI, \ldots, ESITO\_OPSC, ESITO\_TGDS, \ldots),$$
$$ESITO\_OPSC = "2", ESITO\_TGDS = "0".$$

$$Abbonati\_on\_line2(CLI) :\!-$$
$$Abbonati\_on\_line(CLI, \ldots, ESITO\_OPSC, ESITO\_TGDS, \ldots),$$
$$DatiOPSC(ESITO\_OPSC).$$

$$DatiOPSC(codifica : "11"). \; DatiOPSC(codifica : "12").$$
$$DatiOPSC(codifica : "13").$$

$$Clienti\_Linee1(CLI) :\!- Clienti\_Linee(CLI, \ldots, TIPO\_CLIENTE, STATO, \ldots),$$
$$TIPO\_CLIENTE = "ABB", STATO = "A".$$

Deployment and Performance

The system is in production

- It runs in a production system at Telecom Italia
- It handles *over one million telephone calls every day*
  - $\rightarrow$ Customer categories are detected in less than 100 ms
  - $\rightarrow$ 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
    $\rightarrow$ contract violations $\rightarrow$ pecuniary sanctions for B.L.G.
  - Thus, **team building is a crucial management task!**

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ASP-Based Team-builder

Manual team composition required several hours!

$\rightarrow$ costly and risky management task

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

$\rightarrow$ the user exploits a friendly User Interface

$\rightarrow$ teams are automatically built in a few minutes!

$\rightarrow$ full warranty of respecting all constraints!

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Requirements (1)

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)

Requirements (2)

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.)

Team-Building Encoding (simplified)

% Guess the assignment of available employees to shifts in appropriate roles

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

% Workers potentially allocable on the given shift.

(r_{aux_1}) $canBeAssigned(Em, Sh, Sk) \text{ :- } neededEmployees(Sh, Sk, \_),$
$hasSkill(Em, Sk), \text{not } exceedTimeLimit(Em, Sh),$
$\text{not } absent(Em, Sh), \text{not } excluded(Em, Sh),$

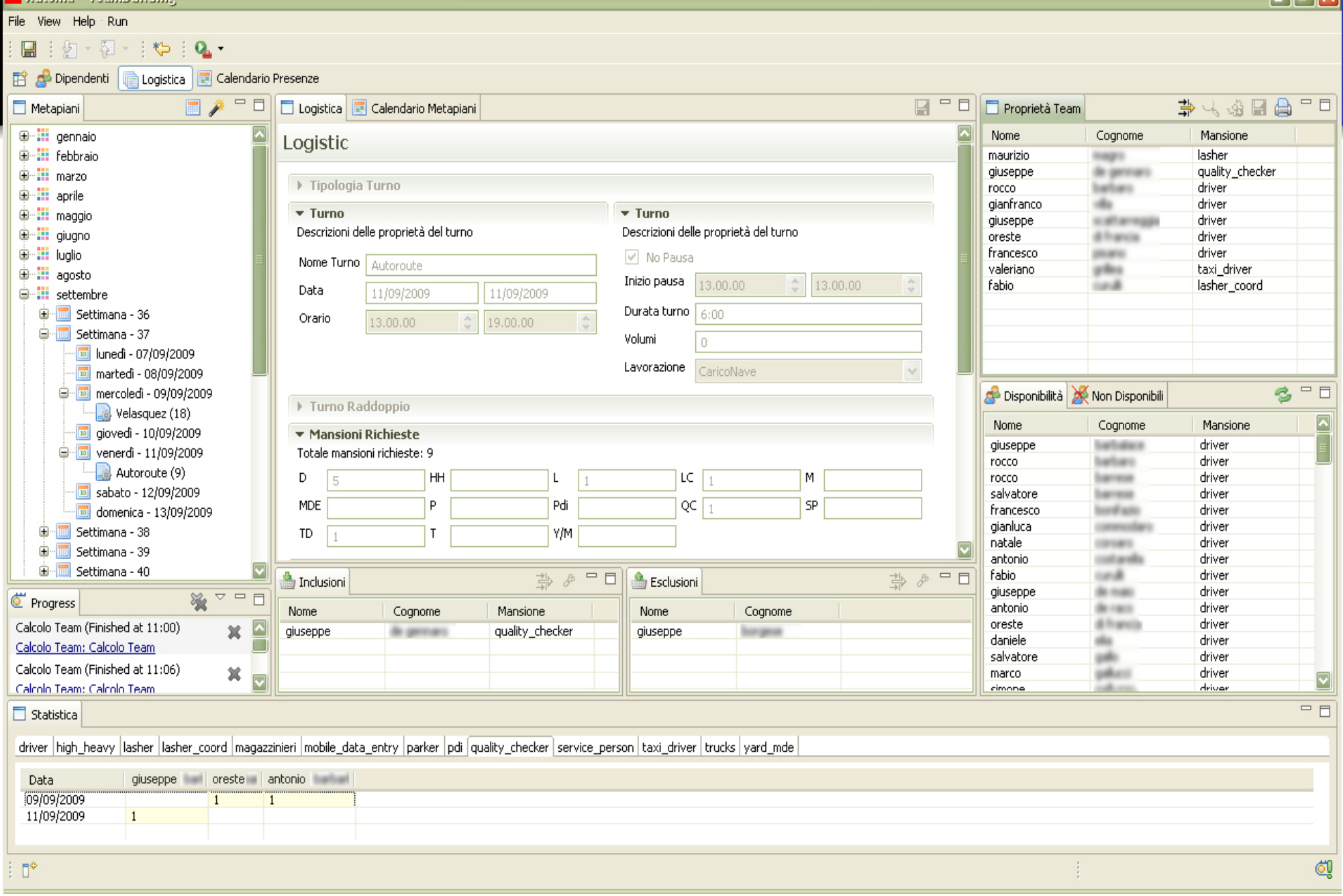
% Workers not allocable due to contract constraints.

(r_{aux_2}) $exceedTimeLimit(Em, Sh) \text{ :- } shift(Sh, \_, Dur),$
$workedWeeklyHours(Em, Wh), \text{not } Dur + Wh > 36.$

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

(r_{aux_3}) $exceedTimeLimit(Em, Sh) \text{ :- } .....$

(r_{aux_4}) $exceedTimeLimit(Em, Sh) \text{ :- } .....$


File View Help Run
Dipendenti
Logistica
Calendario Presenze
Metapiani
gennaio
febbraio
marzo
aprile
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giugno
luglio
agosto
settembre
Settimana - 36
Settimana - 37
lunedì - 07/09/2009
martedì - 08/09/2009
mercoledì - 09/09/2009
Velasquez (18)
giovedì - 10/09/2009
venerdì - 11/09/2009
Autoroute (9)
sabato - 12/09/2009
domenica - 13/09/2009
Settimana - 38
Settimana - 39
Settimana - 40
Logistica
Calendario Metapiani
Logistic
Tipologia Turno
Turno
Descrizioni delle proprietà del turno
Nome Turno
Autoroute
Data
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Turno
Descrizioni delle proprietà del turno
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Durata turno
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Lavorazione
CaricoNave
Turno Raddoppio
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Totale mansioni richieste: 9
D 5
HH
L 1
LC 1
M
MDE
P
Pdi
QC 1
SP
TD 1
T
Y/M
Proprietà Team
Nome Cognome Mansione
maurizio lasher
giuseppe quality_checker
rocco driver
gianfranco driver
giuseppe driver
oreste driver
francesco driver
valeriano taxi_driver
fabio lasher_coord
Disponibilità
Non Disponibili
Nome Cognome Mansione
giuseppe driver
rocco driver
rocco driver
salvatore driver
francesco driver
gianluca driver
natale driver
antonio driver
fabio driver
giuseppe driver
antonio driver
oreste driver
daniele driver
salvatore driver
marco driver
Progress
Calcolo Team (Finished at 11:00)
Calcolo Team: Calcolo Team
Calcolo Team (Finished at 11:06)
Calcolo Team: Calcolo Team
Inclusioni
Nome Cognome Mansione
giuseppe quality_checker
Esclusioni
Nome Cognome
giuseppe
Statistica
driver high_heavy lasher lasher_coord magazzinieri mobile_data_entry parker pdi quality_checker service_person taxi_driver trucks yard_mde
Data giuseppe oreste antonio
09/09/2009 1 1
11/09/2009 1

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

Acknowledgments

Thanks for your attention!

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