Monitoring Electronic Exams

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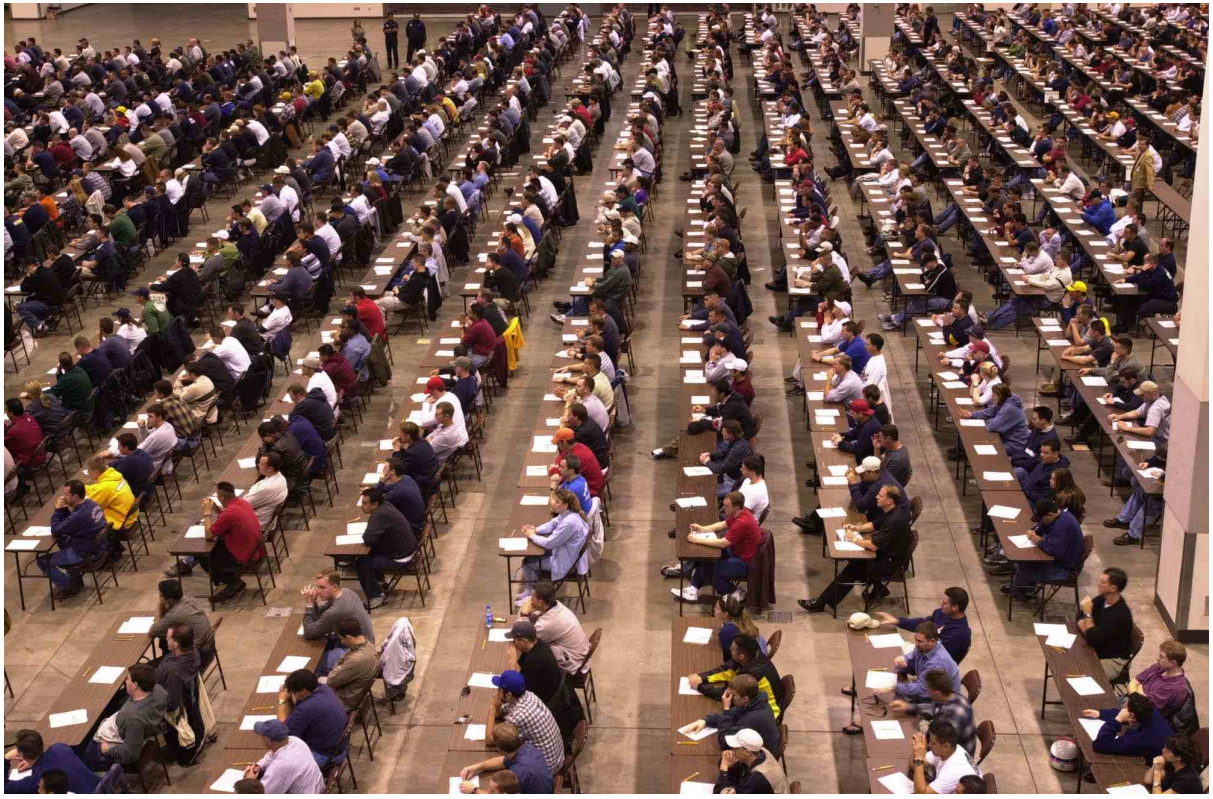
Traditional Exam



e-exam

Information technology for the assessment of knowledge and skills.

Reality


coursera


UDACITY

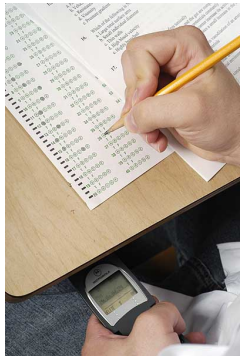

edX


IELTS
English for International Opportunity


CISCO
CCNA


TOEFL iBT

Threats. . .



- Candidate cheating
- Bribed, corrupted or unfair examiners
- Dishonest/untrusted exam authority
- Outside attackers
- . . .

. . . and their Mitigation

Most existing e-exam systems assume **trusted authorities** and focus on **student cheating**:

- Exam centers
- Software solutions, e.g. ProctorU

ProctorU
Real People.
Real Proctoring.

. . . and their Mitigation

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Yet also the **other threats** are real:

- Atlanta Public Schools cheating scandal (2009)
- UK student visa tests fraud (2014)

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So what about **dishonest authorities** or **hackers**?

Several Security Properties

Secrypt'14 **Authentication Properties:** Mark Authenticity, Answer Origin Authentication, Form Authorship, Form Authenticity.
Privacy Properties: Anonymous Marking, Question Indistinguishability, Anonymous Examiner, Mark Privacy, Mark Anonymity

ISPEC'15 **Individual Verifiability**: Question Validity, Marking Correctness, Exam-Test Integrity, Exam-Test Markedness, Marking Integrity, Marking Notification Integrity
Universal Verifiability: Eligibility (Registration), Marking Correctness Exam-Test Integrity, Exam-Test Markedness, Marking Integrity.

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How can we use it on real e-exam?

Plan

Plan

E-exam: Players and Organization

Three Roles:

Candidate

Examination Authority

Examiner

E-exam: Players and Organization

Three Roles:

Candidate

Examination Authority

Examiner

Four Phases:

1. Registration 2. Examination 3. Marking 4. Notification

Event Based Model

Event Based Model

1. Registration

Event Based Model

1. Registration

Register

register( )

Event Based Model

1. Registration

Register

register( )

2. Examination

Event Based Model

1. Registration

Register

register( )

2. Examination

begin( )

Event Based Model

1. Registration

Register

register( )

2. Examination

begin( )

get(, ?)

Question

Event Based Model

1. Registration

Register

register( )

2. Examination

begin( )

get(,)

Question

change(, ,)

Event Based Model

1. Registration

Register

register( )

2. Examination

begin( )

get(, ?)

Question

change(, ? , !)

submit(, ? , !)

Answer

accept(, ? , !)

Event Based Model

1. Registration

Register

register( )

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begin( )

get(, ?)

Question

change(, ? , !)

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Answer

accept(, ? , !)

end( )

Event Based Model

3. Marking

Event Based Model

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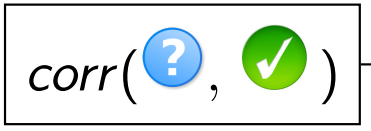

Correct Answer

Event Based Model

3. Marking

corr( ,)

Correct Answer

Evaluation

mark( ,  ,  , )

Event Based Model

3. Marking

corr( ,)

Correct Answer

Evaluation

mark( ,  ,  , )

4. Notification

Event Based Model

3. Marking

corr(,)

Correct Answer

Evaluation

mark(, , ,)

4. Notification

Mark

assign(,)

Plan

Quantified Event Automata (QEAs)

- Properties expressed as **QEAs** [BFH+12]: **event automaton** with quantified variables.
- An event automaton is a **finite-state machine** with transitions labeled by parametric events.
- Transitions may include **guards** and **assignments**.
- We extend the initial definition of QEAs by:
  1. variable declaration and **initialization** before reading the trace
  2. **global variable** shared among all event automaton instances.
     - $event(parameters)\frac{[guard]}{assignment}$

Candidate Eligibility

No answer is accepted from an unregistered candidate

$$\Sigma = \{register(i), accept(i, q, a)\}$$

$\forall i$

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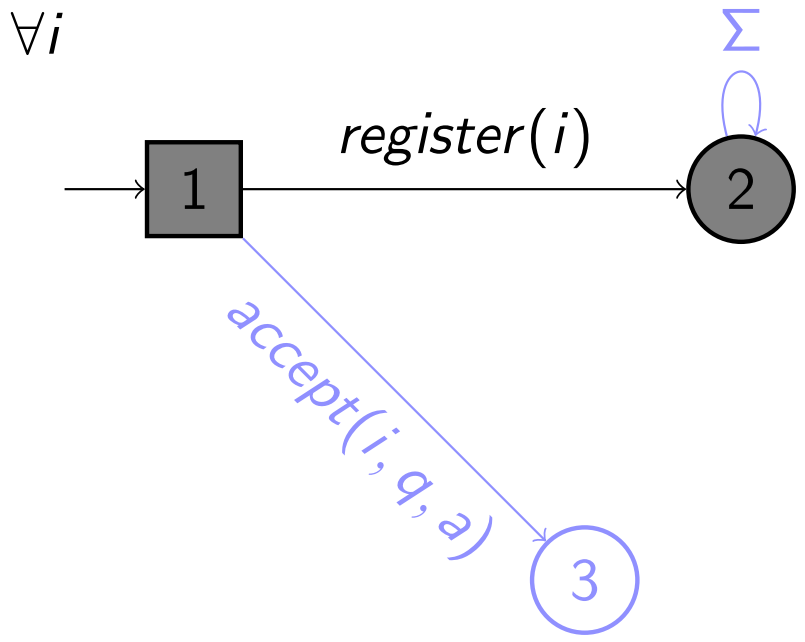
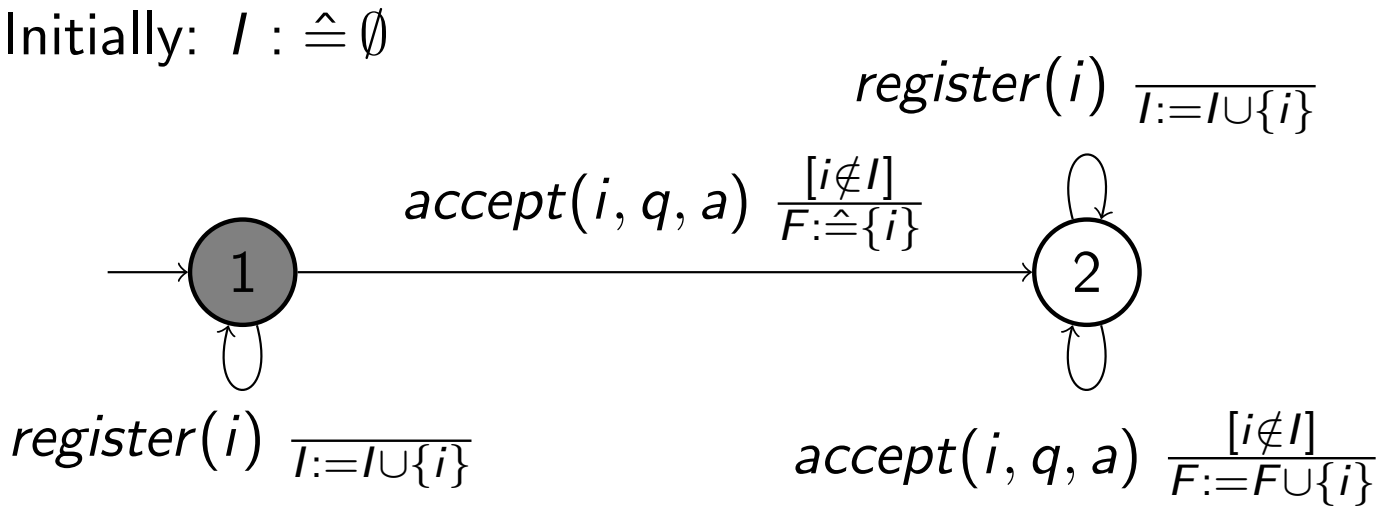


Candidate Eligibility with Auditing

All candidates that violates the requirement are collected in a set F.



Properties

Candidate Registration: an unregistered candidate tried to take the exam.

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Answer Authentication:

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- more than one answer were accepted from a candidate.

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Questions Ordering:

- a candidate got a question before validating the previous ones.

Properties (continued)

Exam Availability: an answer was accepted outside exam time.

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Exam Availability with Flexibility:

- supports different duration and starting time between candidates.

Marking Correctness: an answer was marked in a wrong way.

Mark Integrity:

- an accepted answer was not marked; or
- a candidate was not assigned the corresponding mark.

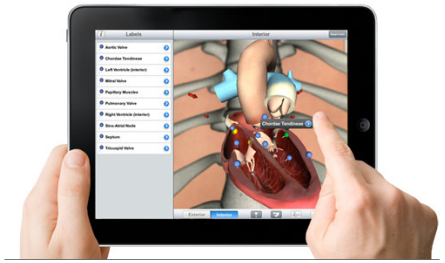
Plan

E-exam at Université Joseph Fourier (UJF)

Registration:

- 2 weeks before the exam.
- Using login/password.

E-exam at Université Joseph Fourier (UJF)



Examination in a supervised room

Authentication and answers questions as follows:

- In a fixed order.
- Once validates the current question, he gets the next one.
- He can change the answer unlimited times before validating.
- Once he validates, then he cannot go back and change any of the validated answers.

E-exam at Université Joseph Fourier (UJF)

Marking:

- For each question, the professor specifies the correct answer(s).
- For each question, all the answers provided by the candidates are collected.
- Each answer is evaluated by an examiner to 0 or 1.
- The mark for each candidate is calculated as the summation of all the scores attributed to his answers.

Notification:

- The marks are notified to the candidates.
- A candidate can consult his submission and check the marking.

Analysis

Verification of two real e-exam executions using MarQ tool [RCR15].

From the logs: $register(i)$, $change(i, q, a)$, $submit(i, q, a)$, $accept(i, q, a)$.

4 Properties

- Candidate Registration
- Candidate Eligibility
- Answer Authentication
- Exam Availability

5 new properties

- Answer Authentication *:
  - All accepted answers are submitted by candidates.
  - **Allow the acceptance of the same answer again**.
  - **But, still forbids the acceptance of a different answer**.

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- Answer Editing: A candidate cannot change an answer after validation it.
- Question Ordering *: A candidate cannot changes the answer to a future question before validating the current question.
- Acceptance Order: A candidate has to validate the questions in order, but he can skip some questions.

Results: Exam 1

233 students, 40875 events

Property	Result	Time (ms)
Candidate Registration	✓	538
Candidate Eligibility	✓	517
Answer Authentication	×	310
Exam Availability	✓	518
Answer Authentication *	✓	742
Answer Authentication Reporting	×[1]	654
Answer Editing	✓	641
Question Ordering *	×	757
Acceptance Order	✓	697

Results: Exam 2

90 students, 4641 events

Property	Result	Time (ms)
Candidate Registration	✓	230
Candidate Eligibility	✓	214
Answer Authentication	✓	275
Exam Availability	×[1]	237
Answer Authentication *	✓	223
Answer Authentication Reporting	✓	265
Answer Editing	×	218
Question Ordering *	×	389
Acceptance Order	✓	294

Plan

Conclusion

- Event-based model of e-exams.
- Several properties defined as QEAs.
- Analysis of 2 real e-exams at UJF using MarQ tool.
- Discovering some misbehaviours.

Future Work

- Analyze more existing e-exams from other universities.
- Perform on-line verification with our monitors during live e-exams.
- Study more expressive and quantitative properties that can detect colluded students through similar answer patterns.
- Automatic transformation from verifiability to monitors.

Thank you for your attention!

Questions?

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Howard Barringer, Yliès Falcone, Klaus Havelund, Giles Reger, and David E. Rydeheard.
Quantified event automata: Towards expressive and efficient runtime monitors.
In *FM 2012: Formal Methods - 18th International Symposium, Paris, France, August 27-31, 2012. Proceedings*, volume 7436 of *Lecture Notes in Computer Science*, pages 68–84. Springer, 2012.


Giles Reger, Helena Cuenca Cruz, and David E. Rydeheard.
MarQ: Monitoring at runtime with QEA.
In *Tools and Algorithms for the Construction and Analysis of Systems - 21st International Conference, TACAS, London, UK*, pages 596–610, 2015.

Candidate Eligibility

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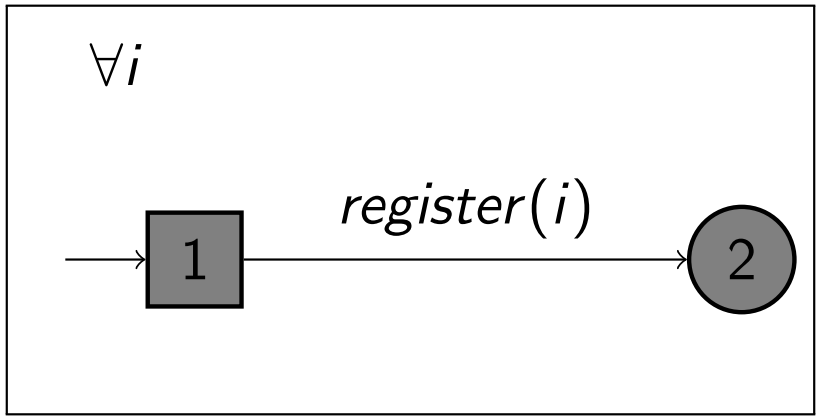
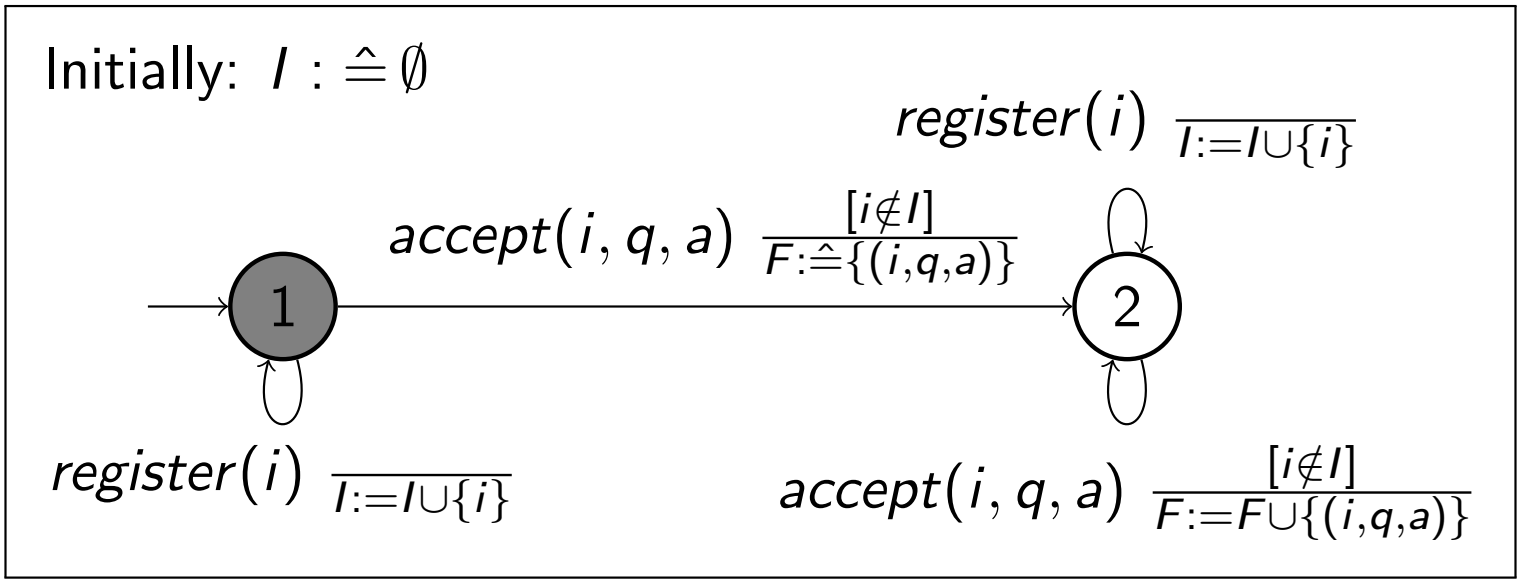
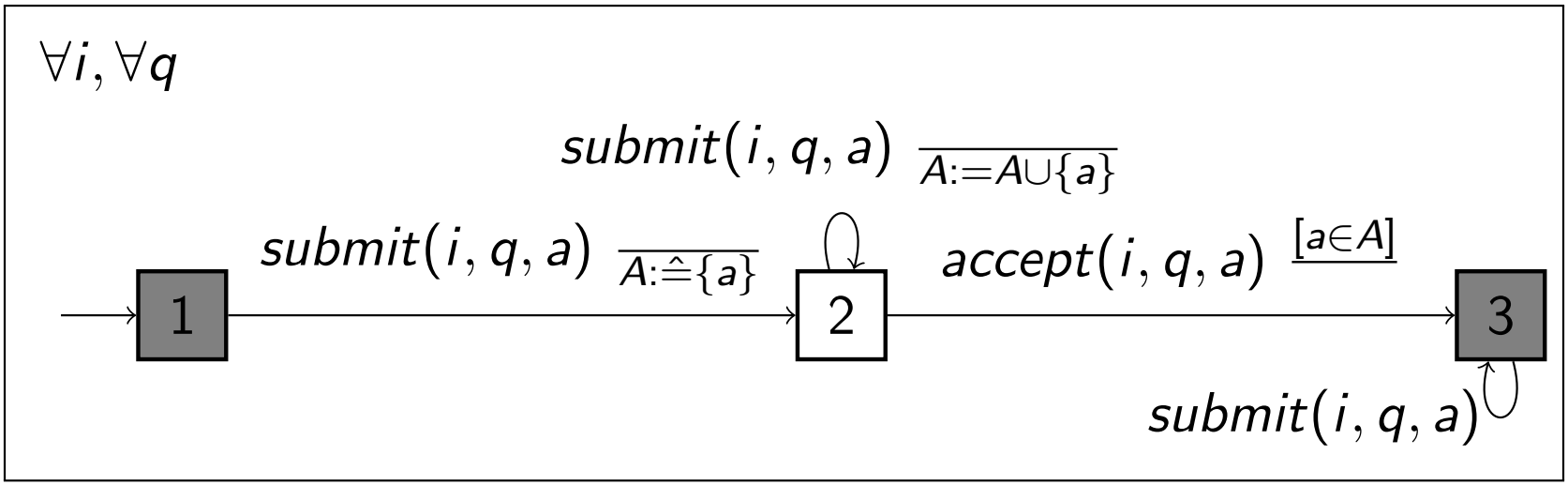


Candidate Eligibility with Auditing



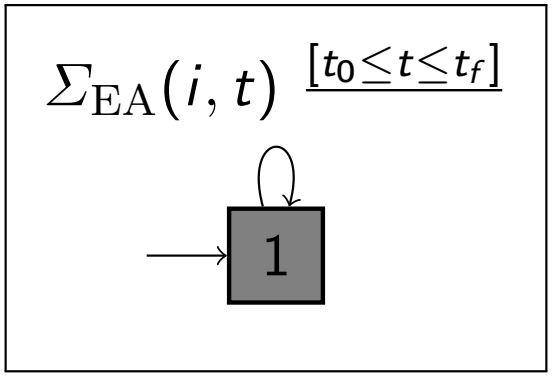
Answer Authentication

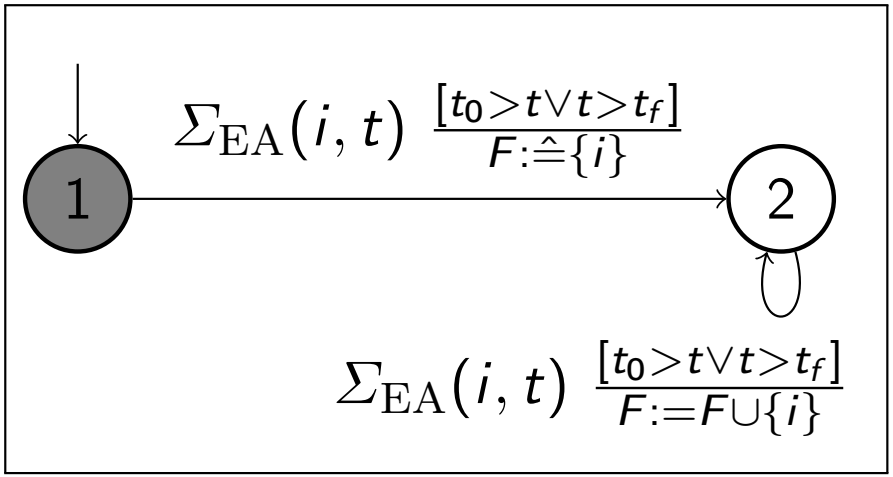
- All accepted answers are submitted by candidates.
- Exactly one answer is accepted from each candidate.



Exam Availability

A candidates can take the exam only during the examination time.

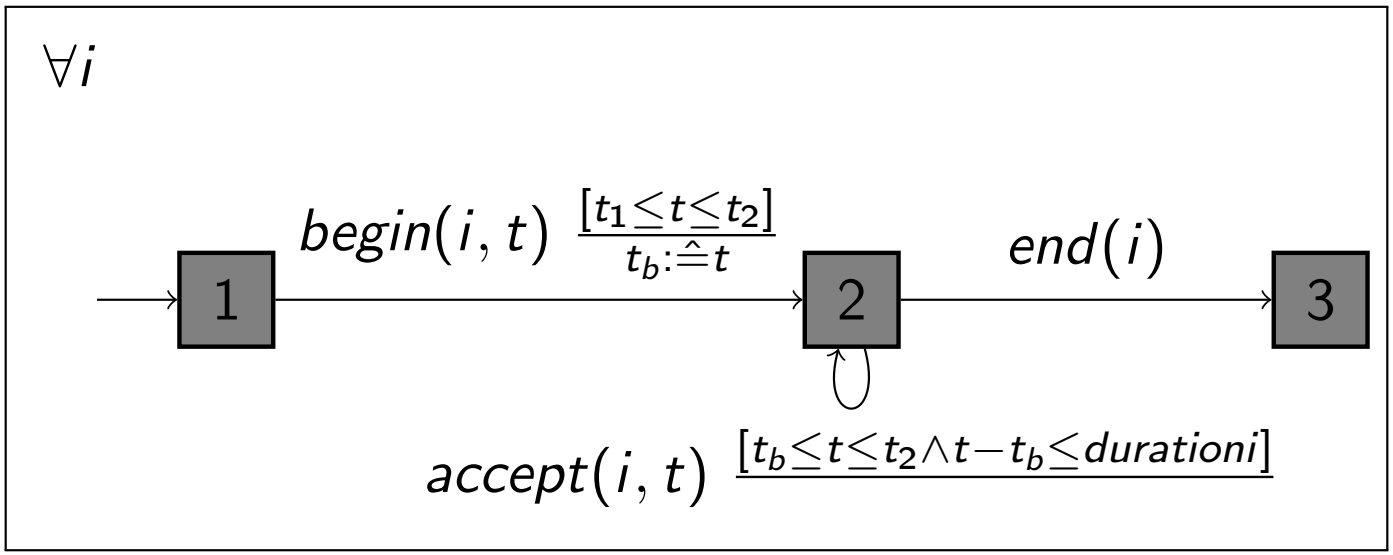




- $\Sigma_{\mathrm{EA}} = \{get(i,t), change(i,t), submit(i,t), accept(i,t)\}$.
- t_0 is the starting instant of the exam.
- t_f is the ending instant of the exam.

Exam Availability with Flexibility

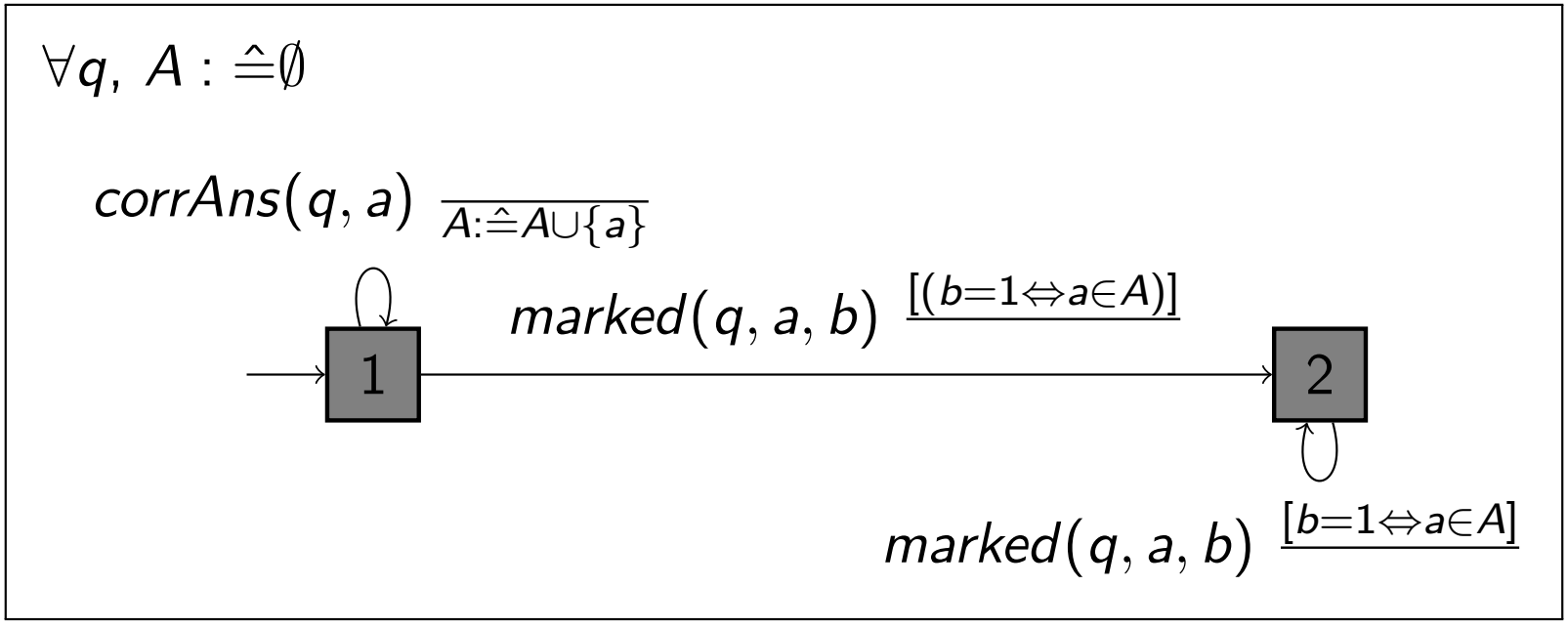
Exam Availability with flexible starting time and duration.



- t_1 is the starting instant of the allowed period.
- t_2 is the ending instant of the allowed period.

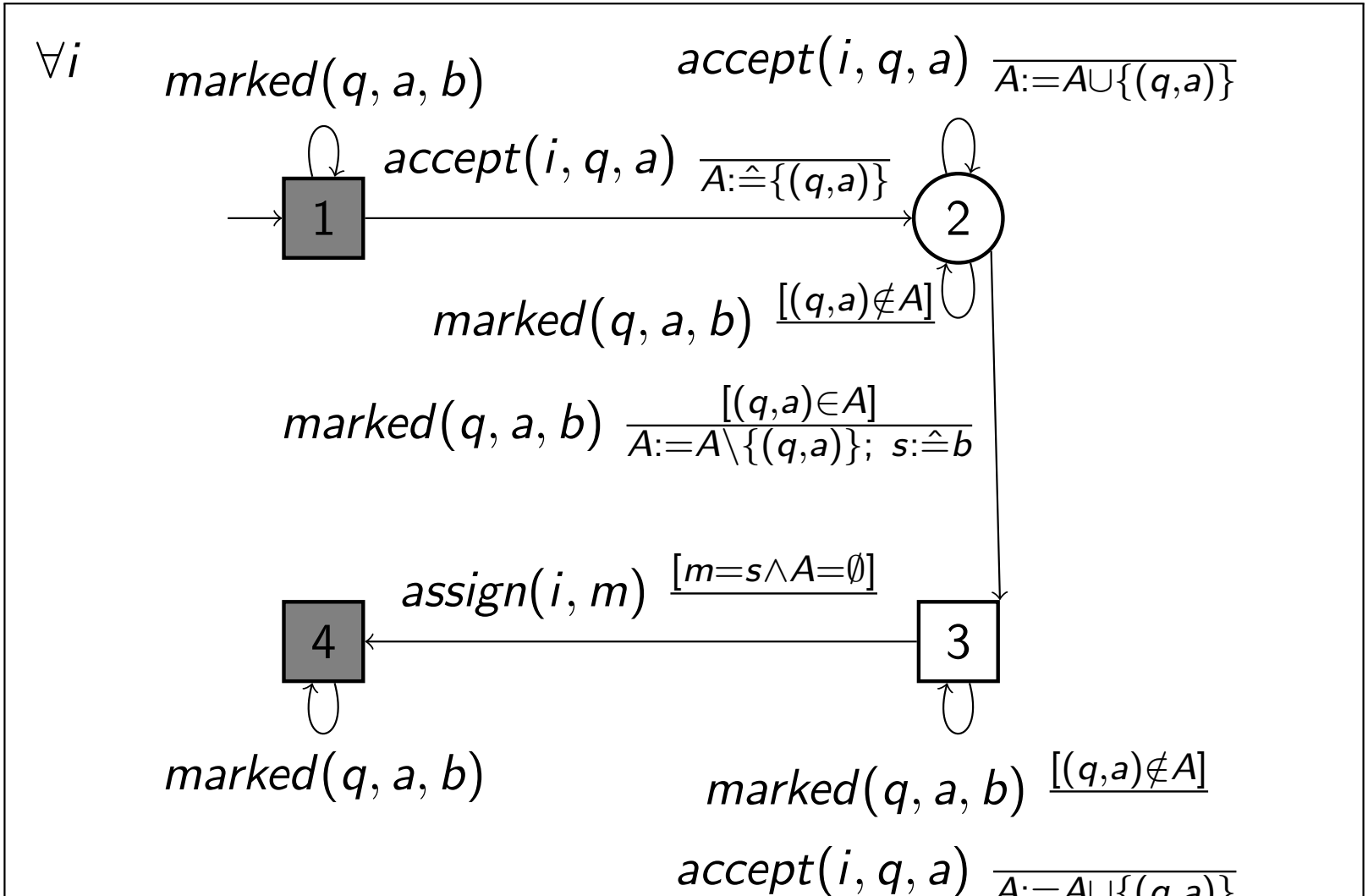
Marking Correctness

All answers were marked correctly.



Mark Integrity

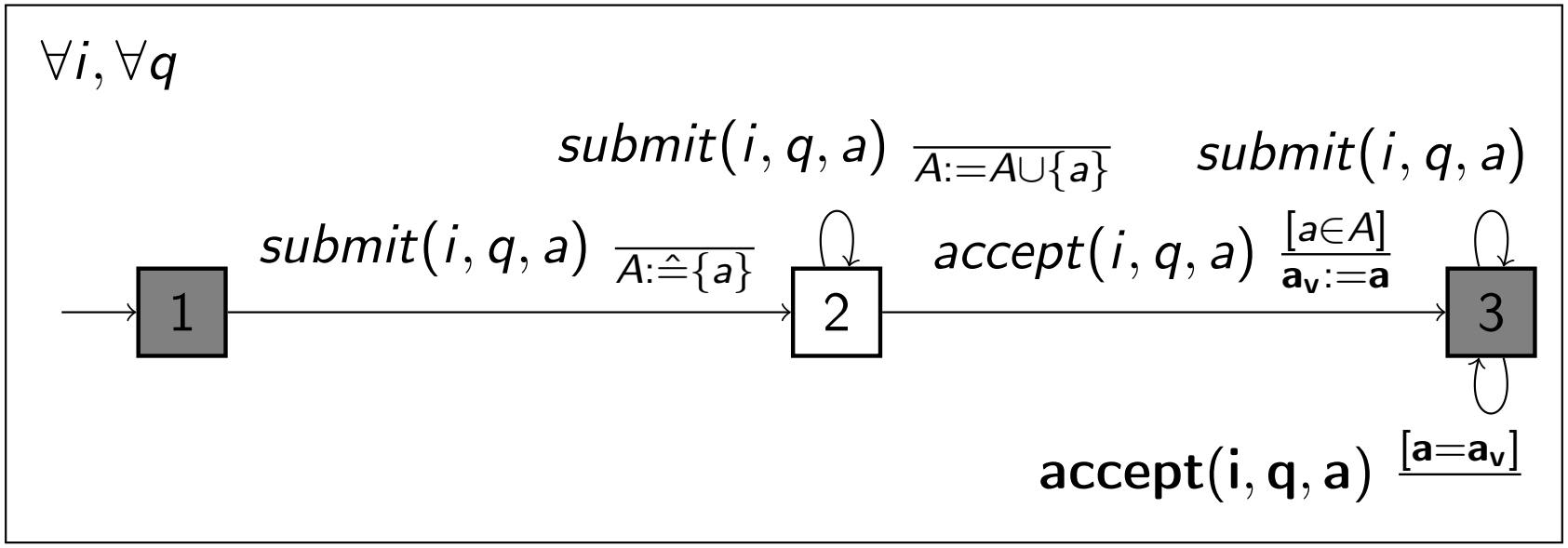
- All accepted answers were marked;
- each candidate was assigned the mark attributed to his answers.



Answer Authentication *

A weaker variant of Answer Authentication:

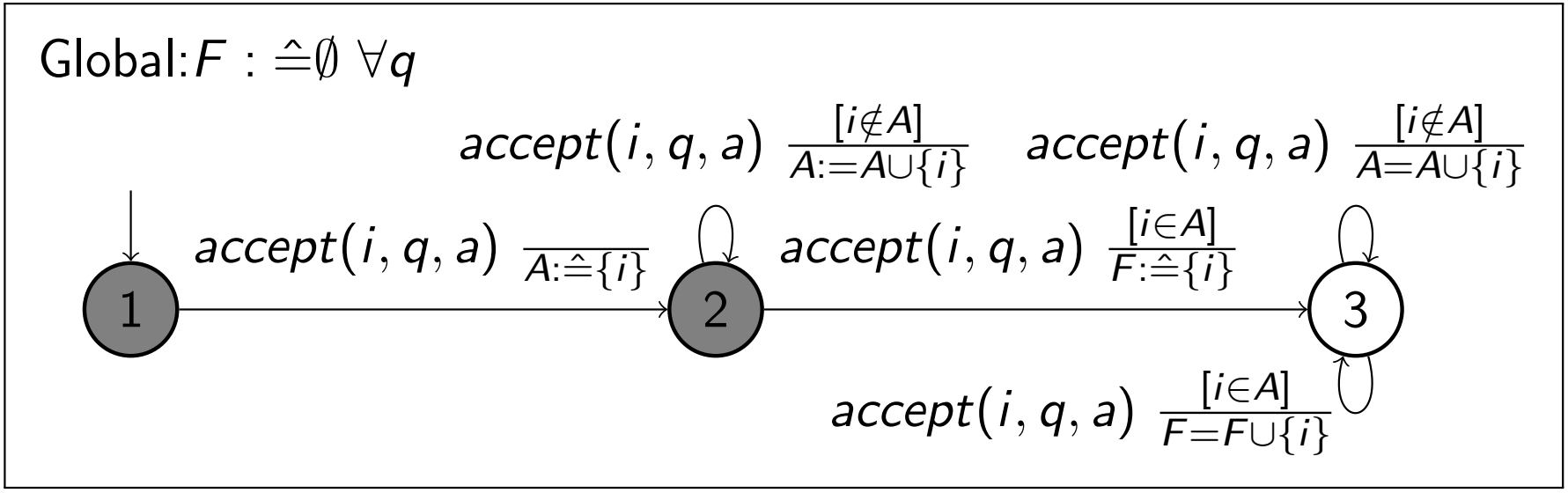
- All accepted answers are submitted by candidates.
- **Allow the acceptance of the same answer again.**
- **But, still forbids the acceptance of a different answer.**



Motivation: UJF exam allows the acceptance of the same answer twice.

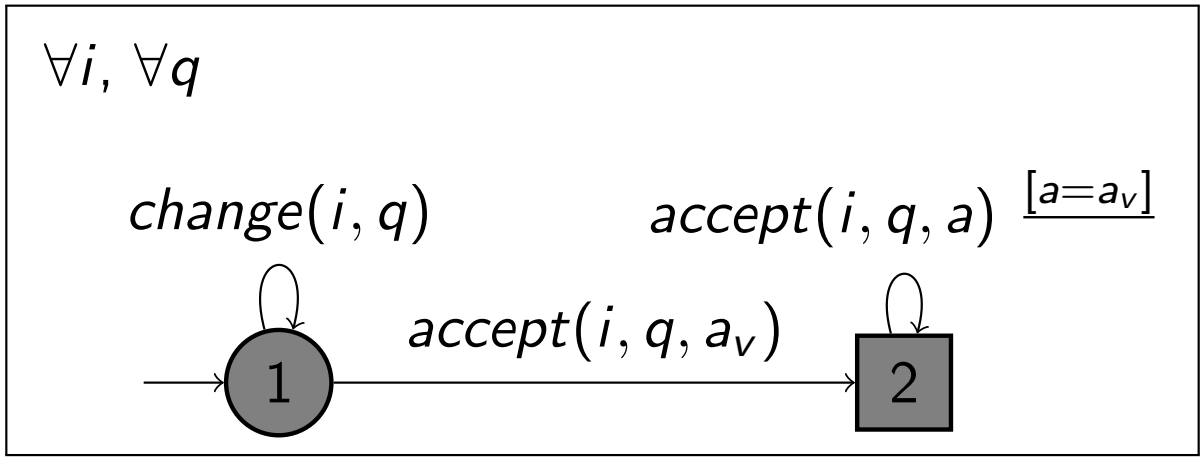
Answer Authentication Reporting

Collects in a set F every candidate from which more than one answer are accepted.



Answer Editing

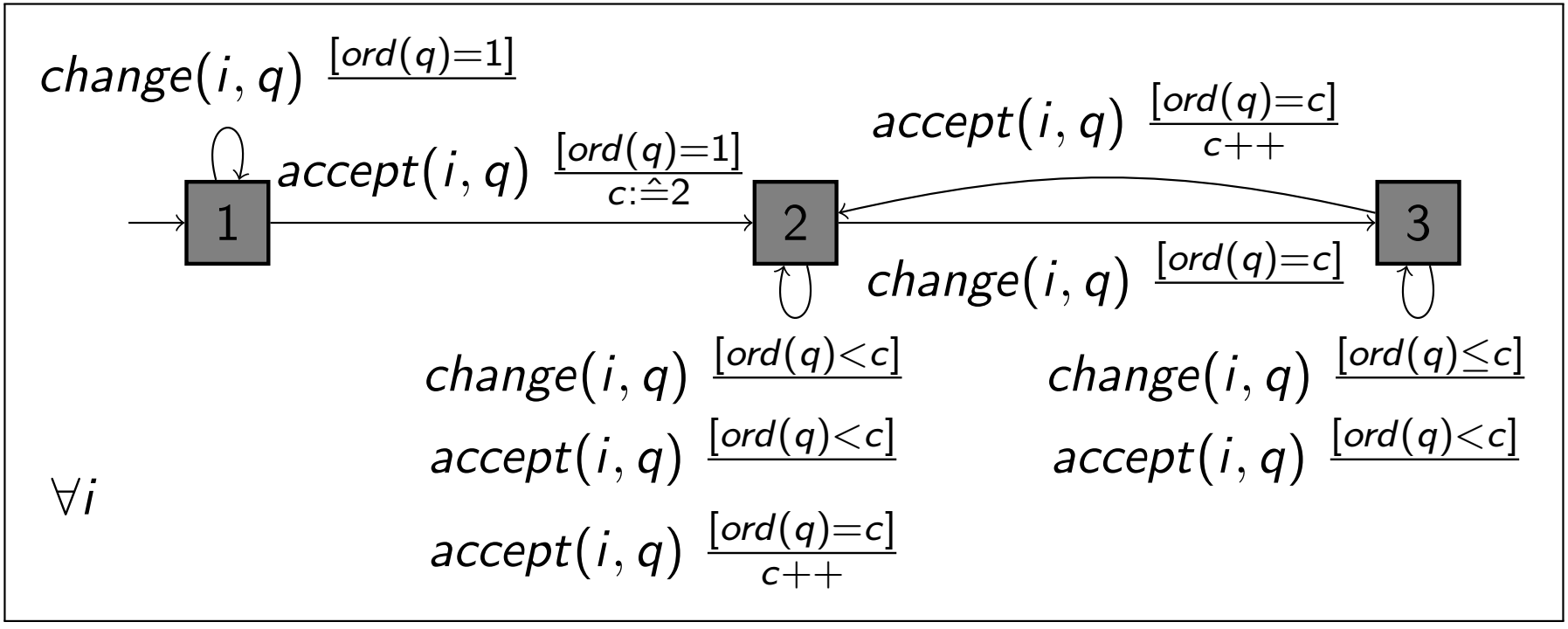
A candidate cannot change an answer after validation it.



Motivation: UJF exam does not allow a candidate to change any of the previously validated answers.

Question Ordering *

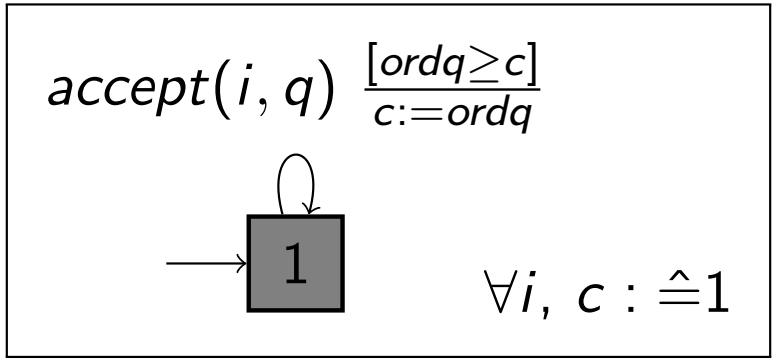
A candidate cannot changes the answer to a future question before validating the current question.



Motivation: developers did not log anything related to the event $get(i, q)$ (needed for Question Ordering).

Acceptance Order

A candidate has to validate the questions in order, but he can skip some questions.



Motivation: allows us to check if candidates answer the question in lexicographic order when Question Ordering * fails.

It is the case when a candidate able to skip some questions.