Information Systems Analysis

Temporal Logic and Timed Automata

(10)

Temporal logic and temporal databases

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Temporal database

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Temporal database

What is a temporal database?

- A database, that contains informations on data validity time and, sometimes, on data transfer time.

A temporal database:

- usually stores data like a non temporal database;
- stores **validity time** for data (*valid time*);
- may also store **time stamps** for every action performed in the database (e.g. inserting, updating or deleting data) to remember when it was performed (*transaction time*);
- may allow access to data, using a temporal language in queries.

Temporal database

Divisions of temporal databases

- historical temporal database:
  - — stores valid time only,
  - — does not store time stamps,
- bitemporal database:
  - — stores valid time and time stamps.

Temporal database

Time in temporal databases

- discrete: *time* $\in$ N (natural numbers)
- dense: *time* $\in$ Q (rational numbers)
- continuous: *time* $\in$ R (real numbers)

What can be defined in temporal logic?

- operation rules of the database management system (DBMS),
- query language.

Temporal database

Examples of using temporal databases

- management of office or business archives;
- management of financial, medical (etc.) data;
- management of reservation systems of tickets, hotel rooms, etc.;
- management of a computer system.

In general:

- to remember all actions performed in the database,
- to remember all changes done on data,
- to check temporal properties of some data (e.g. validity), etc.

Temporal logic and integrity constraints

- Database Management System (DBMS)
- Examples of integrity constraints in LTL logic
- Examples of integrity constraints in CTL logic

Temporal logic and integrity constraints

Database Management System (DBMS)

- DBMS manages the database logically and physically,
- controls and perform all actions on the database, including:
  - insertion, modification and deletion of data,
  - control of integrity and security of data,
  - optimization of memory and time,
  - analysis of data,
  - provision of data, e.g. in views,
- uses an access language for database management and queries.

Temporal logic and integrity constraints

Examples of integrity constraints in LTL logic

- integrity constraints are given as LTL formulas,
- a database stores files with limited validity time (accessibility for a user):

$G\ (user.wants(file) \wedge file.valid \Rightarrow user.gets(file))$

$\neg F\ \neg(\neg(user.wants(file) \wedge file.valid) \vee user.gets(file))$

$\neg F\ ((user.wants(file) \wedge file.valid) \wedge \neg user.gets(file))$

$\neg F\ (user.wants(file) \wedge file.valid \wedge \neg user.gets(file))$

$G\ (\neg user.gets(file) \vee file.valid)$

$G\ \neg(user.gets(file) \wedge \neg file.valid)$

$\neg F\ (user.gets(file) \wedge \neg file.valid)$

Temporal logic and integrity constraints

Examples of integrity constraints in CTL logic

- integrity constraints are given as CTL formulas,
- a database stores data on clients,
- if a user is a client, than for every product he sees current prices only:

  $\neg EF\ (user=client \wedge user.sees(product.price) \wedge \neg product.price=current)$

- if a user is a manager, than for every product he sees every price:

  $AG\ (user=manager \Rightarrow user.sees(product.proce))$

Temporal logic and query language

- LTL^{-} logic
- Examples of queries in LTL^{-} logic

Temporal logic and query language

LTL^{-} logic

LTL^{-} is an LTL temporal logic for past time.

- LTL operators concern the future: U, X, G and F;
- LTL^{-} operators concern the past: U^{-}, X^{-}, G^{-} and F^{-};
  - $s_i \models X^{-} p$ means, that *p* was true at the previous state (moment) s_{i-1};
  - $s_i \models G^{-} p$ means, that *p* was true at every past state (moment) and at s_i;
  - $s_i \models F^{-} p$ means, that *p* was true at a past state (moment), or at s_i.
- in NuSMV they are: S, Y, H and O respectively.

Temporal logic and query language

Examples of queries in LTL^{-} logic

- queries are given as LTL^{-} formulas,
- they can concern a past snapshot of the database,
- R(x) is a snapshot of relation R for datum x.

- Do exist such two snapshots R(x), in which the relation R contains the same value of the datum x?

  $F\,(R(x)=a \wedge X^{-}F^{-}\,R(x)=a)$

The end

Literature:

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