Process algebras for quantitative analysis: Lecture 6 — Response-time analysis and safety

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February 11, 2010

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Outcomes

Successful application of the Sensoria methodology, using process calculi cooperatively. Made connections between the FSP and PEPA calculi. Planned integration of tools using scripting.

Outline

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   - Service providers
   - SENSORIA Development Environment (SDE)
2. Service description
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   - UML activity diagram
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- One way to carry out such an assessment is to construct a *precise formal model* of the service and perform the analysis on the model to shed light on the behaviour of the service itself.

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- The service providers delivering these critical services may not themselves have the *technical skills* to apply methods such as these.
- Even if they are able to source the necessary skills from expert users elsewhere, they may not be happy to take advantage of this because they would then *risk revealing information about their current service provision* which they might be unwilling to disclose to anyone outside their organisation.

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- These environments can then be adopted and applied by the service providers in-house, allowing them to *evaluate their service provision without revealing sensitive information* about their current level of service.

SENSORIA Development Environment (SDE)

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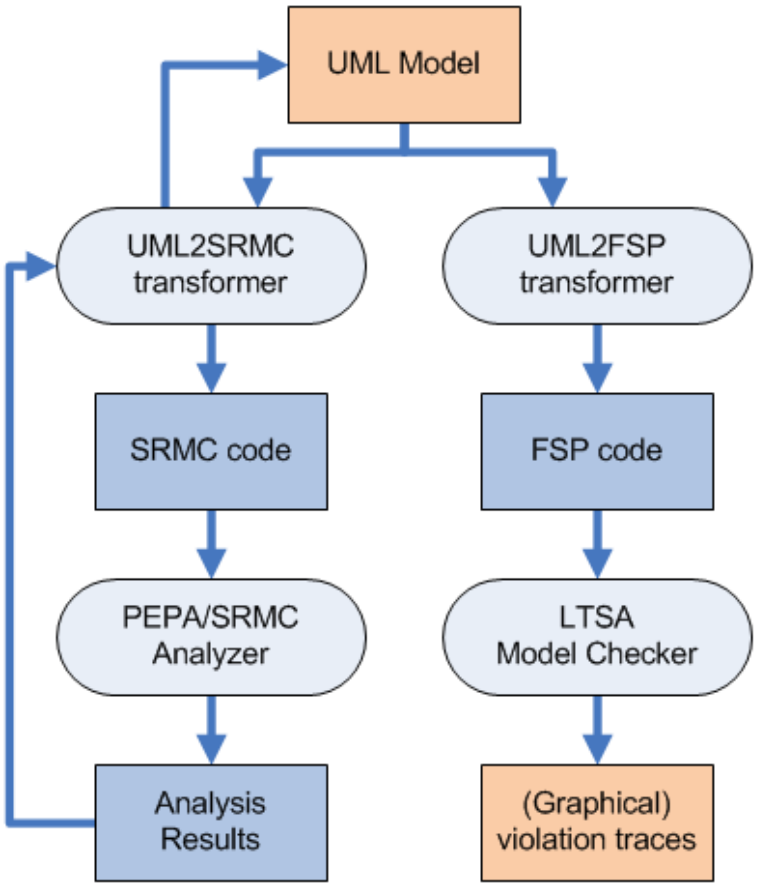
- We use the SDE and other tools to assess an accident assistance service against both safety properties (using model-checking over labelled transition systems) and response-time properties (using transient analysis of continuous-time Markov chains).

SENSORIA Development Environment (SDE)



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- The service is triggered by any impact or collision which causes the car airbag to deploy. Immediately after the airbag has deployed the on-board communication module transmits to the assistance service a report with as much information as it can obtain from the car's diagnostic system.

Accident report

- This report includes information about the state of the car itself obtained from sensors in the engine and the braking system. The report also specifies the speed of the car at the moment of impact and, most importantly, the geographical location of the car as obtained from the on-board GPS.

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Example

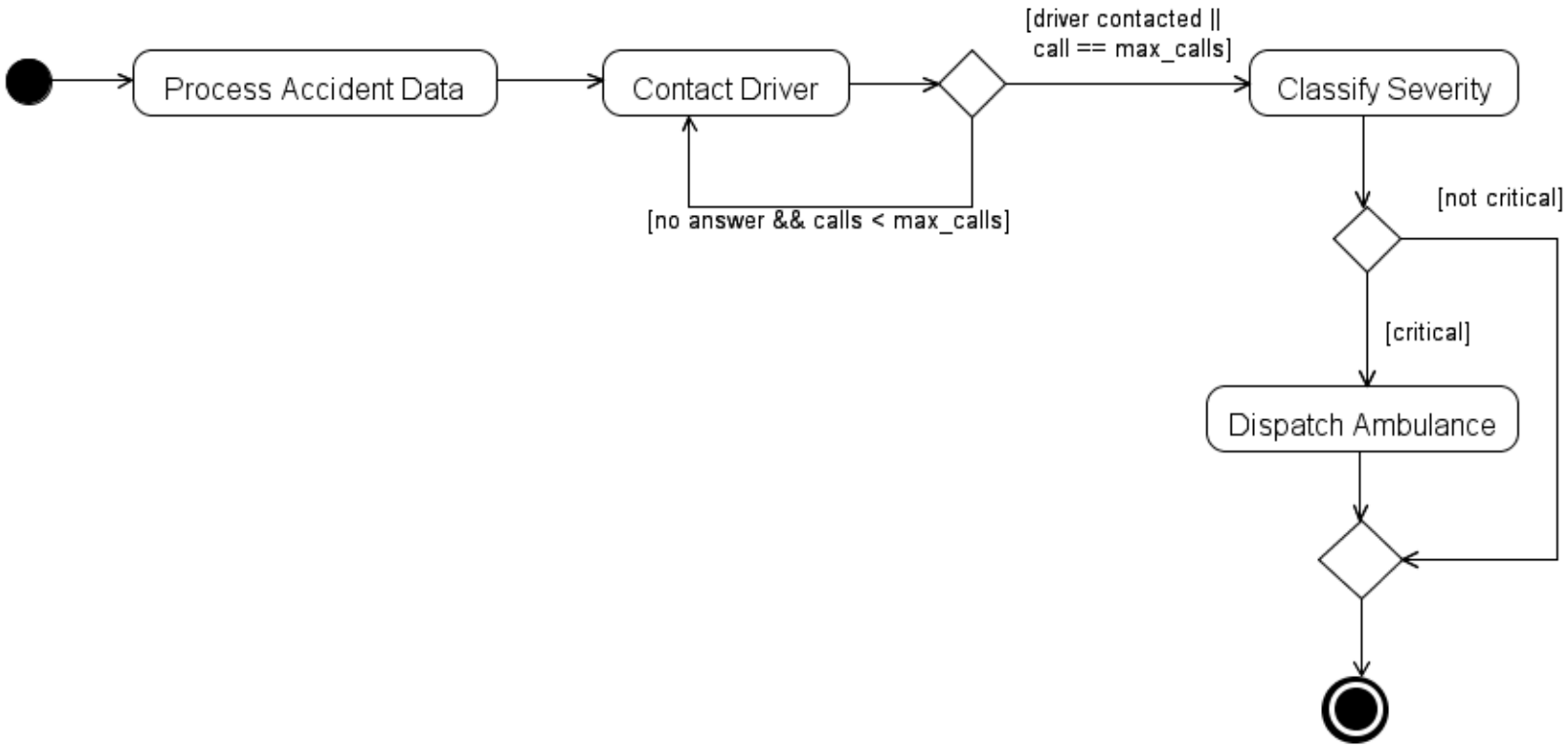
OnStar service from General Motors (`http://www.onstar.com/`)

OnStar in action

The actor Charlie Sheen received a call from OnStar on the morning of February 5th, 2010 after the airbags deployed on one of his cars. His Mercedes Benz was found in a canyon in Beverley Hills after plunging off of Mulholland Drive.

Charlie Sheen's car, February 5, 2010

UML activity diagram of the Accident Assistance Service



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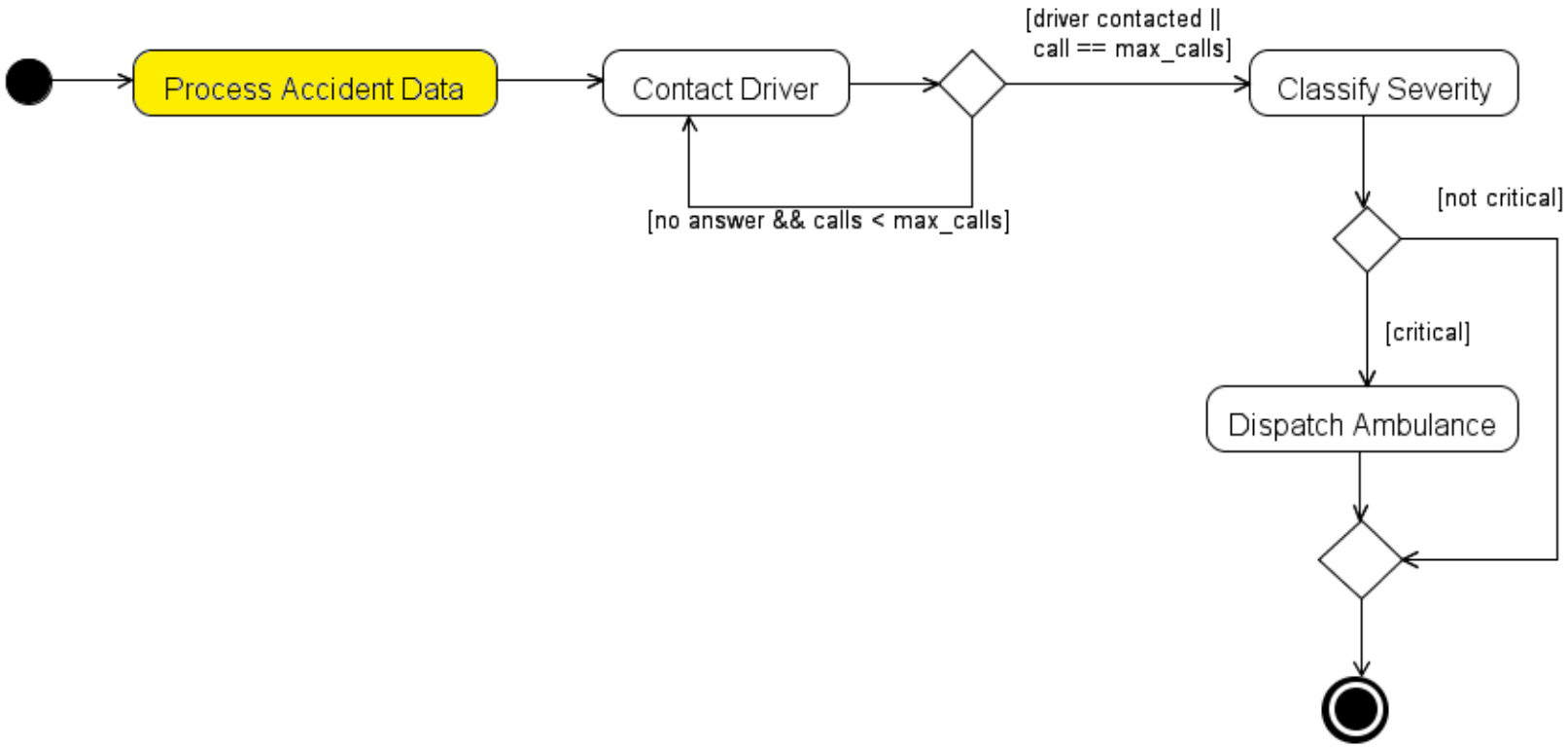

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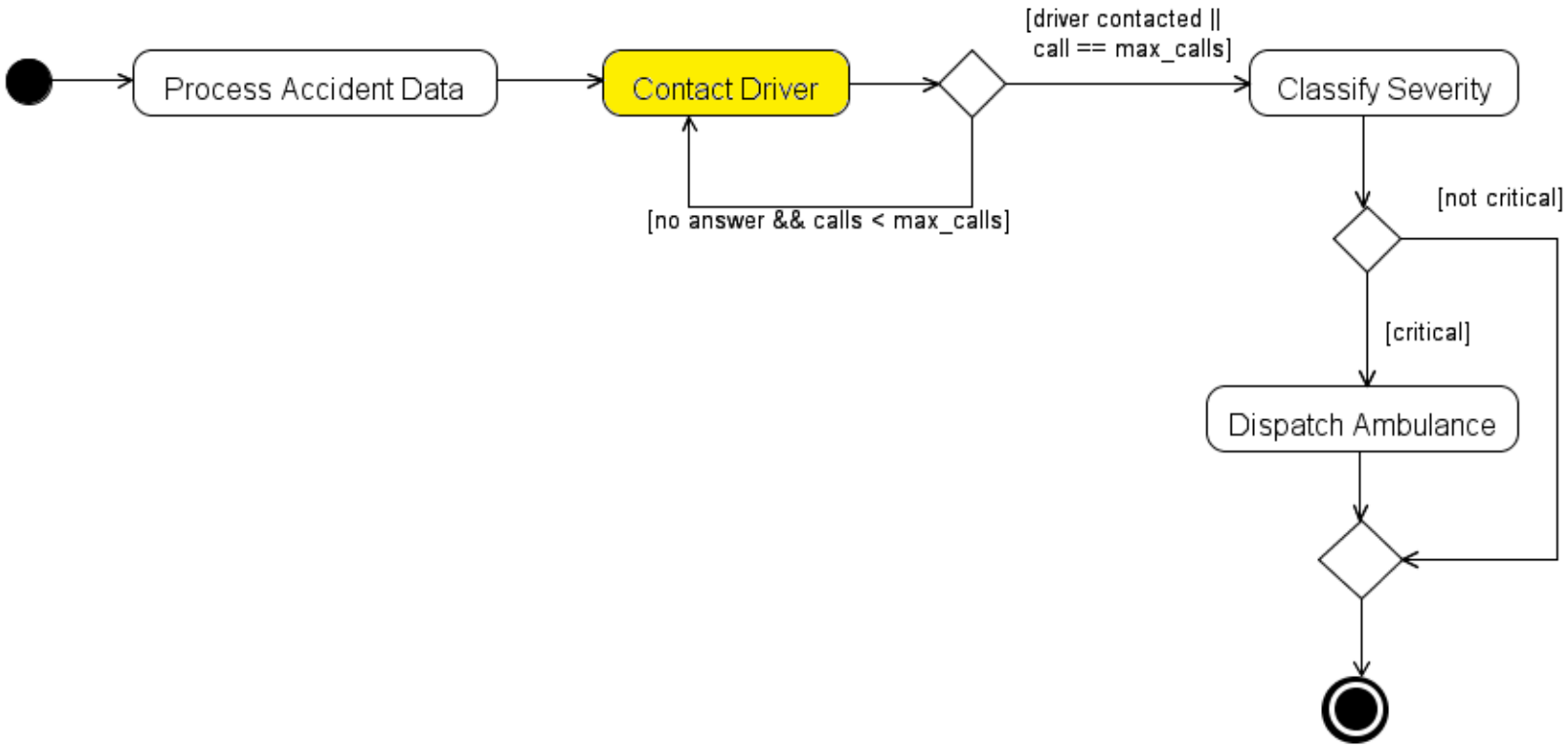

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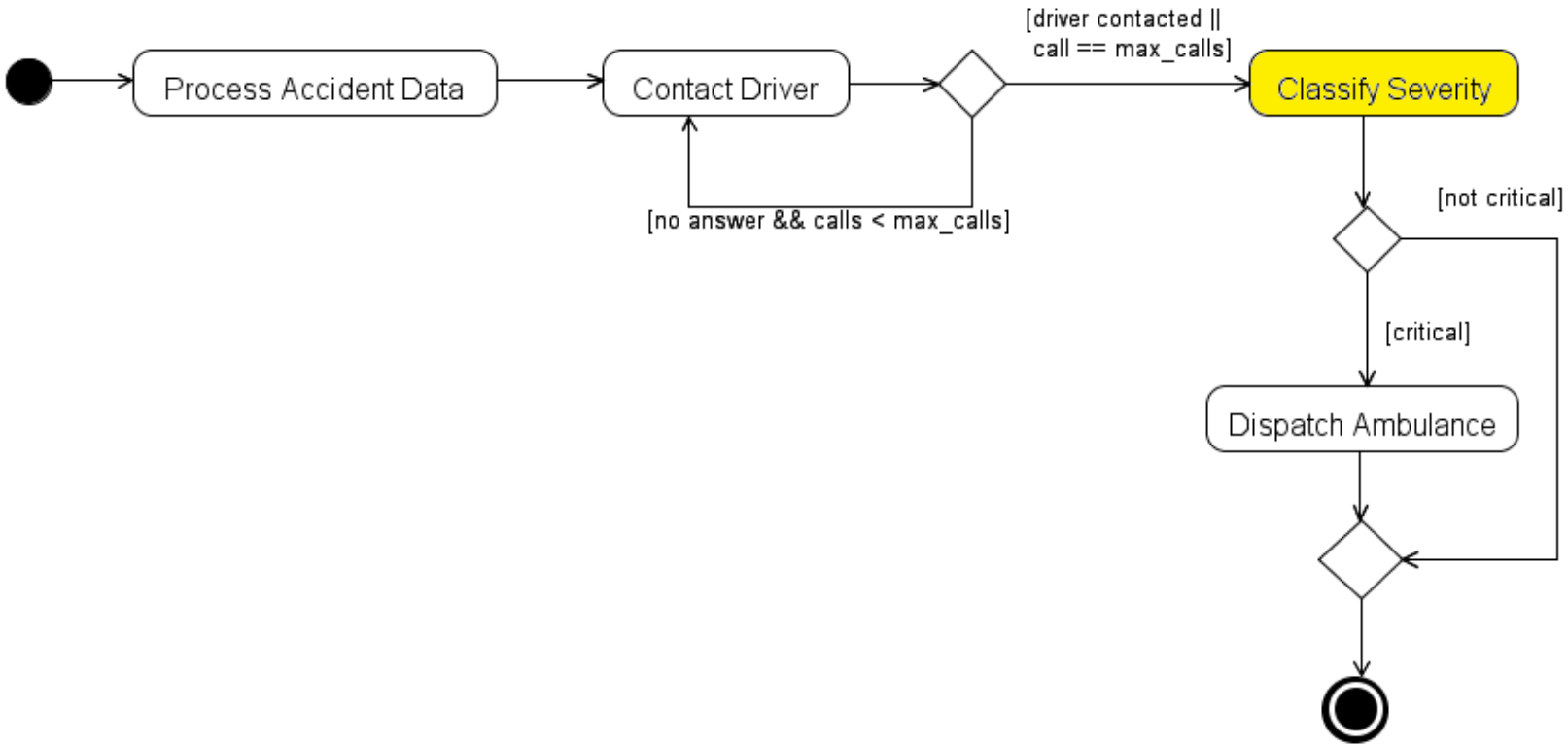

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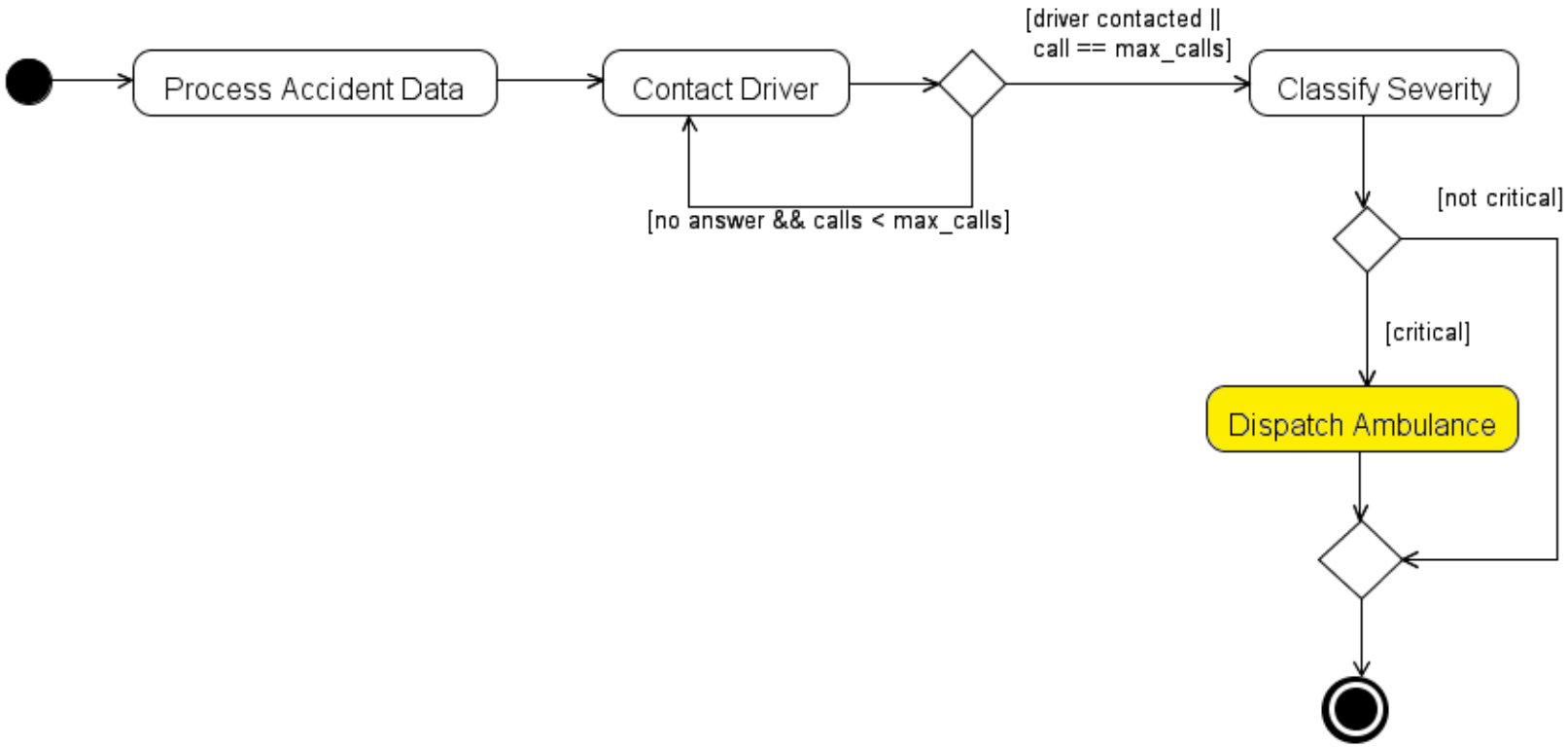

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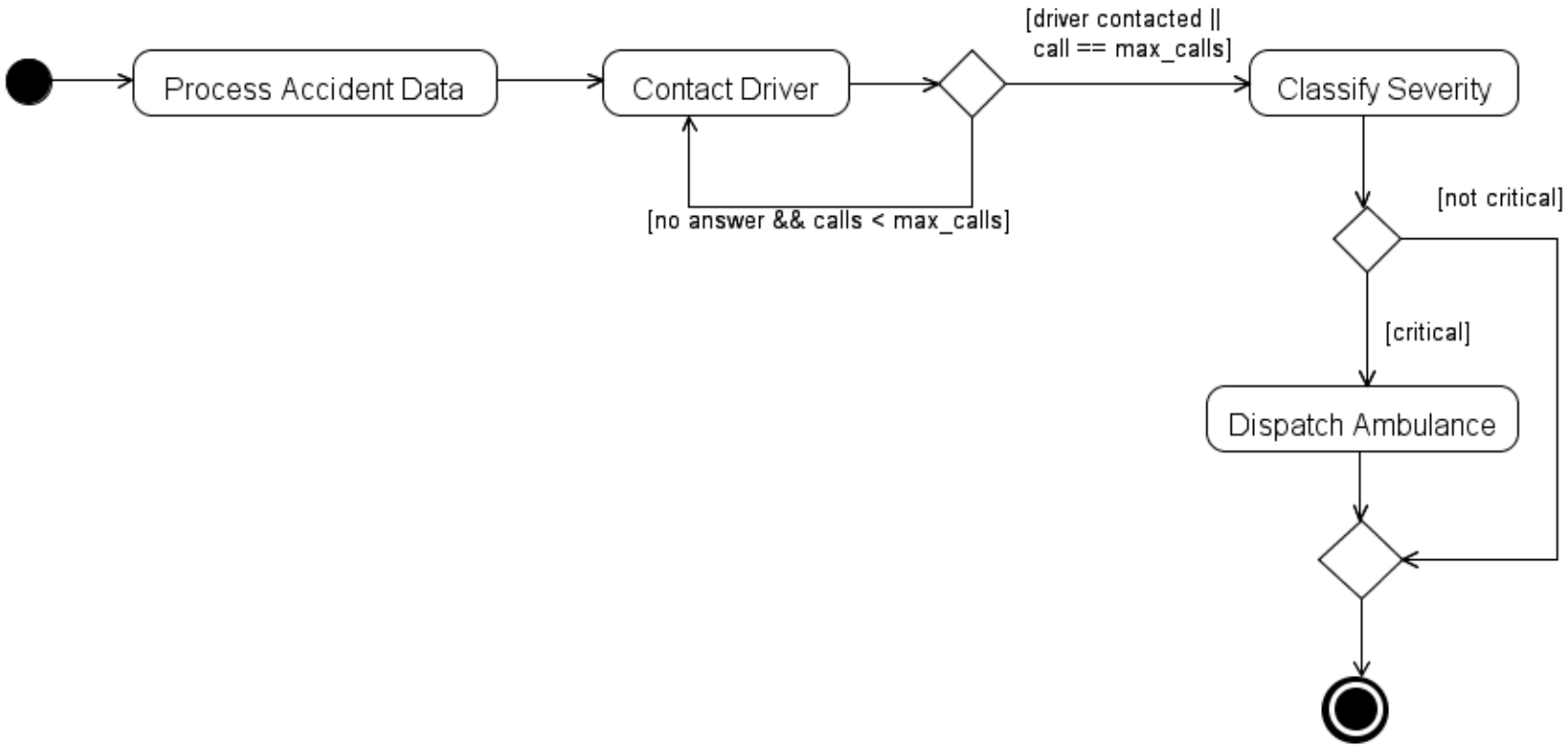

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- It might seem that the obvious course of action should be to consider not getting an answer to be a critical case but there is evidently a possibility that the service will send an ambulance when it is not needed.
- That is, the driver is unhurt but did not have their mobile telephone with them, or it had no battery charge, or they had no signal from their telephone service provider, or many other similar reasons.

An important case: No answer

- Because critical services should not be deployed without good reason, the accident assistance service would like to reduce the number of occasions when an ambulance is dispatched in error. The *information on the car status* and the speed of the car at the moment of impact sent with the accident report become significant when we have no answer from the driver.

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- In the case of no answer and car diagnostics which point to very little damage (say, the car was stationary at the time of impact, and the engine, brakes, lights and other critical functions seem to be functioning normally) then the service will decide *not to send an ambulance* to prevent sending one when it could be needed elsewhere.

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Example

No, not necessarily.
(`http://www.youtube.com/watch?v=6bBVJAFrNOU`)

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- Models are created with a specific purpose in mind.
- Our model of the Accident Assistance Service details the events which are the area of responsibility of the service itself. That is, those activities which occur between an accident report being received and the service discharging its responsibility to act on the accident report.
- In some cases this will lead to an ambulance being sent, and in other cases not.

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- For example, we do not estimate how often accidents occur and we do not calculate how long ambulances take to arrive. Both of these may be interesting to know, but our model here does not speak of them.

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Safety analysis with FSP

- For the purpose of our analysis, we translate the service process workflow into the **Finite State Processes (FSP)** notation to concisely and formally model the workflow states and transitions.

Finite State Processes (FSP)

Action prefix	`(x->P)` describes a process which first engages in the action `x` and then behaves as described by the auxiliary process `P`;
Choice	`(x->P|y->Q)` describes a process which initially engages in either `x` or `y`, and then becomes `P` or `Q`, respectively;
Recursion	The behaviour of a process may be defined in terms of itself, in order to express repetition;
Sequential composition	`(P;Q)` behaves as `P` and when it reaches the `END` state of `P` behaves as `Q`;
Parallel composition	`(P||Q)` describes the parallel composition of processes `P` and `Q`.

FSP model

ProcessAccidentData FSP Process Composition

```
VEHDIAGCHOICE = (
    vehicle.emergsrv.diags_normal->
        emergsrv.diag.write[normal]->END |
    vehicle.emergsrv.diags_critical->
        emergsrv.diag.write[critical]->END).
VEHDIAGSEQ = VEHDIAGCHOICE; END.
||PROCESSACCIDENTDATA = (VEHDIAGSEQ).
```

FSP model

Call Attempts Composition

```
// no of calls before automatic dispatch
const Max = 3

CALLATTEMPT(N=0) = CALL[N],
CALL[v:Int] = (emergsrv.driver.callphone->ANSWER[v]),
ANSWER[v:Int] = (driver.emergsrv.noanswer->CALL[v+1]|
   driver.emergsrv.answer->ANSWEREDACTION),
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FSP model

Check diagnostic information received

```
QUERYDIAGSTATUS = (emergsrv.diag.read[i:Int]->
    QUERYDIAGSTATUS[i]),
QUERYDIAGSTATUS[i:Int] = if (i==critical)
    then DISPATCH; END else END.
CLASSIFYSEQ = QUERYDIAGSTATUS; END.
||CLASSIFYSEVERITY = (CLASSIFYSEQ).
```

FSP model

Dispatch Ambulance

```
SENDAMBULANCE =
    (emergsrv.station.send_ambulance->END).
||DISPATCH = (SENDAMBULANCE).
```

Assistance Log (Final Action)

```
LOG = (emergsrv.log.result->END).
||LOGREPORT = (LOG).
```

Service Main sequence

```
MAINSEQ = PROCESSVEHICLEDATA; CONTACTDRIVER;
    CLASSIFYSEVERITY; LOG; END.
```

Labelled Transition System Analyzer (LTSA)

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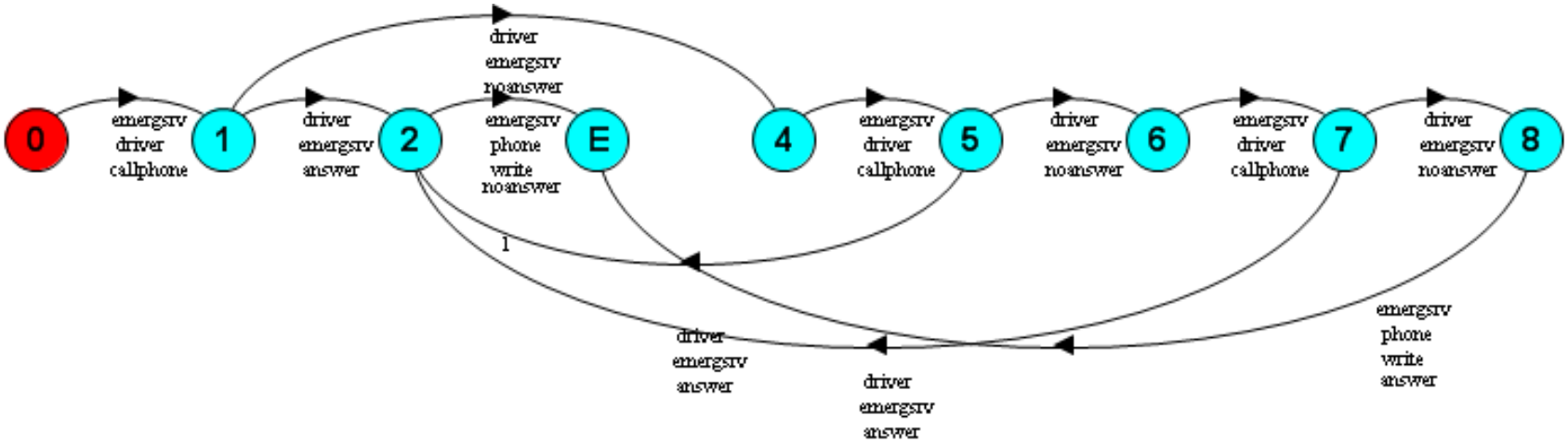
- A default deadlock check of the service process results in no violations being found (i.e. that there are no deadlock states in the model).

Labelled transition system for the driver call process



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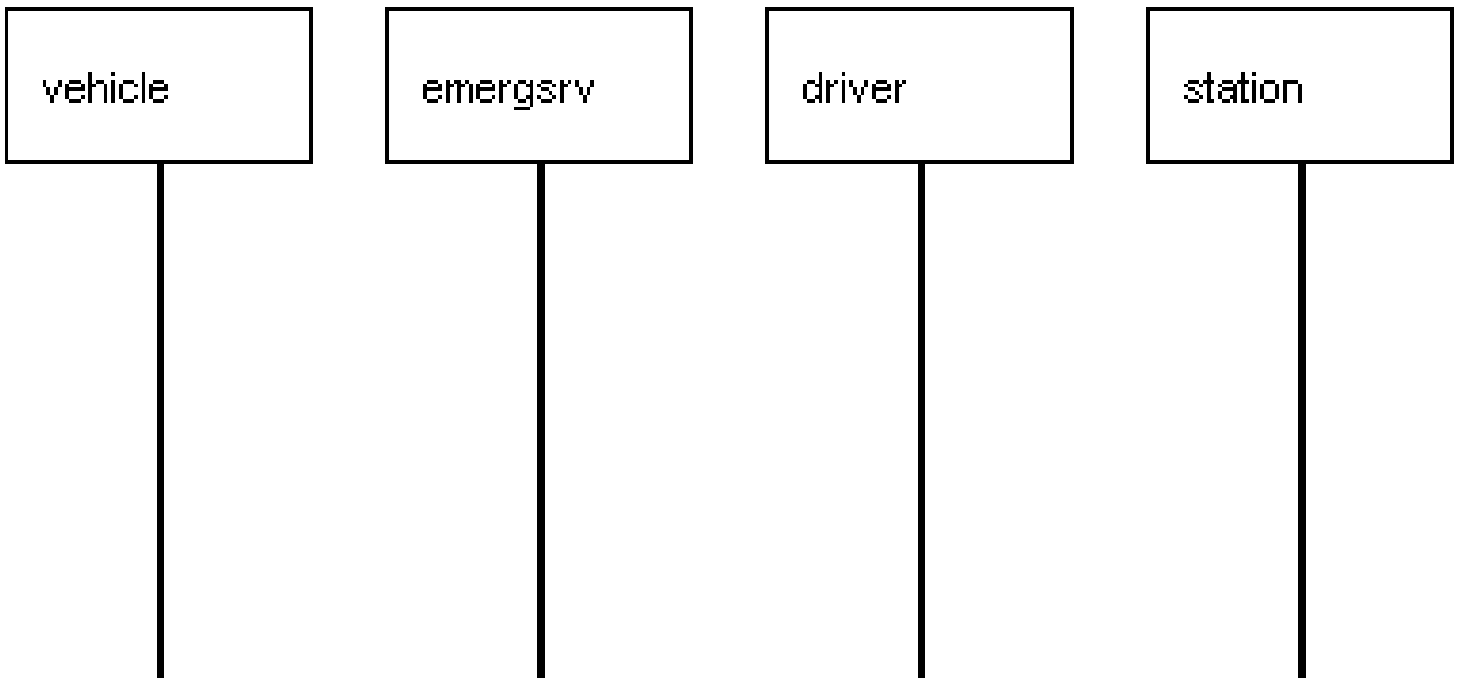
Model-checking uncovered a flaw in an earlier version of the model which (erroneously) omitted the check on the severity reported by the driver in the case that they answer the phone.

- This led to the possibility of an ambulance being sent in error.
- The violation of the property is reported by LTSA in the form of a message sequence chart.

LTSA output of trace leading to violation



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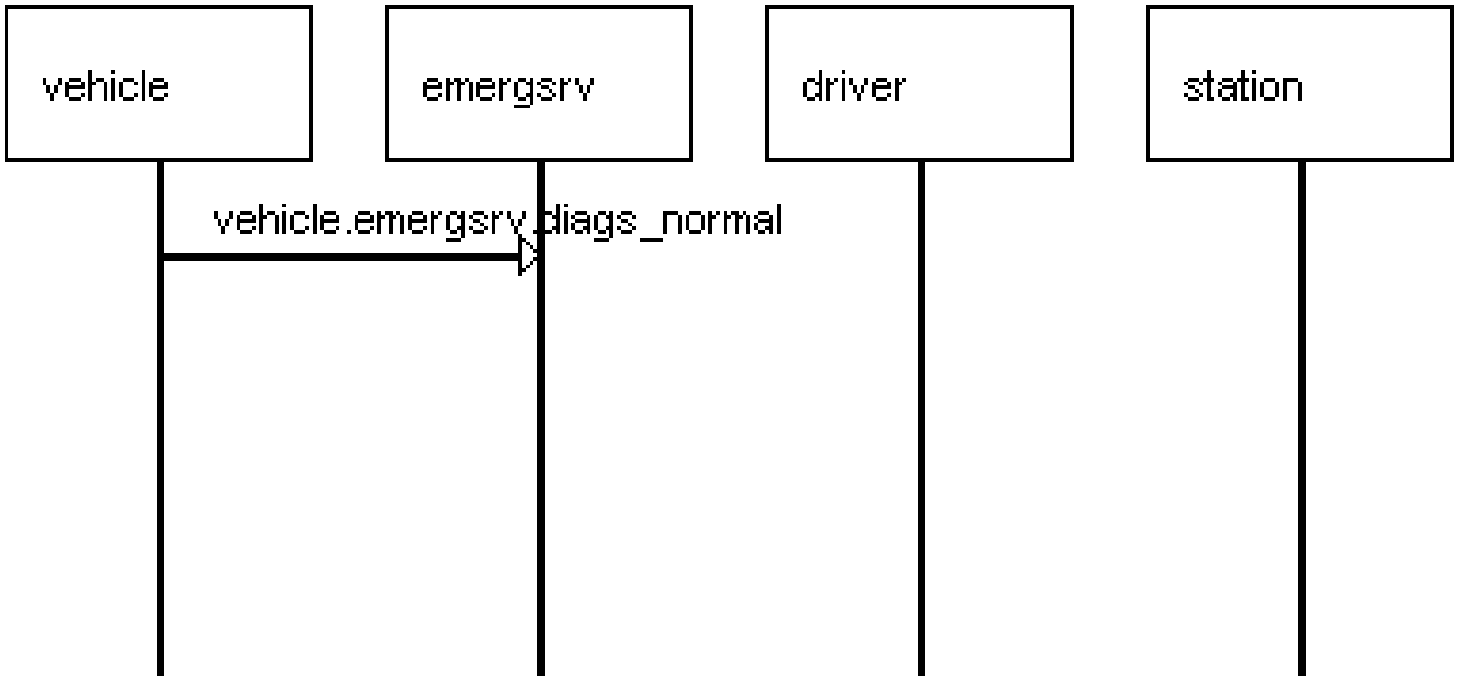

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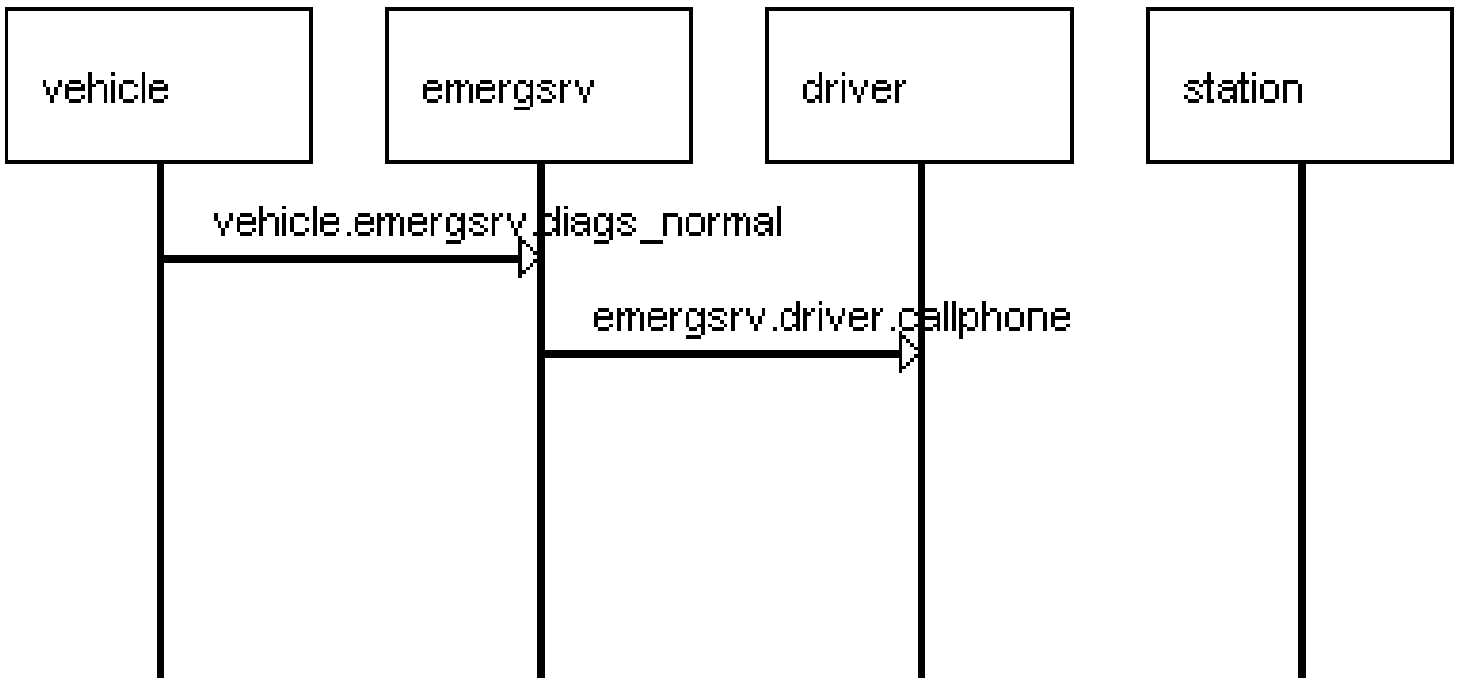

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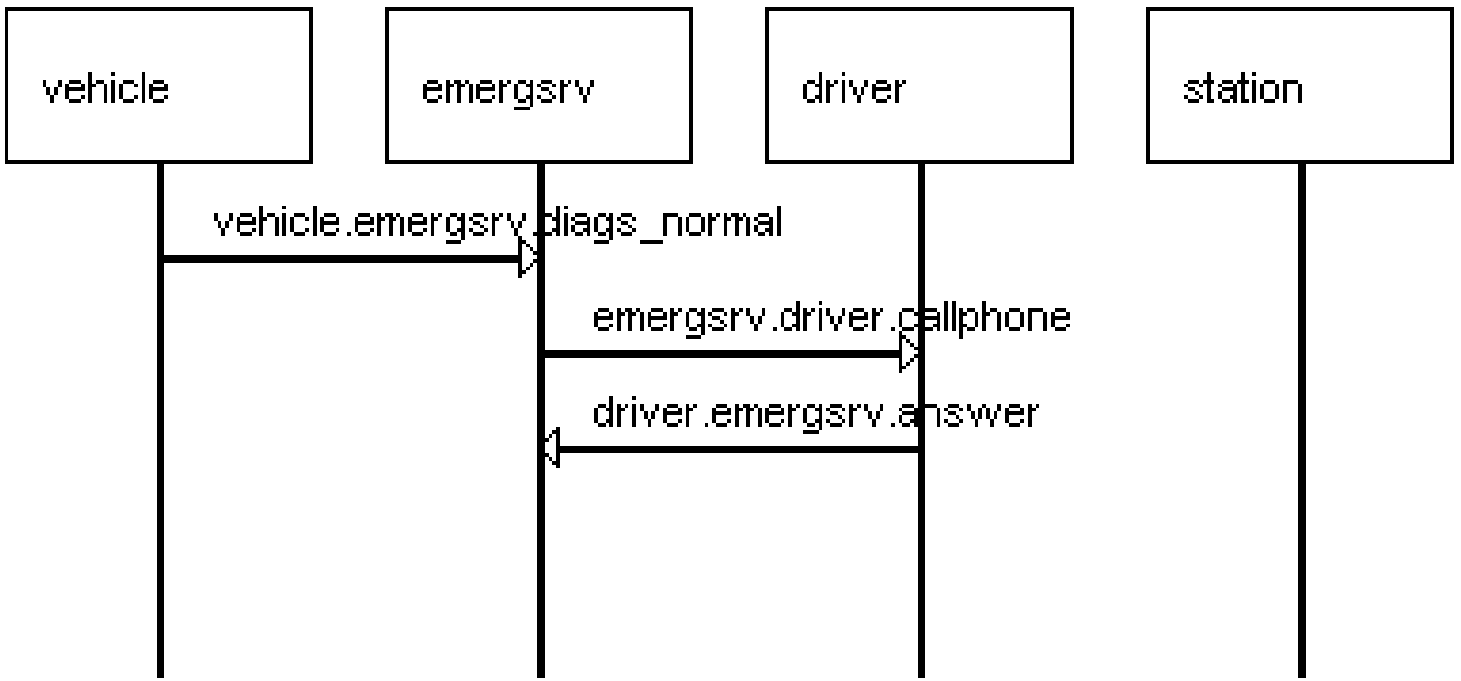

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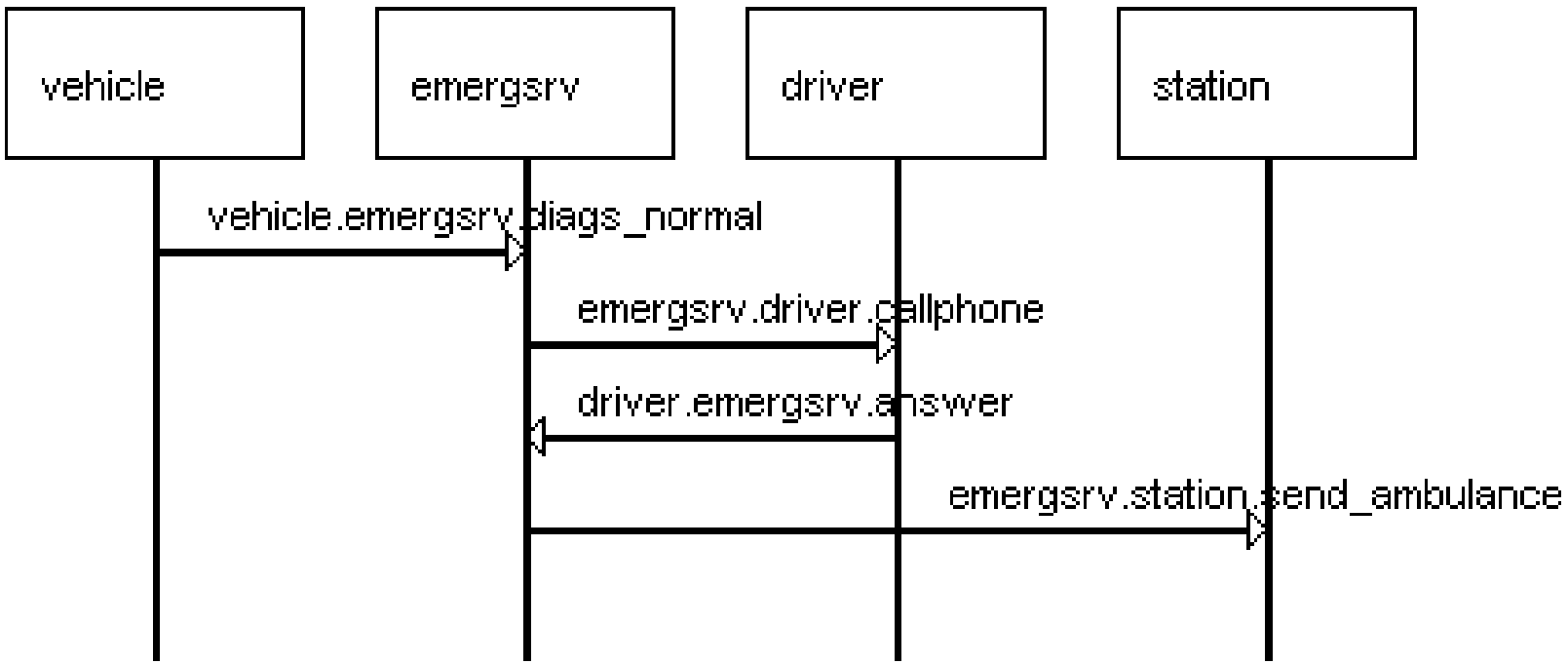

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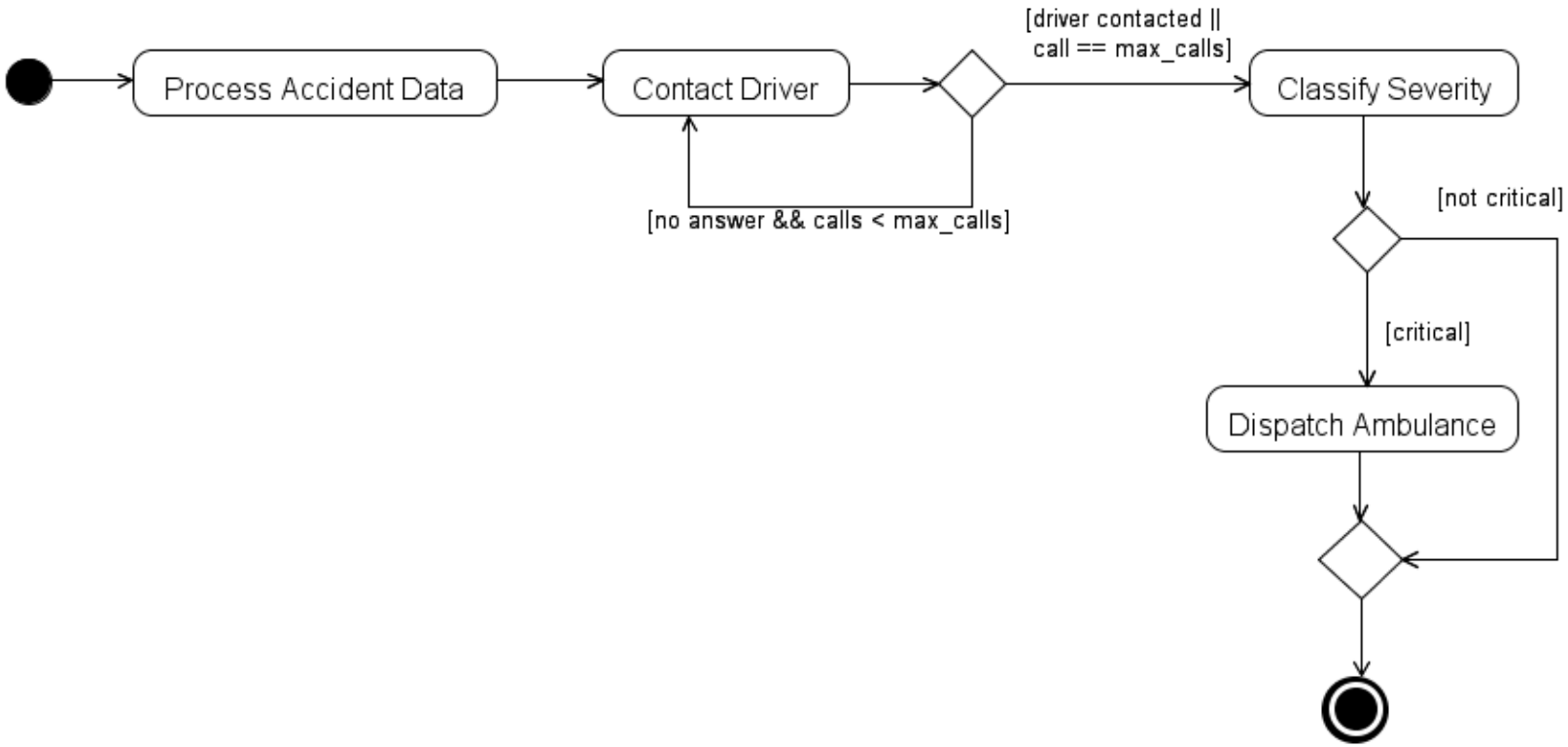
Response-time analysis of the Accident Assistance Service



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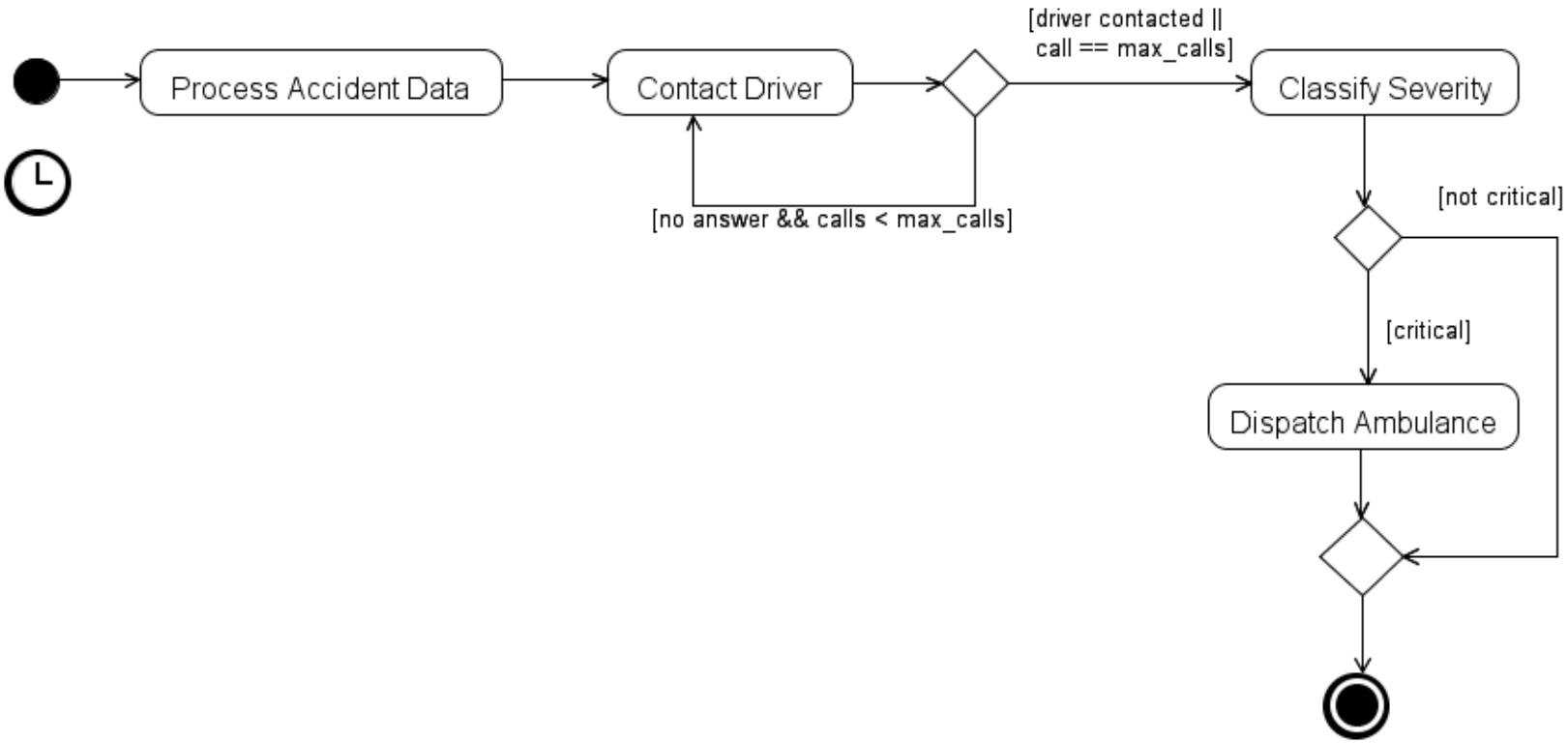

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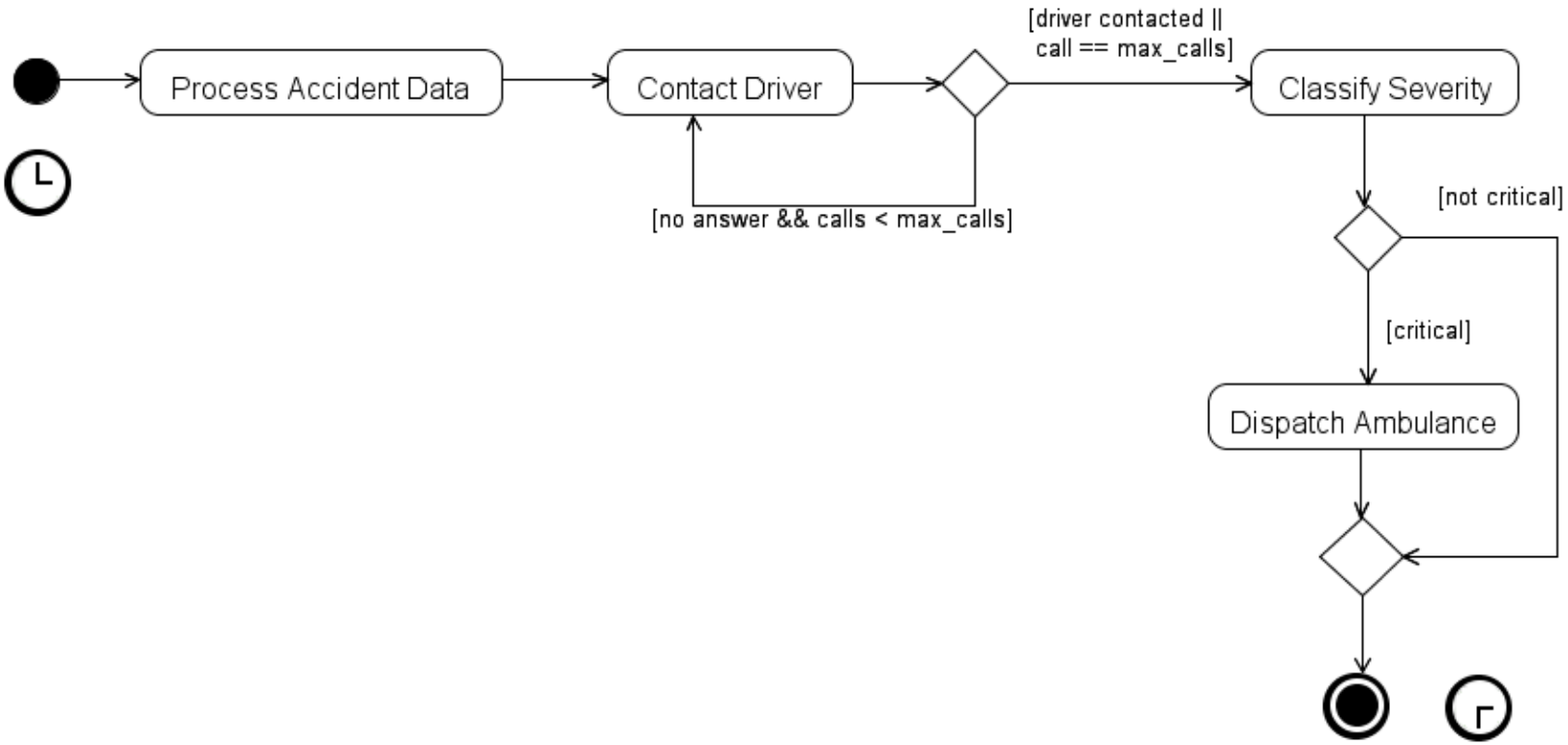

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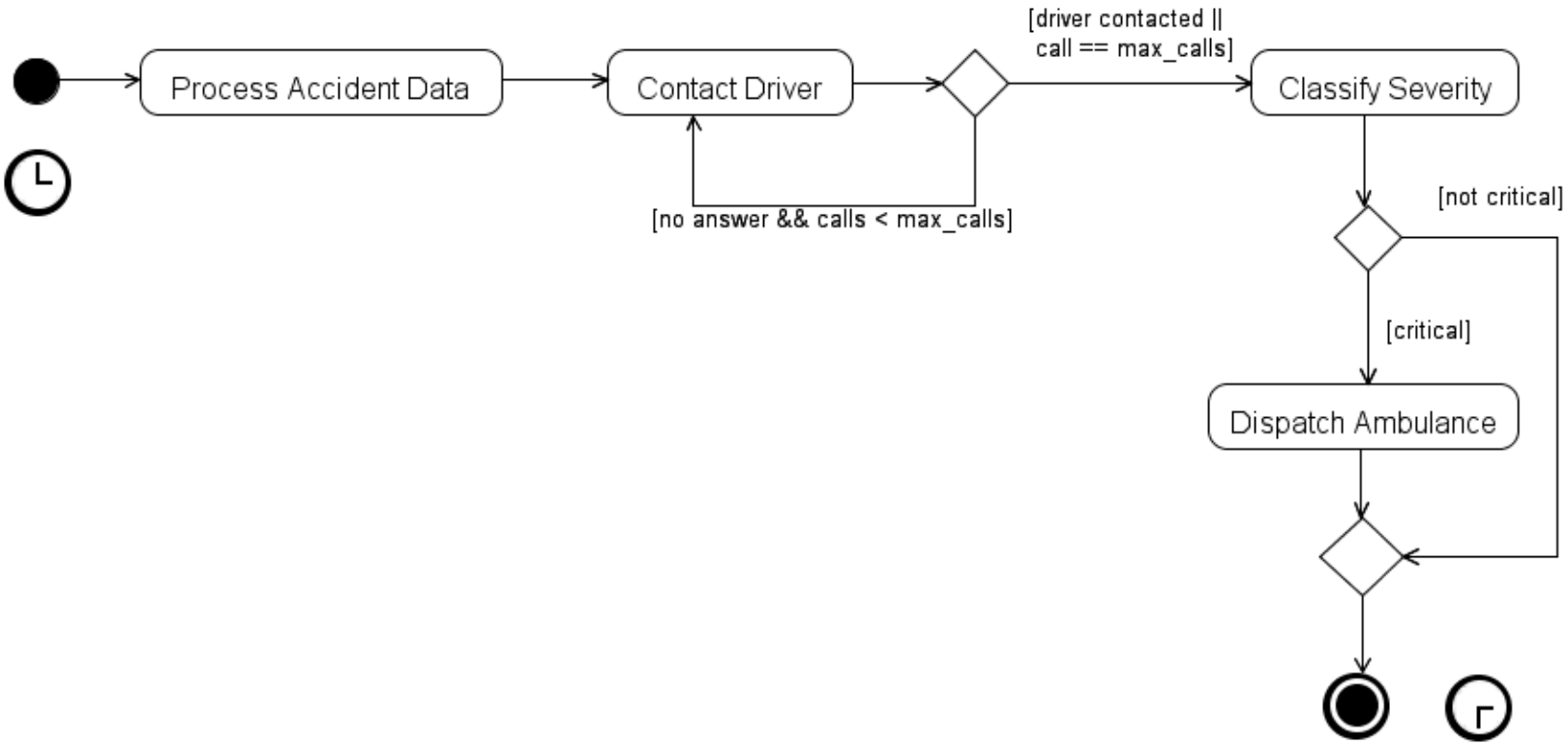
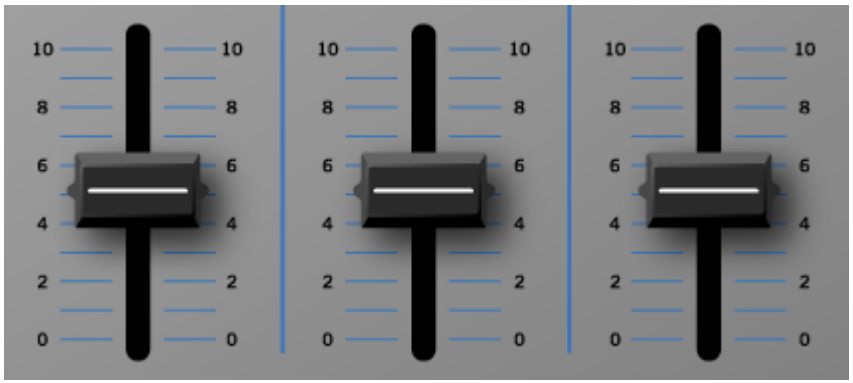


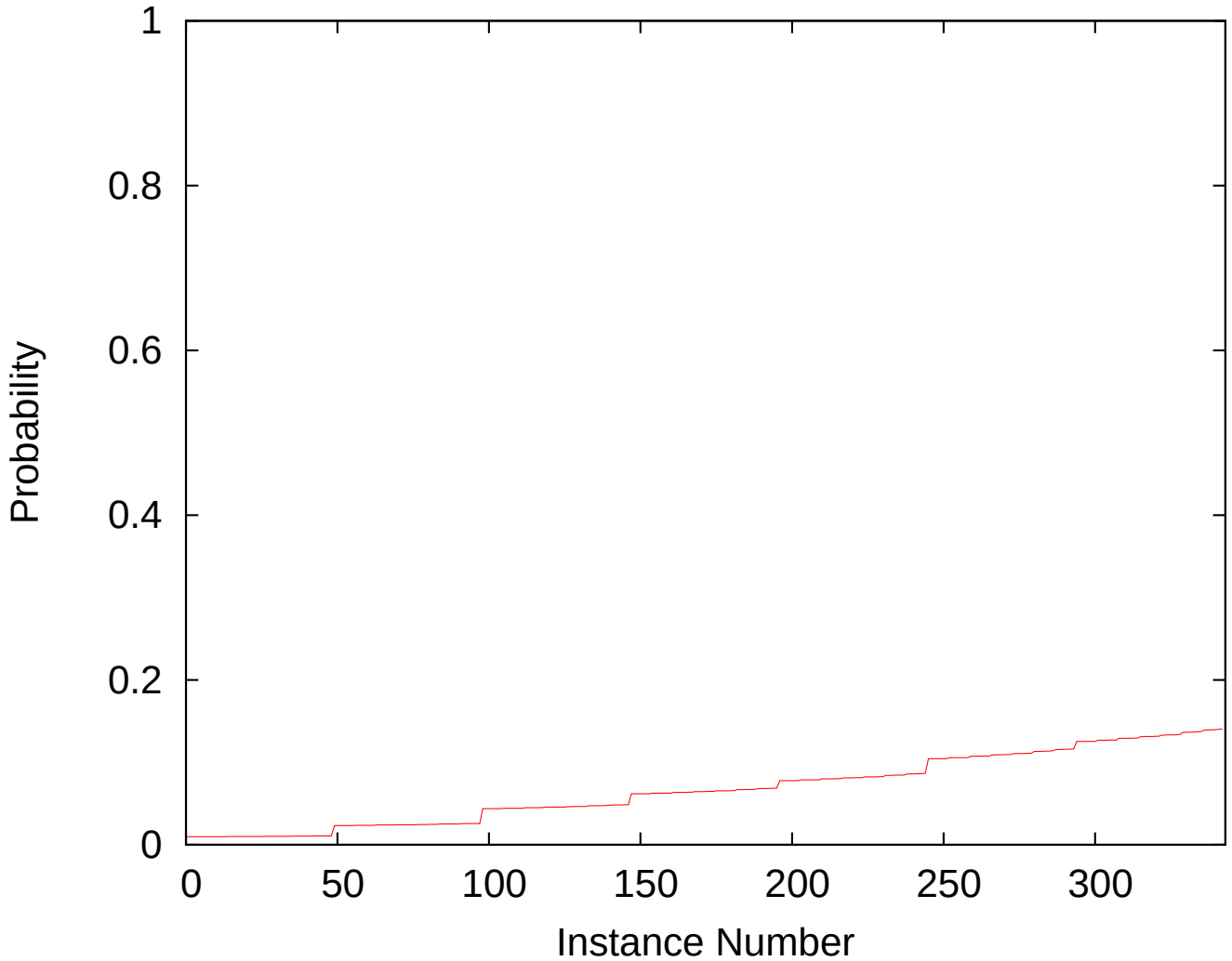
Sensitivity analysis

We vary the rates at which the three calls to the driver are performed. In the PEPA model these are rates *r_wait_answer_1*, *r_wait_answer_2* and *r_wait_answer_3*.



These three variables are varied across the seven values $\{0.01, 0.025, 0.05, 0.075, 0.1, 0.15, 0.2\}$. We do $7 \times 7 \times 7 = 343$ experiments.

Response-time analysis at time 5



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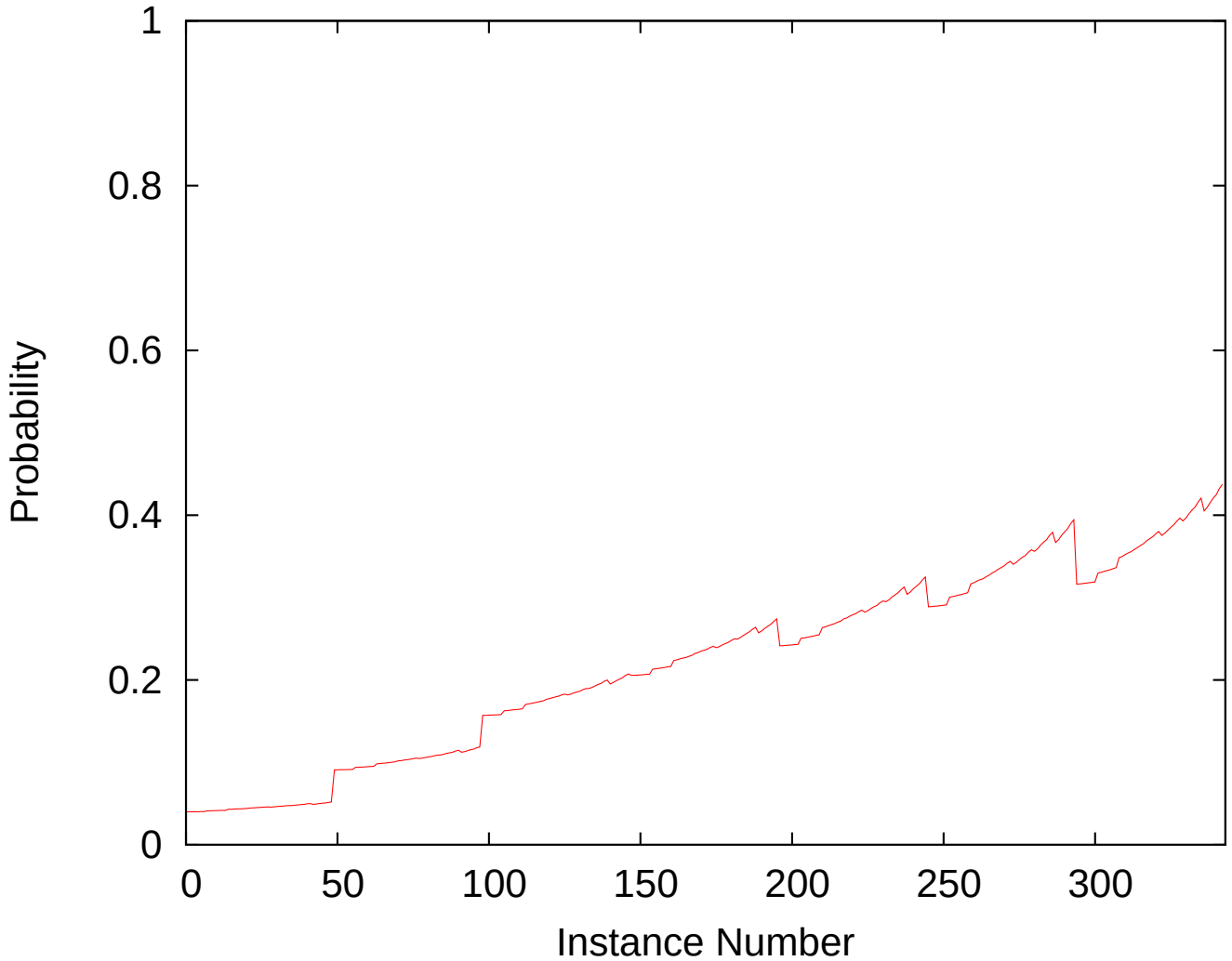
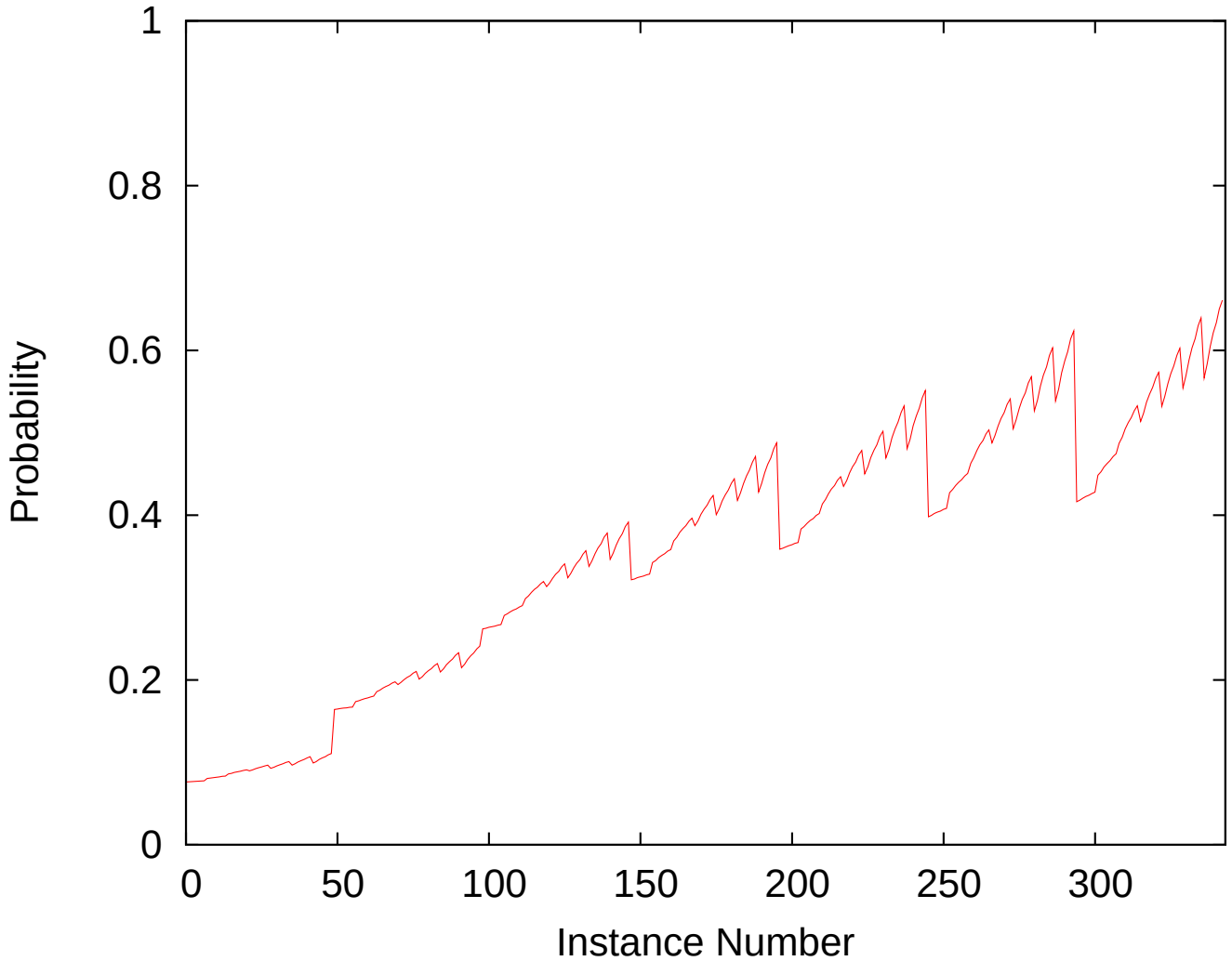
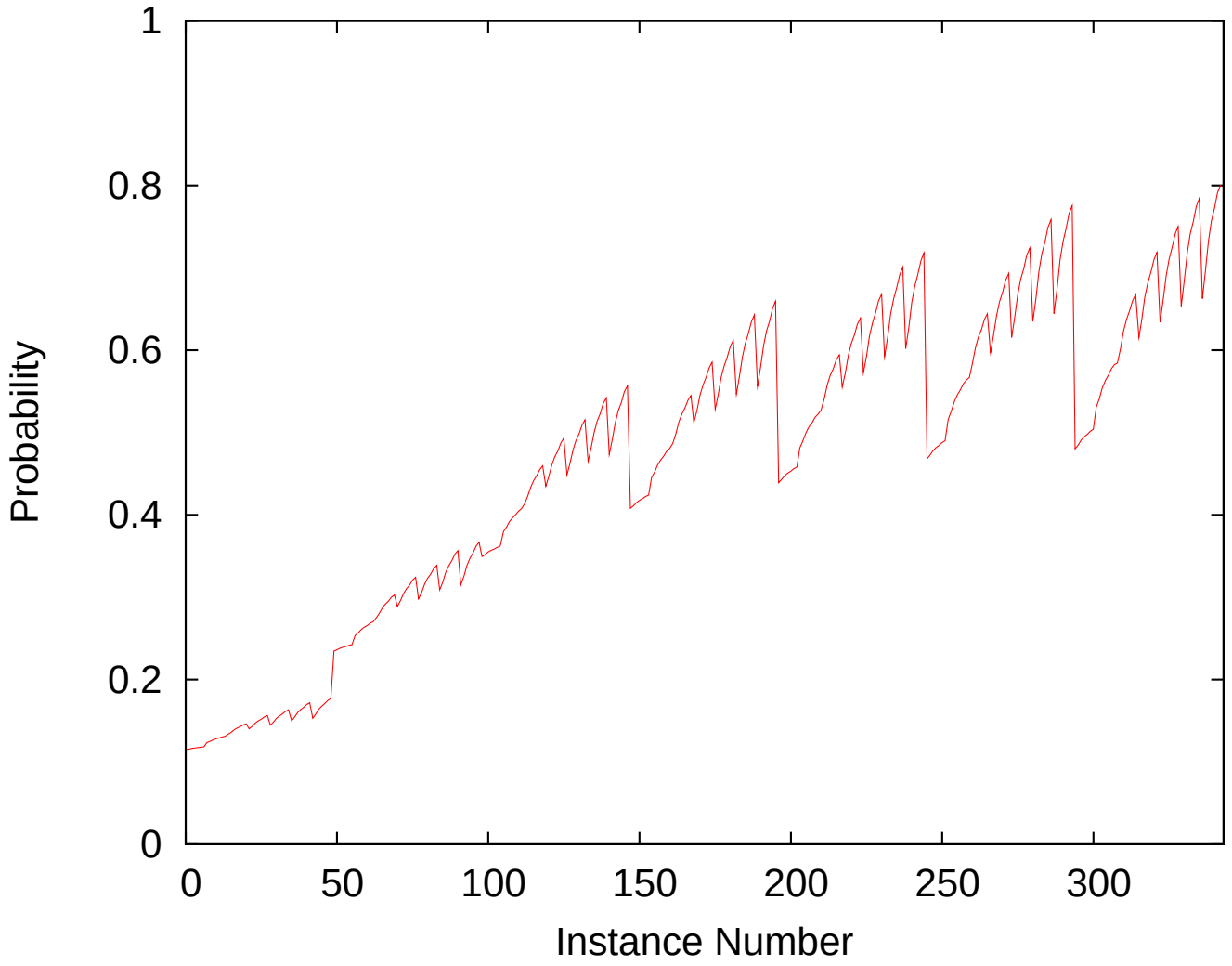


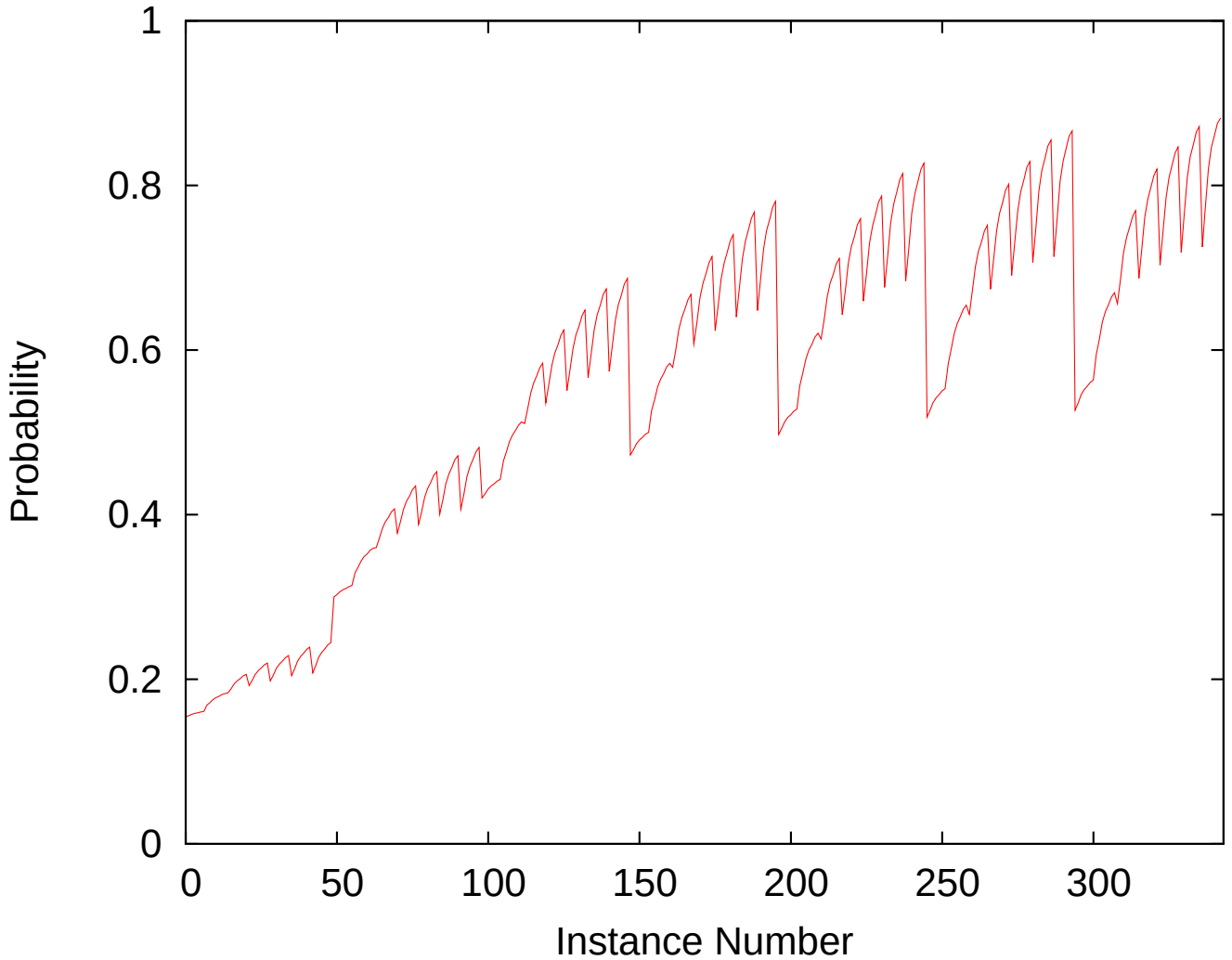
Response-time analysis at time 15



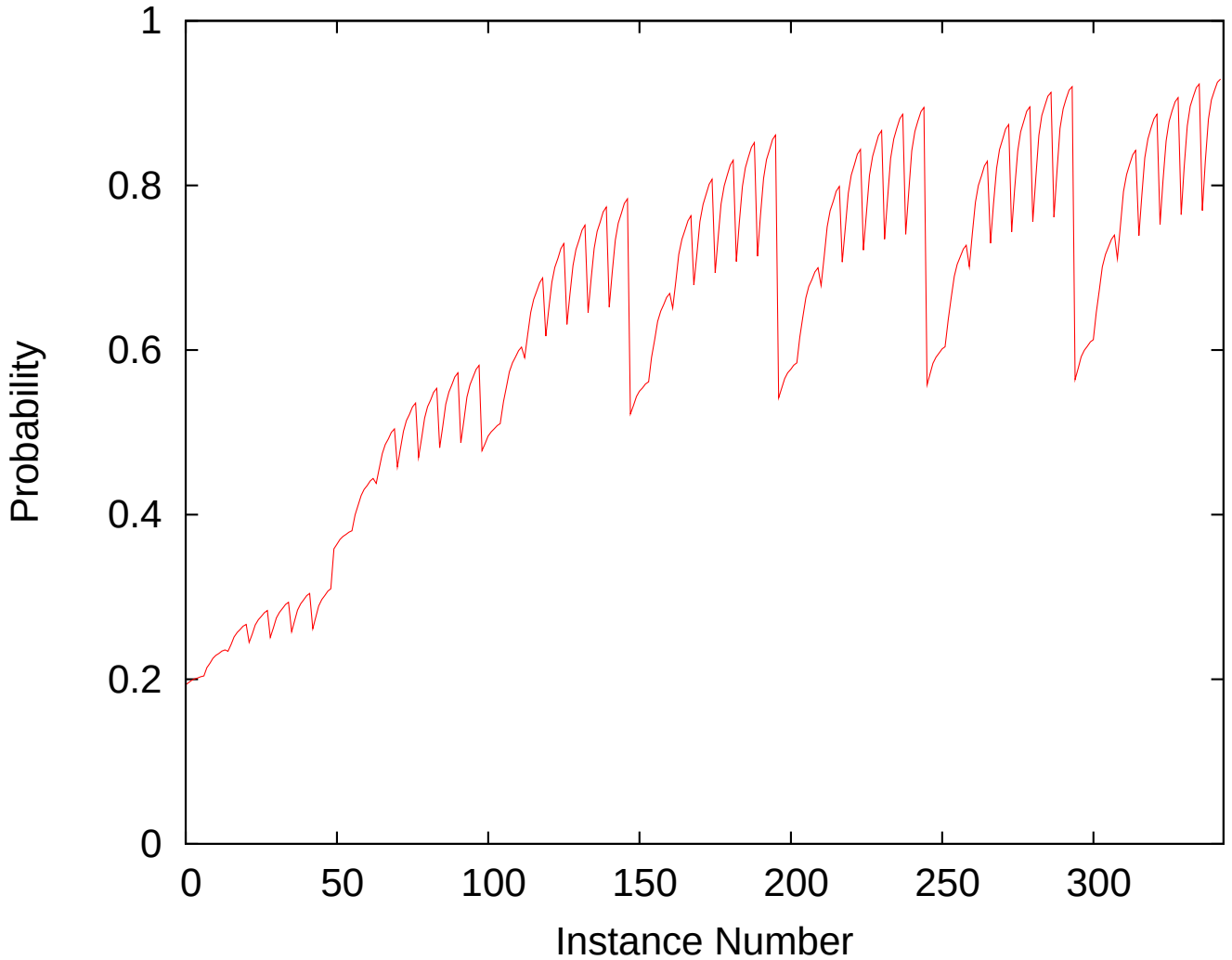
Response-time analysis at time 20



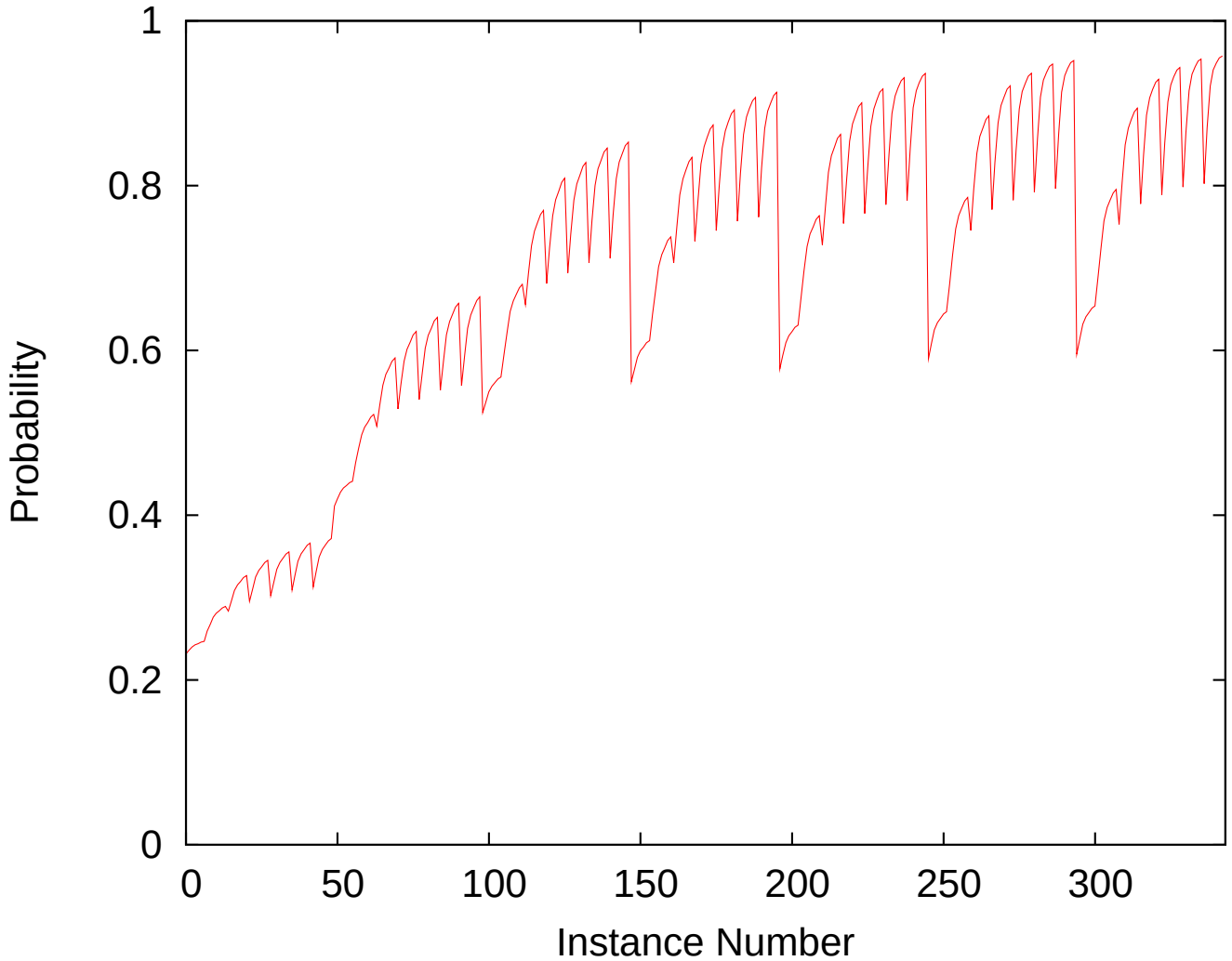
Response-time analysis at time 25



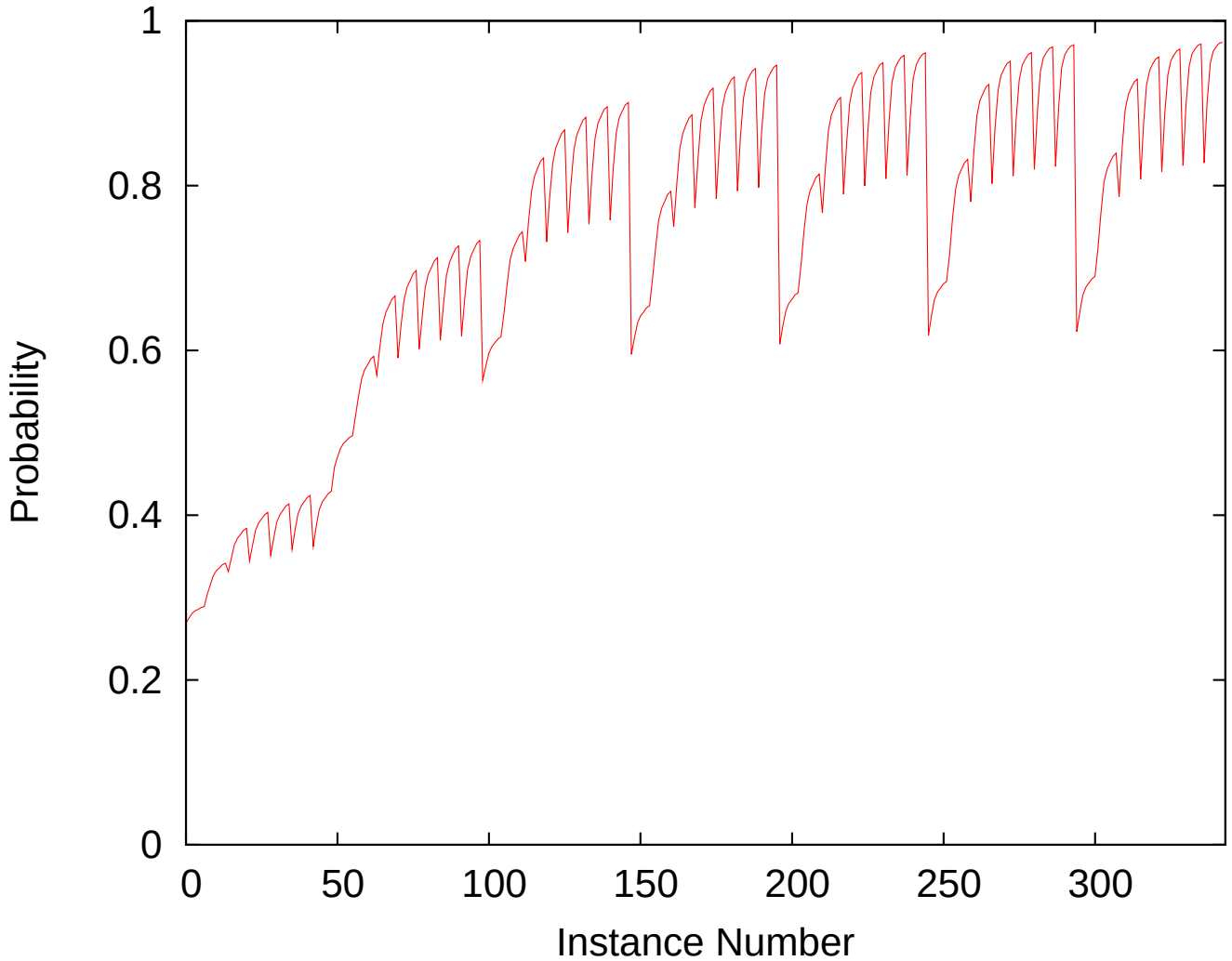
Response-time analysis at time 30



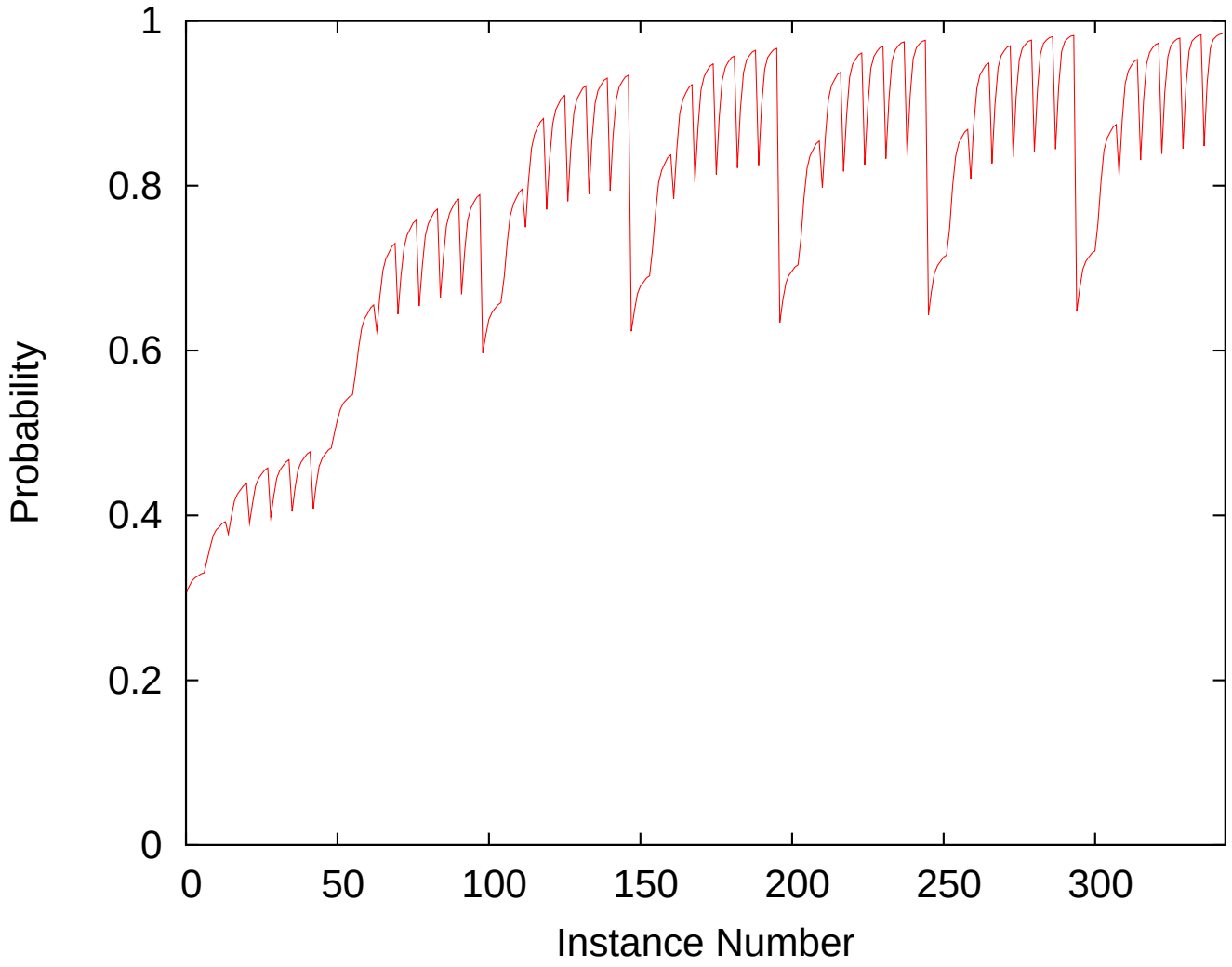
Response-time analysis at time 35



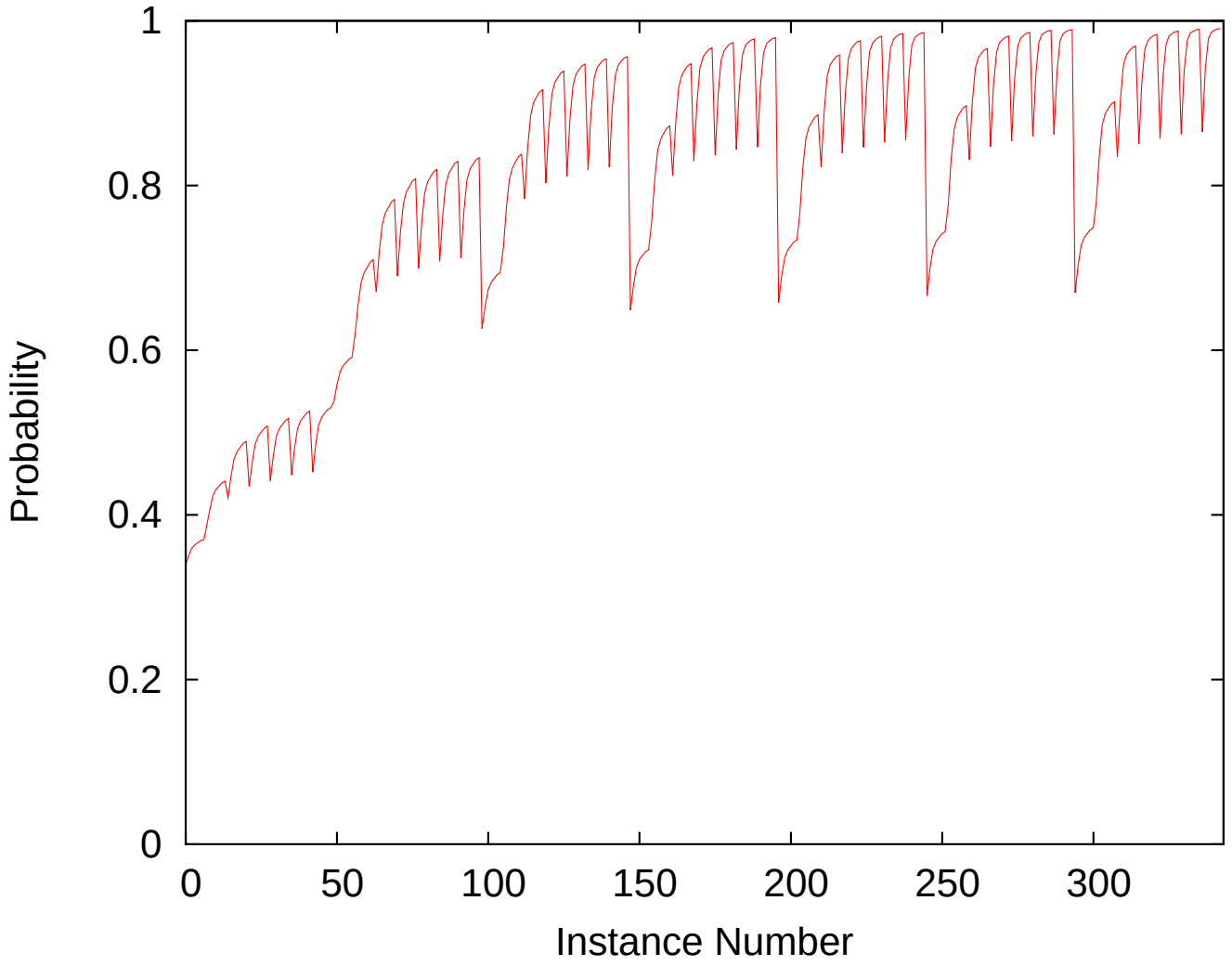
Response-time analysis at time 40



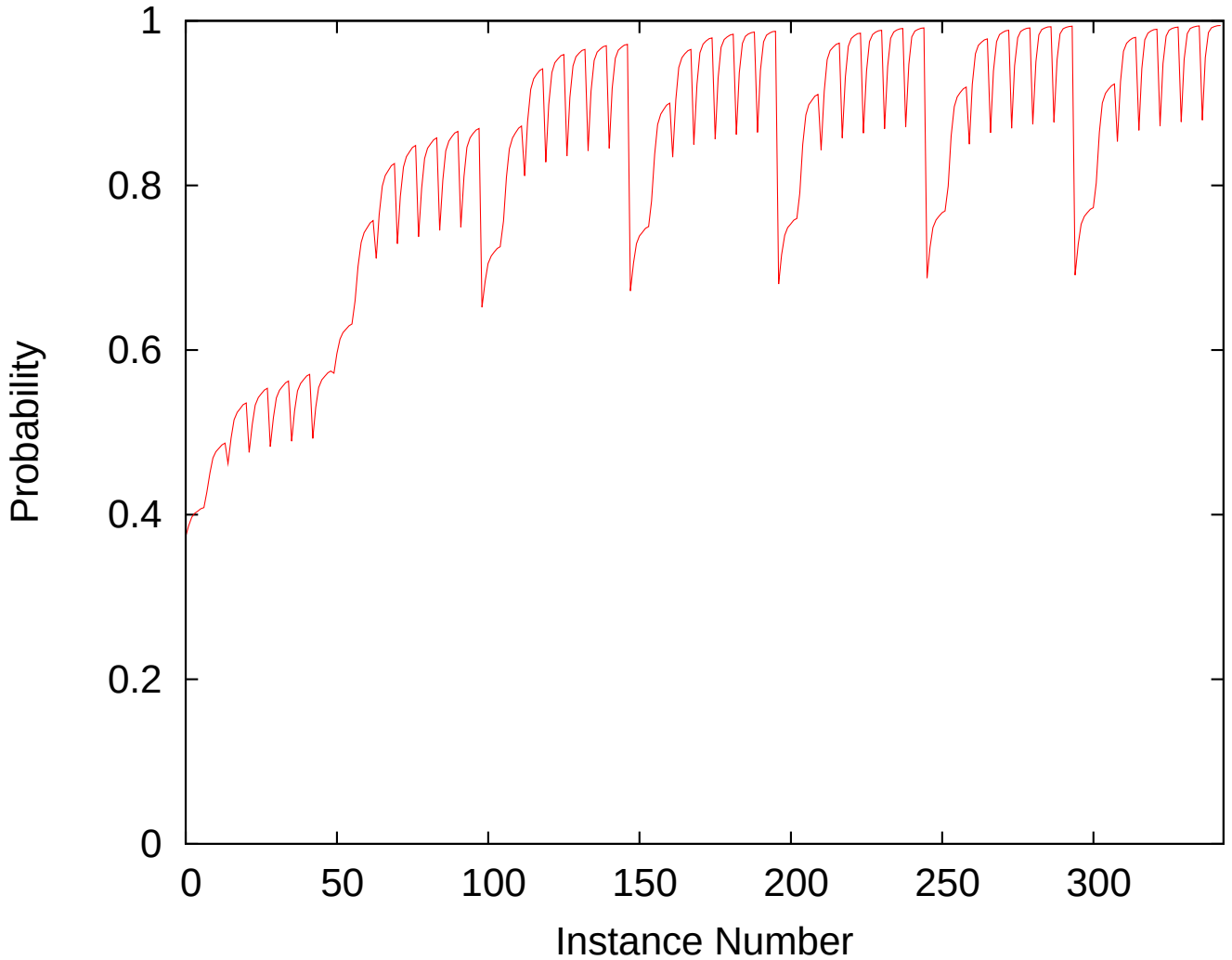
Response-time analysis at time 45



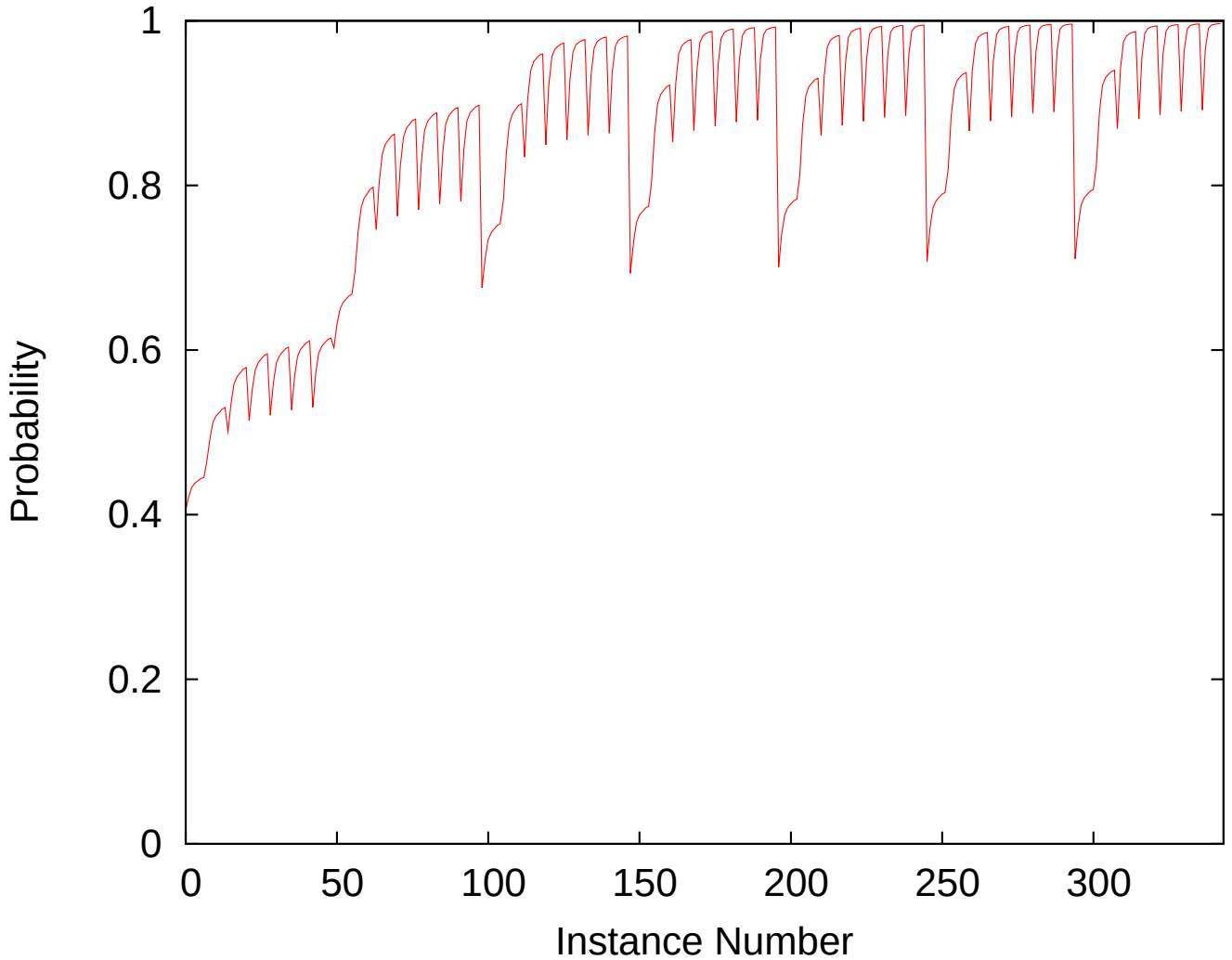
Response-time analysis at time 50



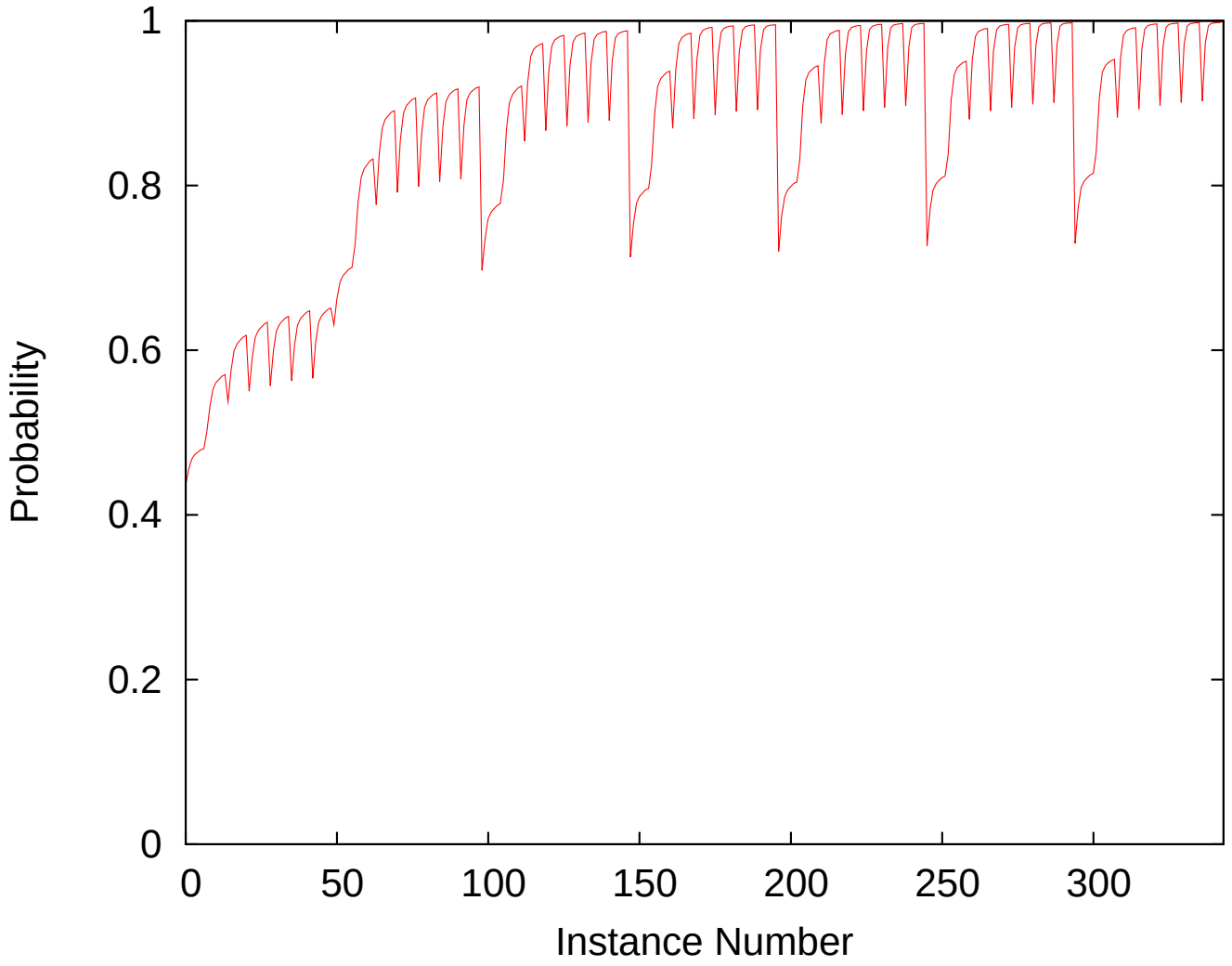
Response-time analysis at time 55



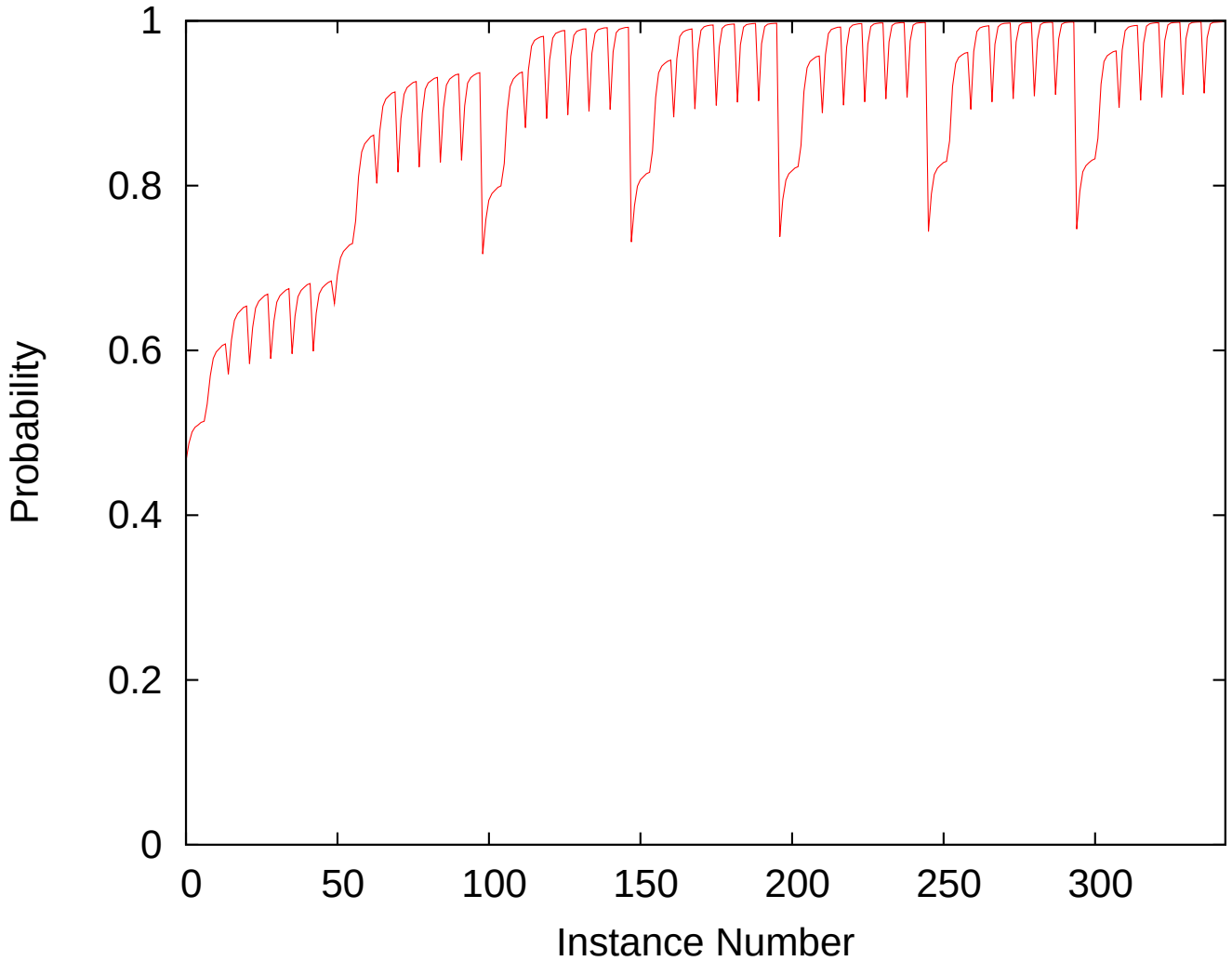
Response-time analysis at time 60



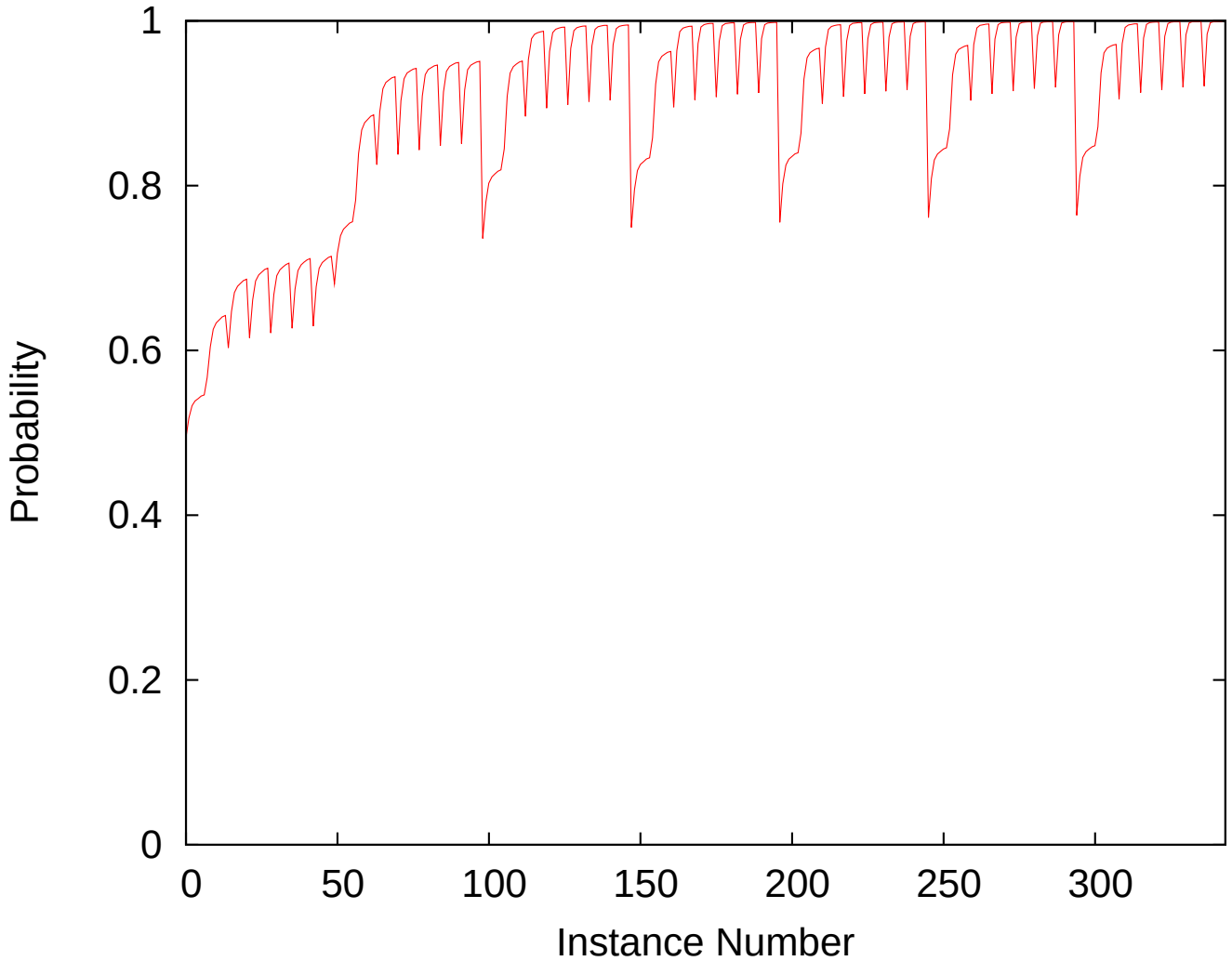
Response-time analysis at time 65



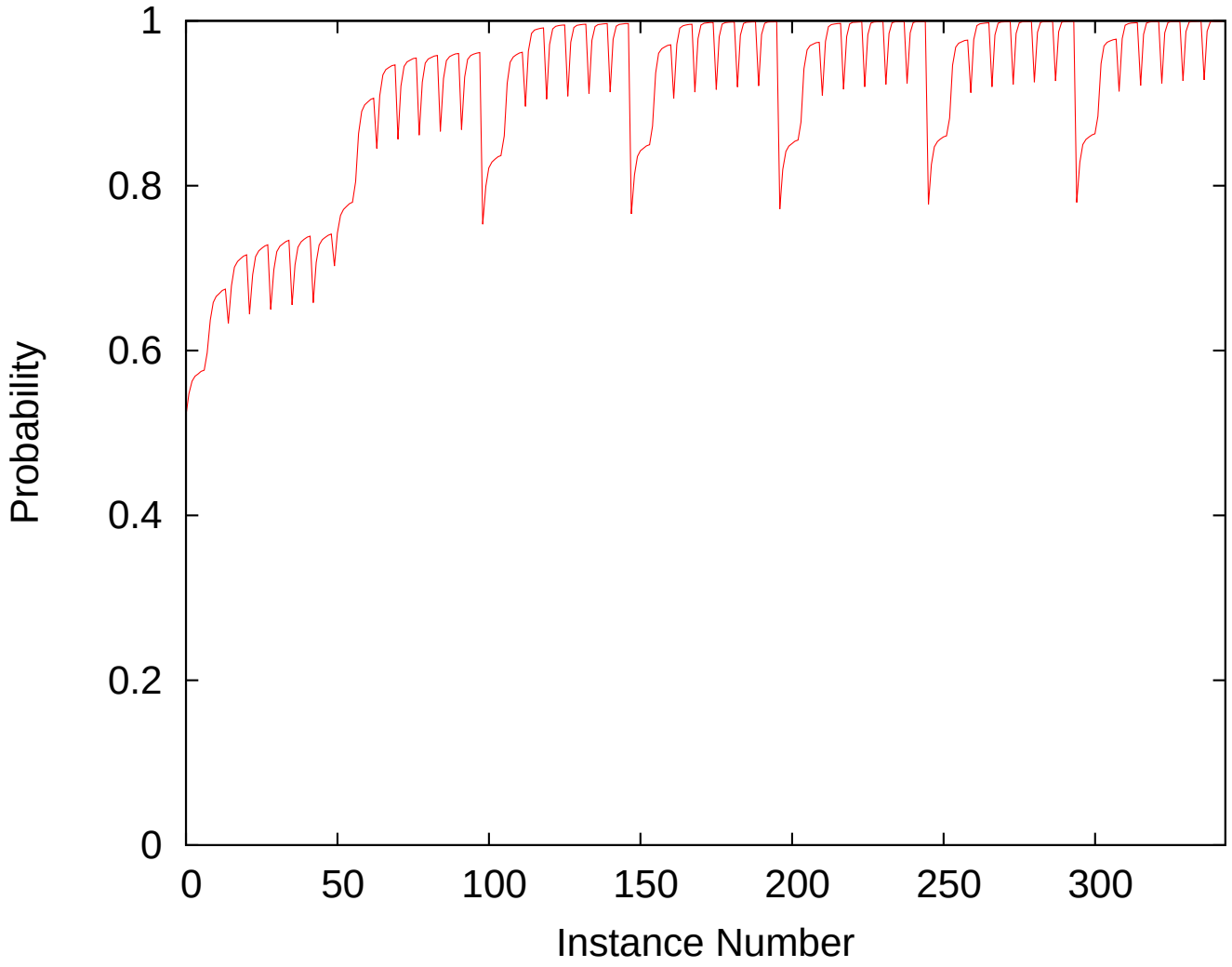
Response-time analysis at time 70



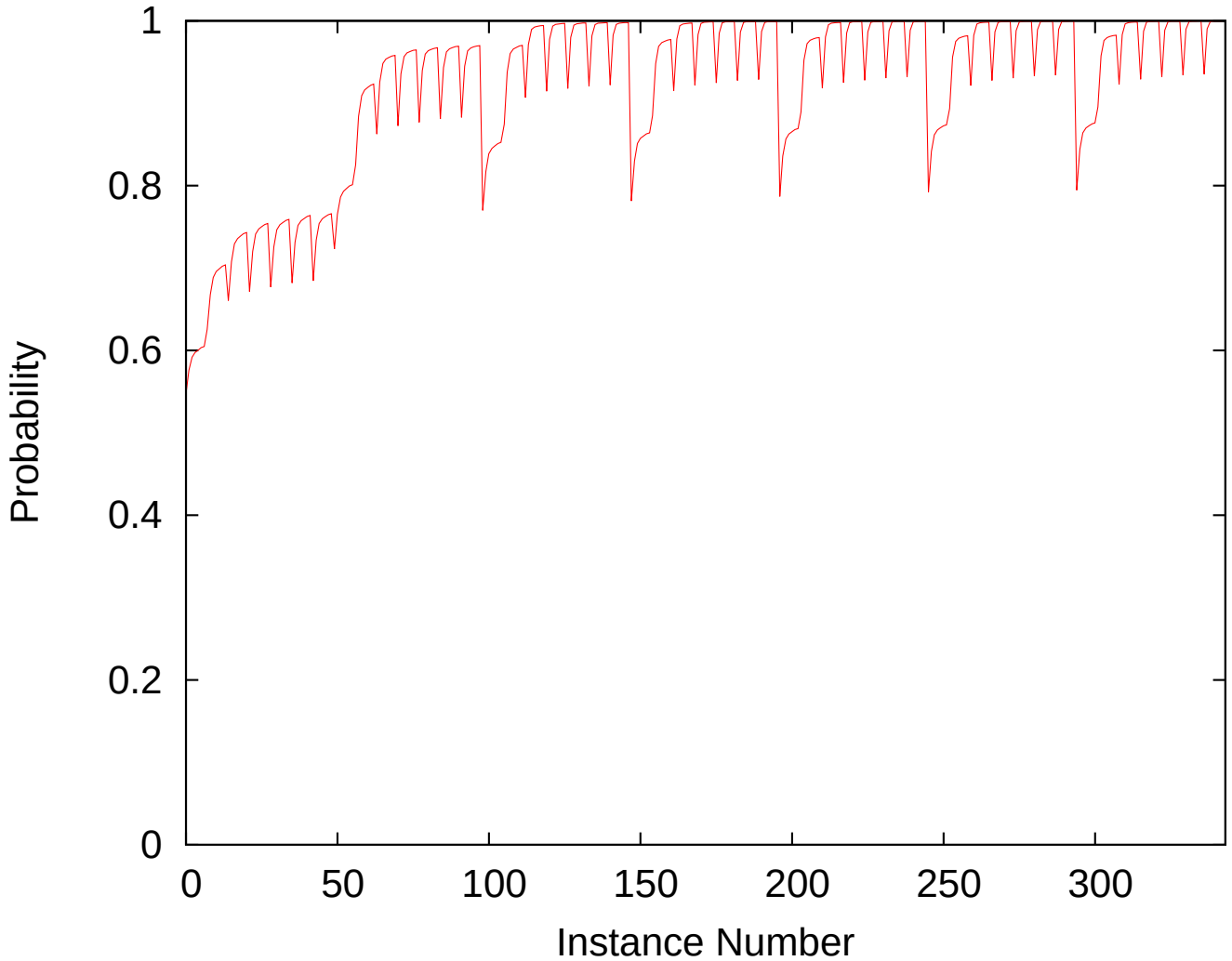
Response-time analysis at time 75



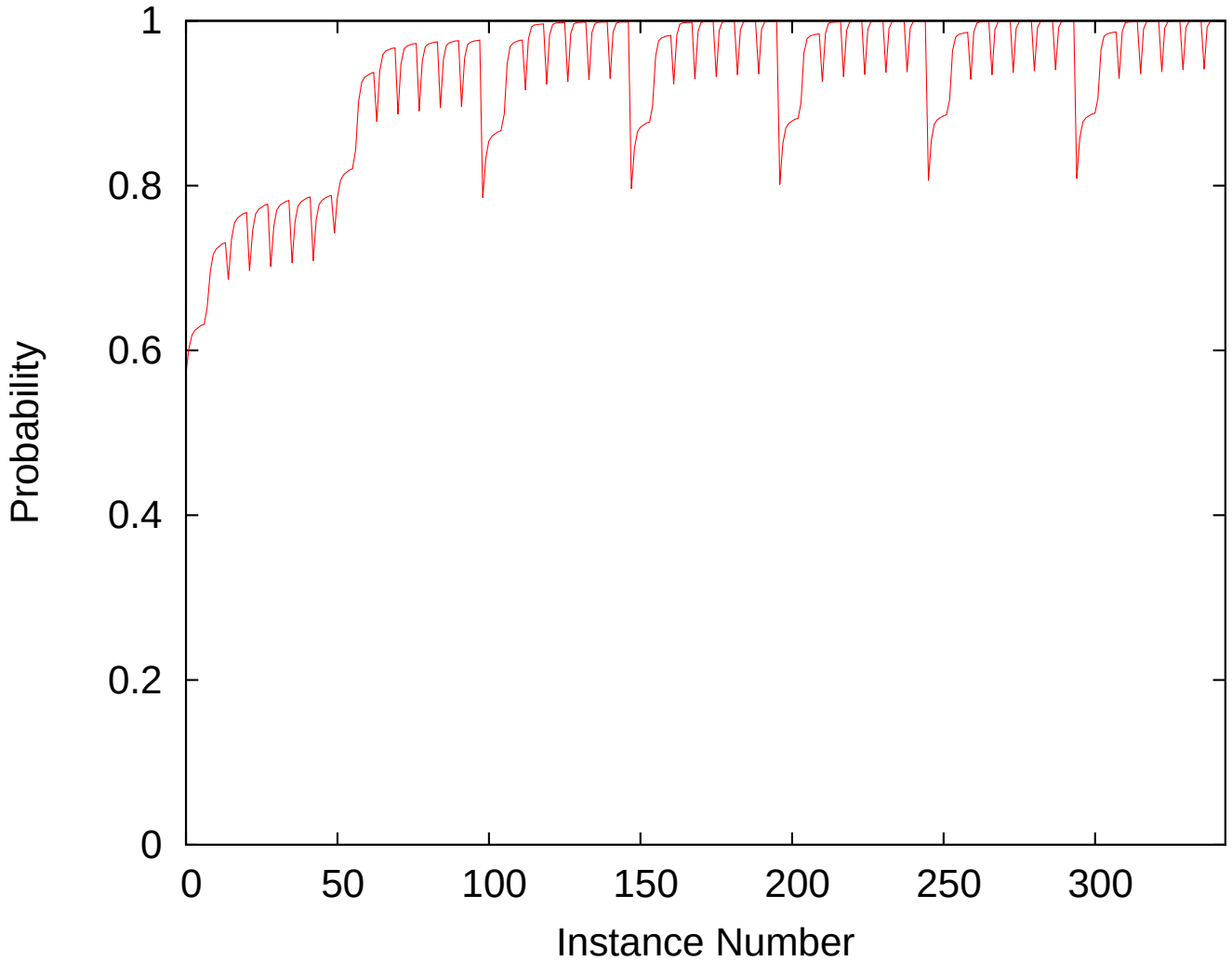
Response-time analysis at time 80



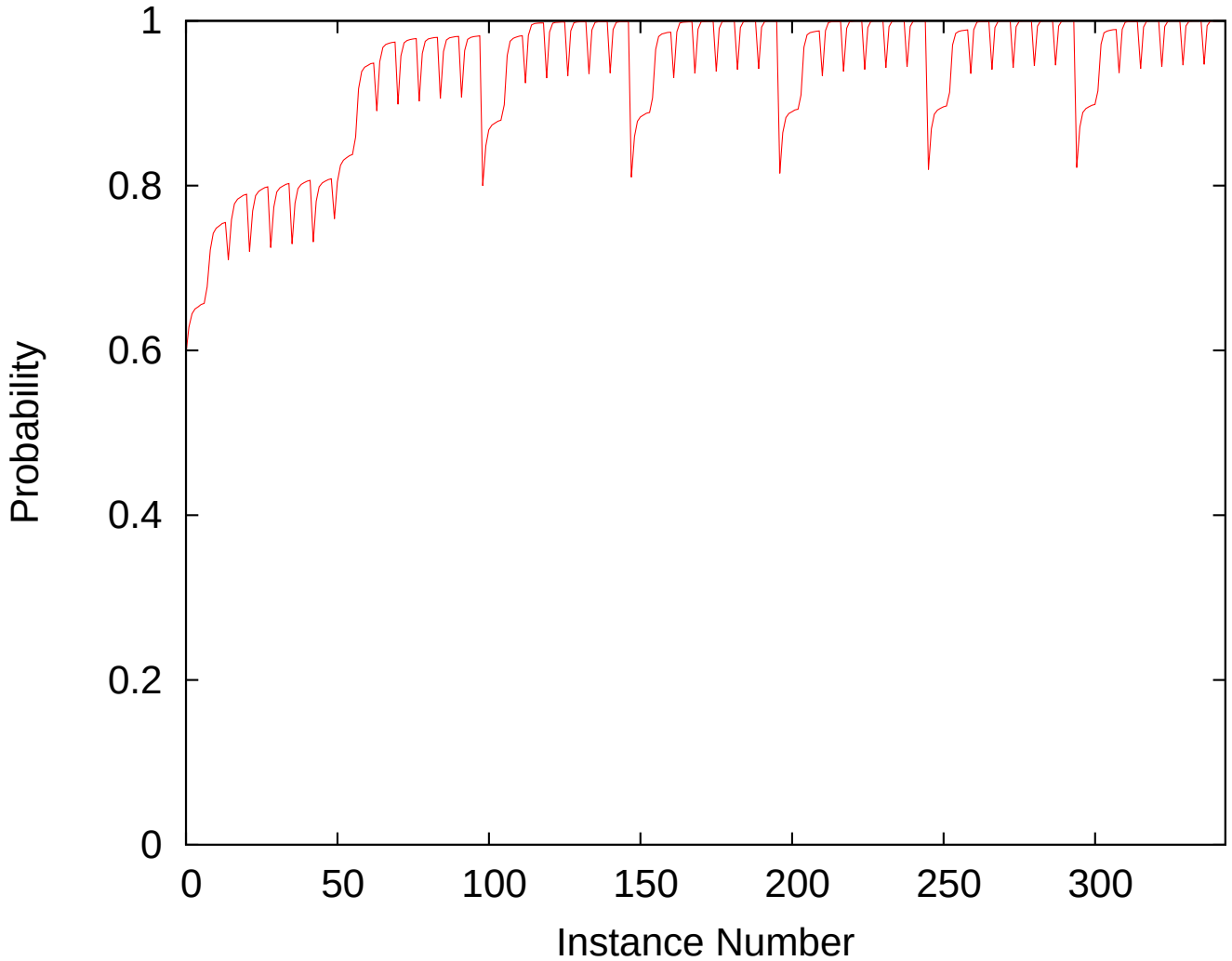
Response-time analysis at time 85



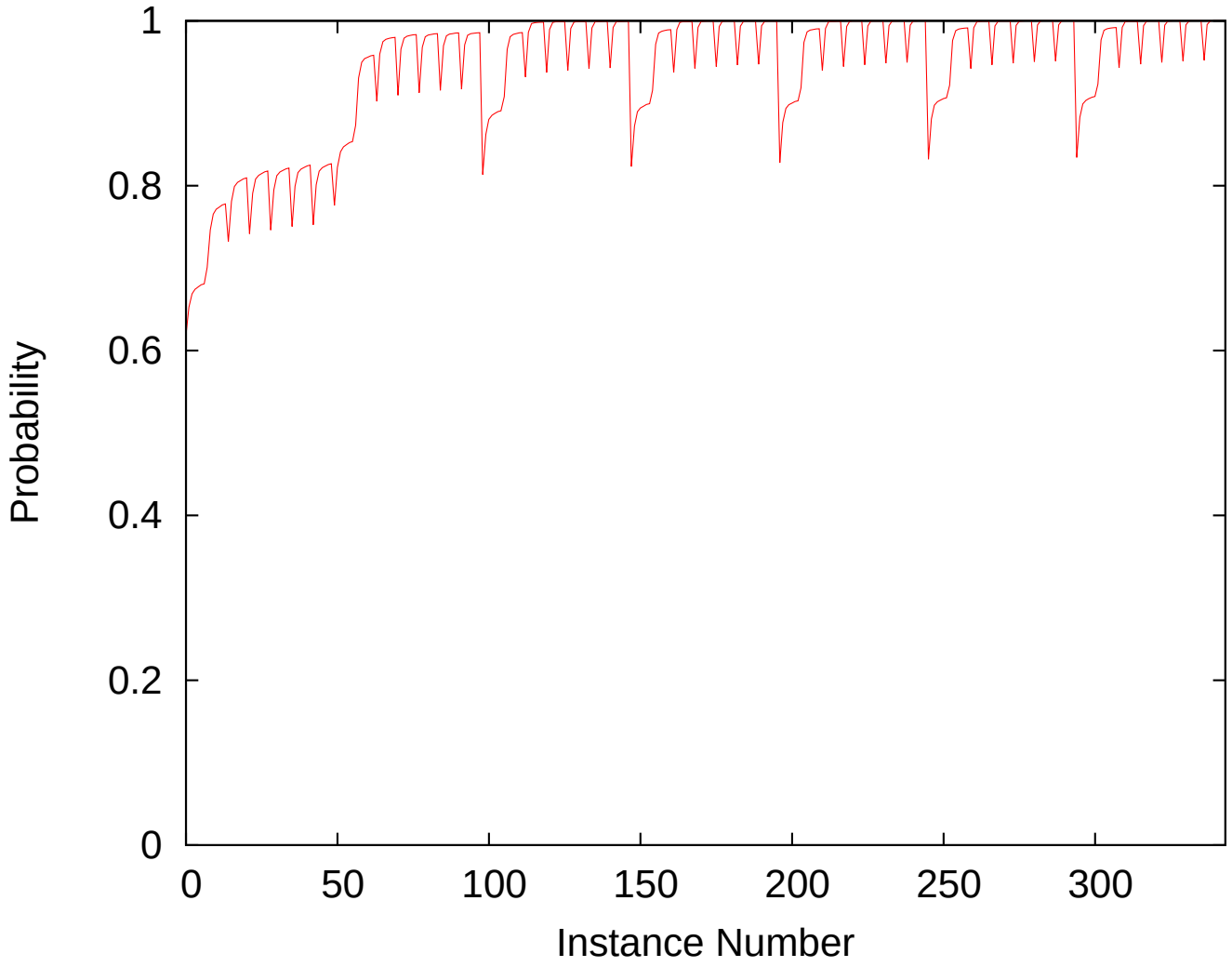
Response-time analysis at time 90



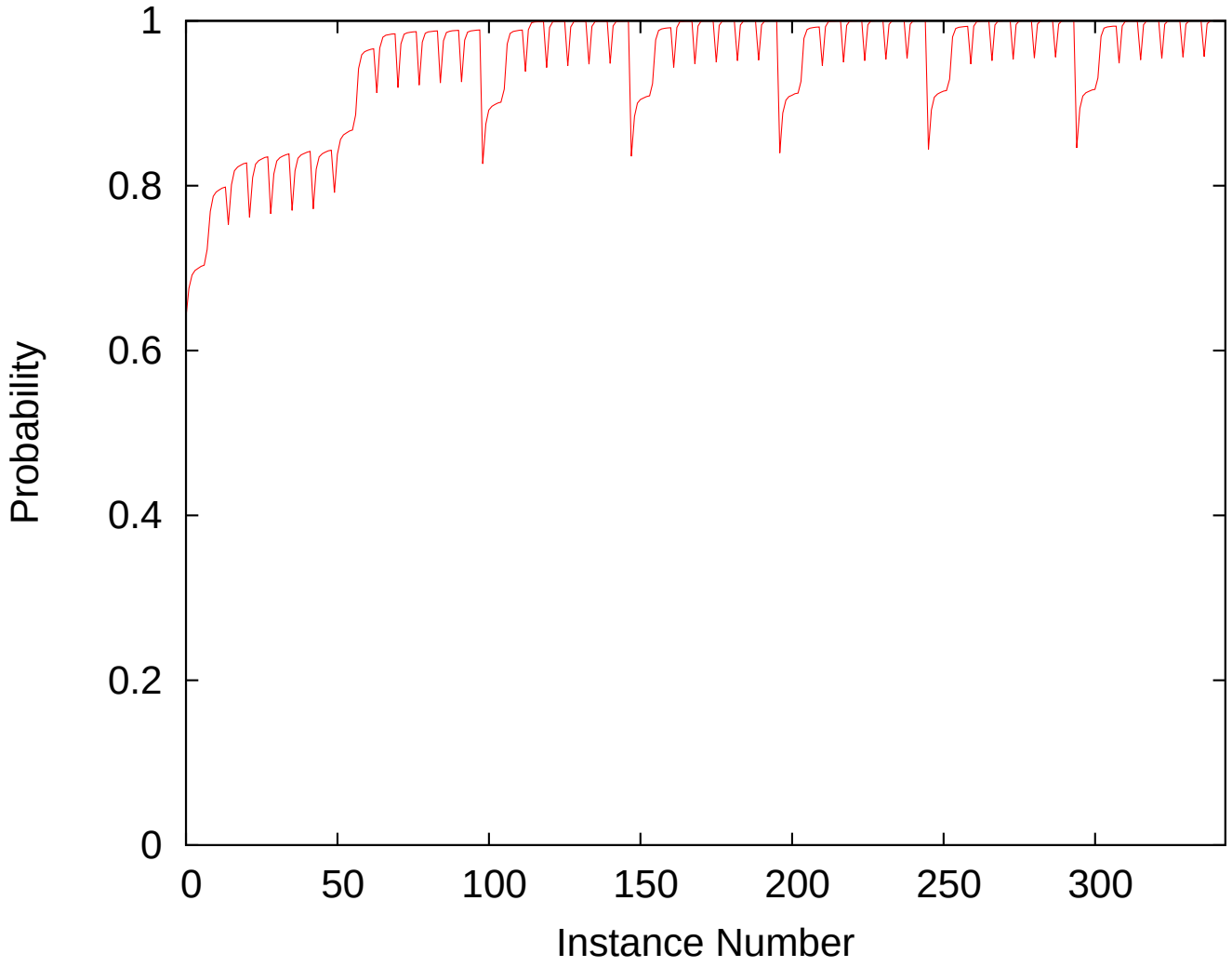
Response-time analysis at time 95



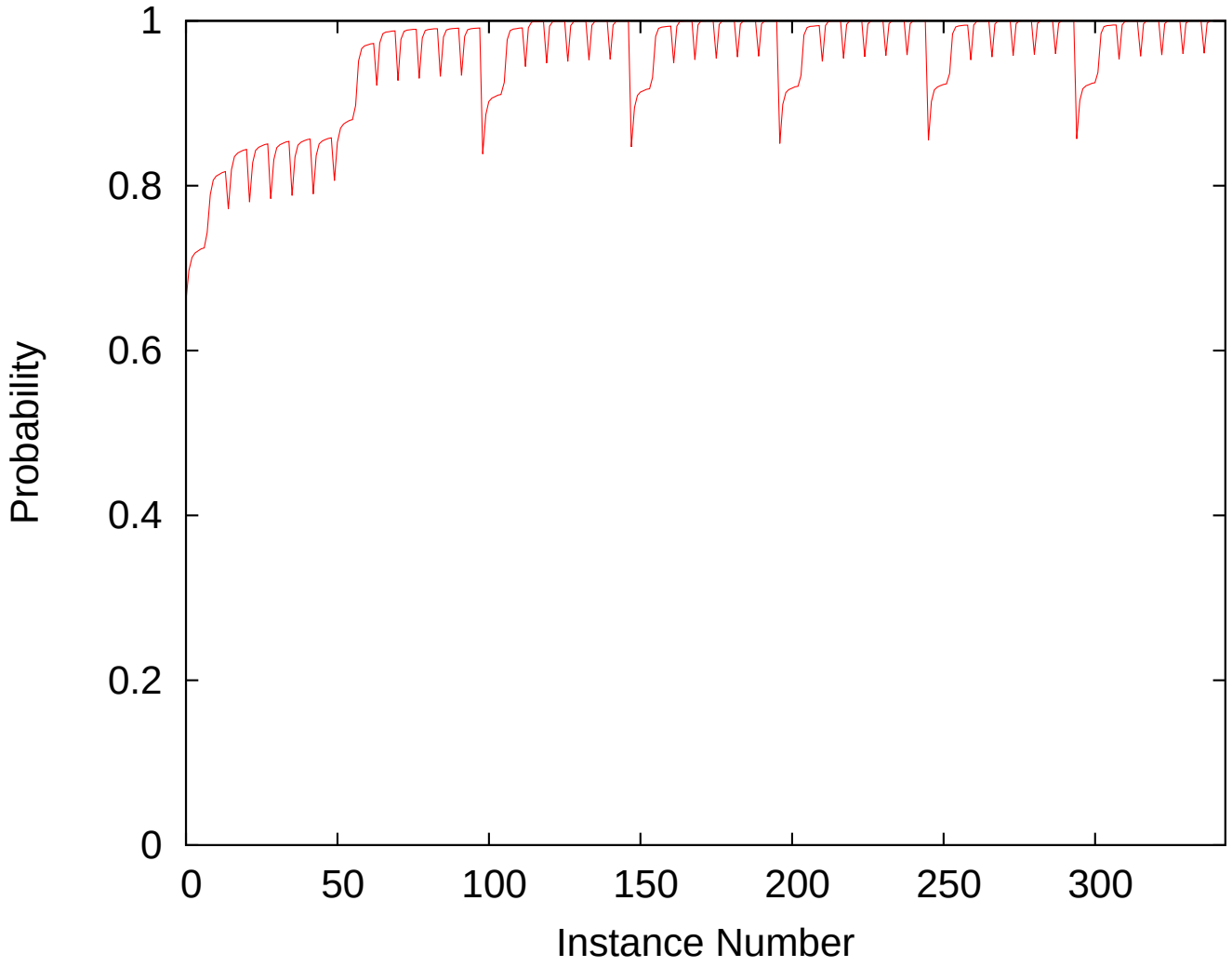
Response-time analysis at time 100



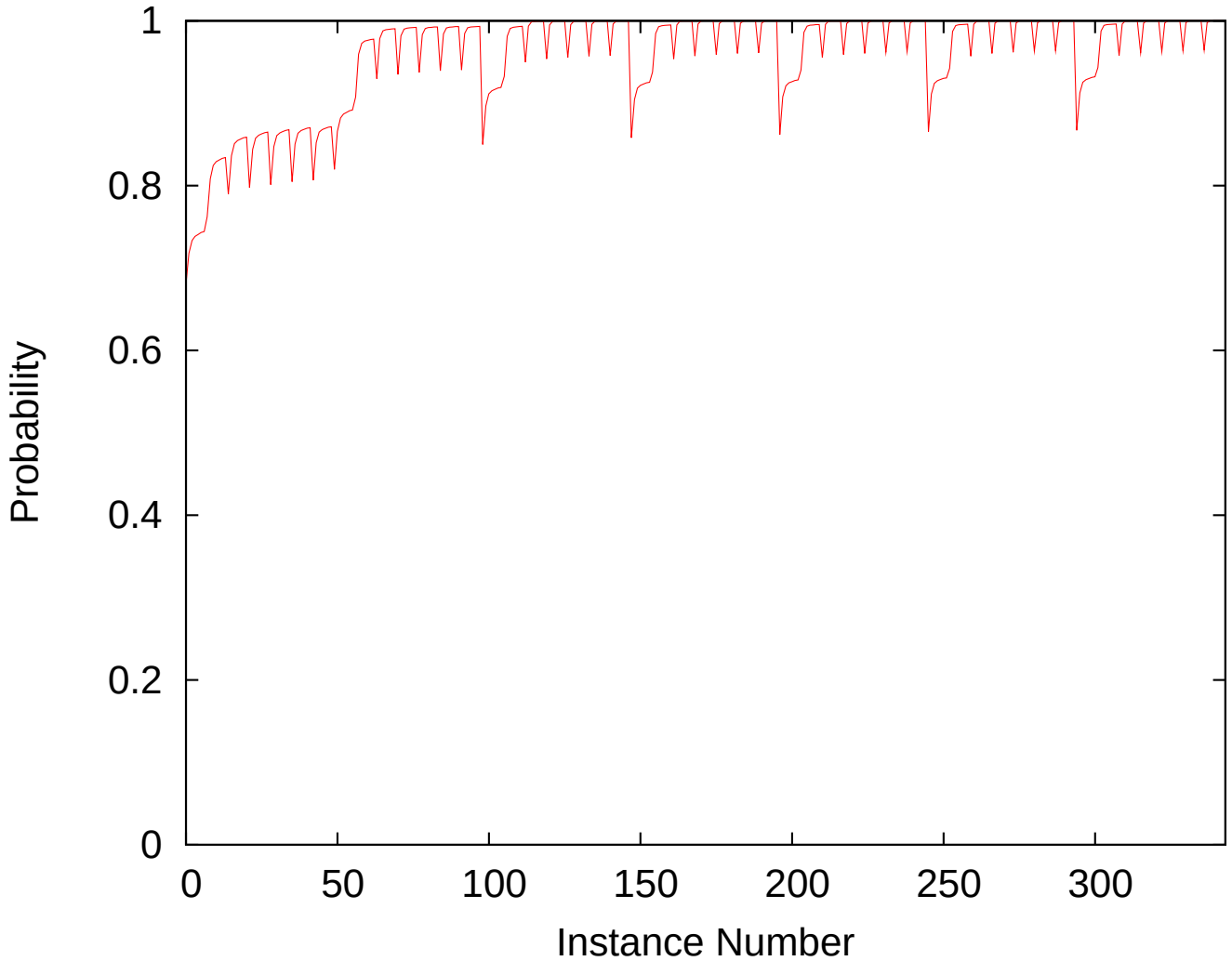
Response-time analysis at time 105



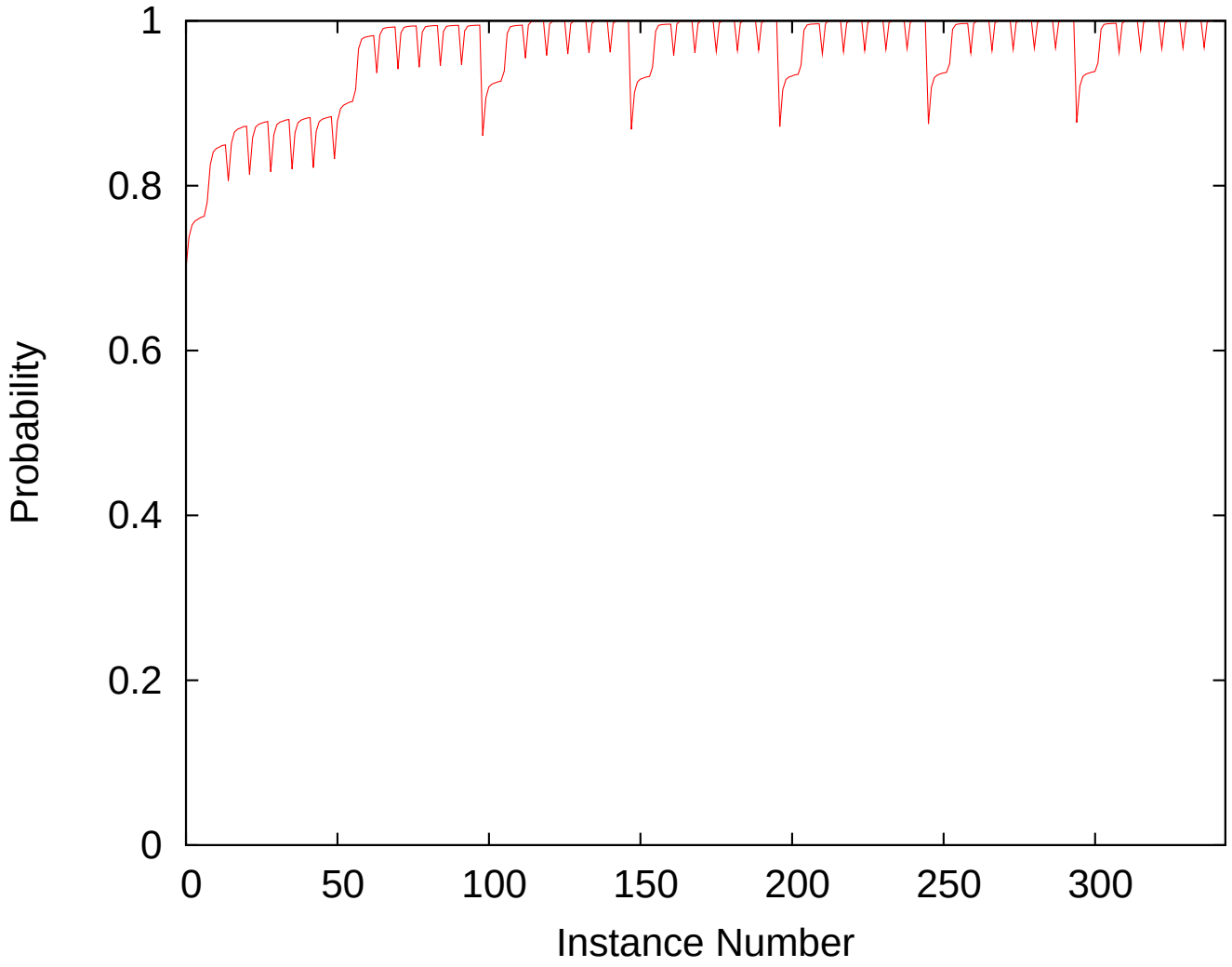
Response-time analysis at time 110



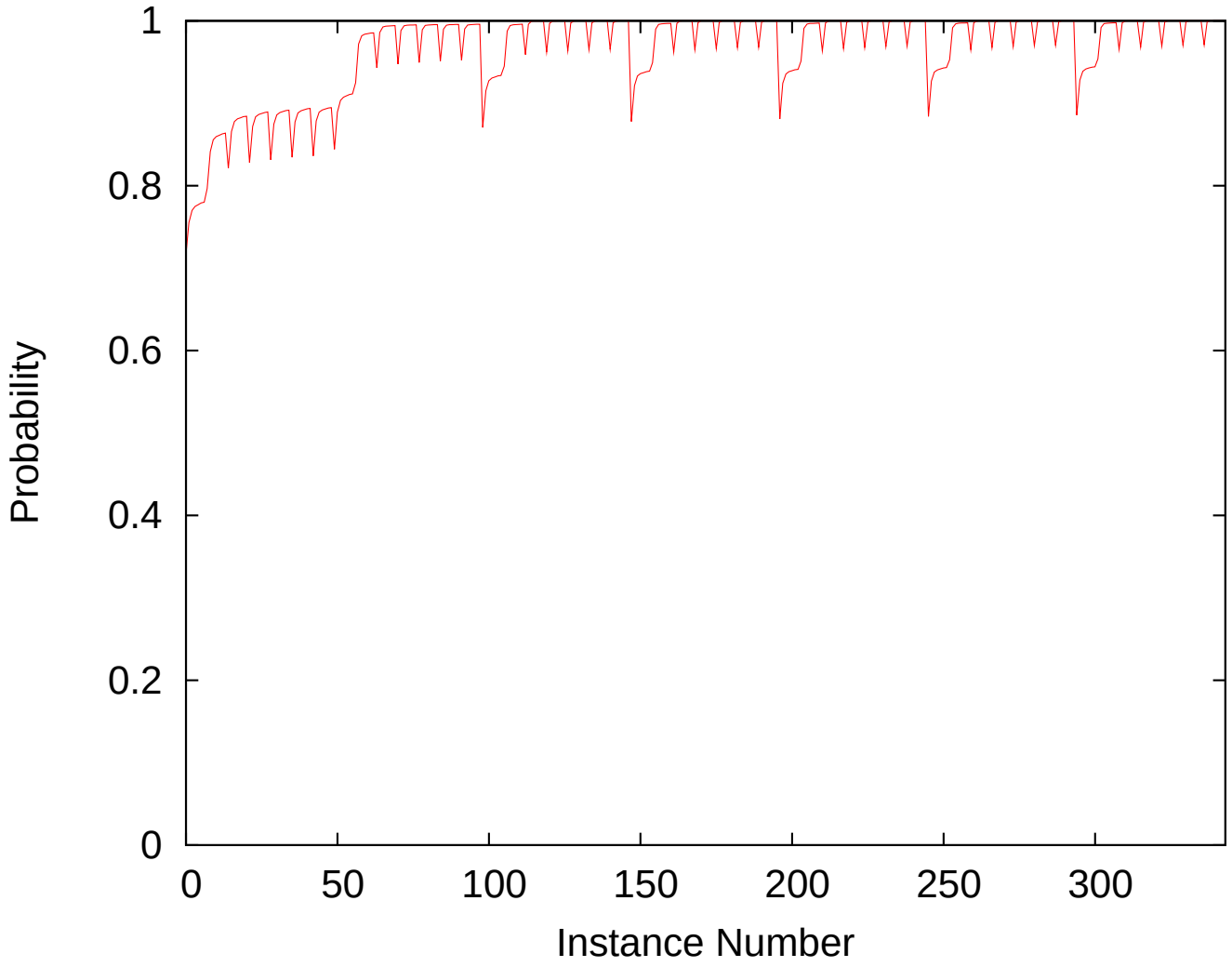
Response-time analysis at time 115



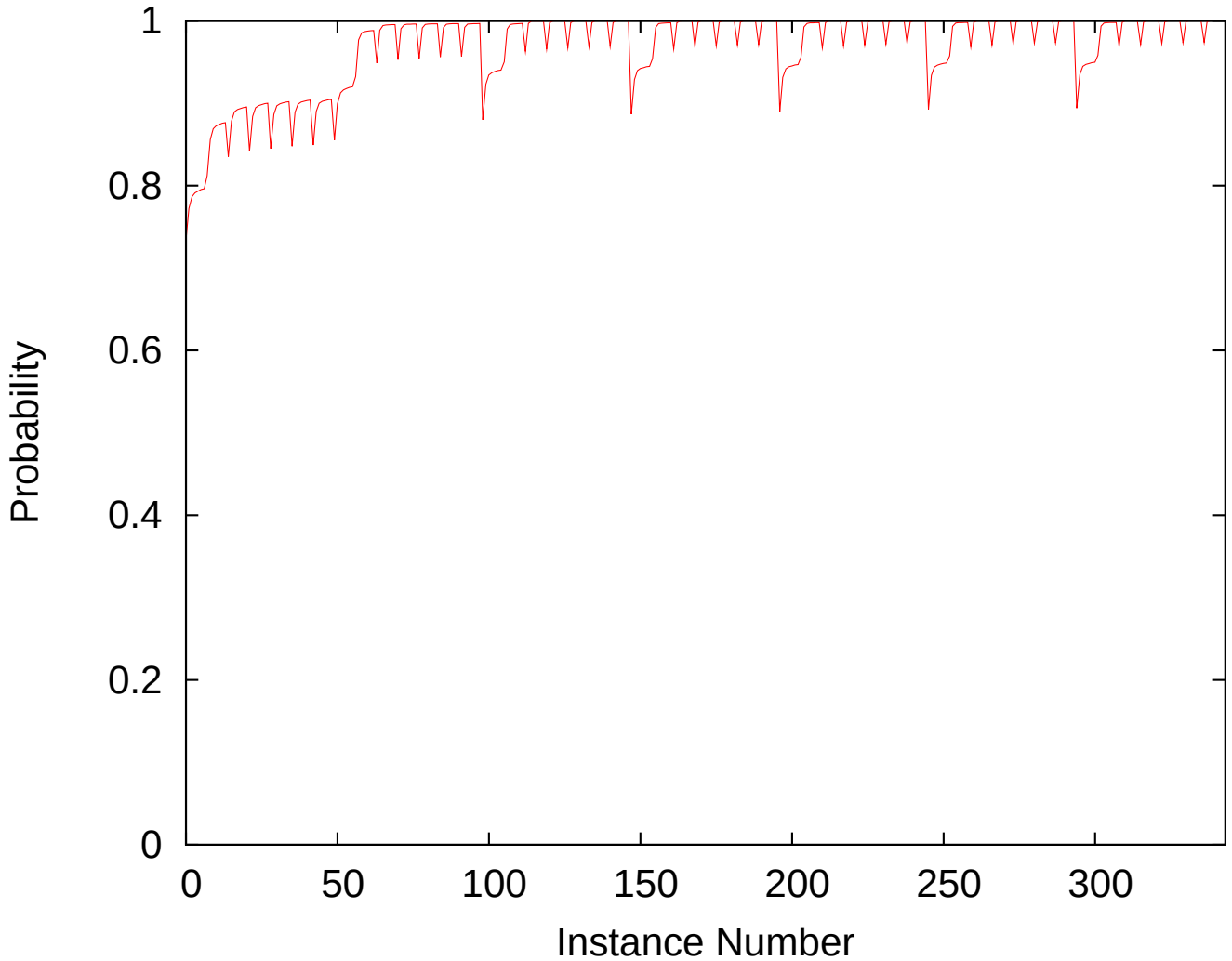
Response-time analysis at time 120



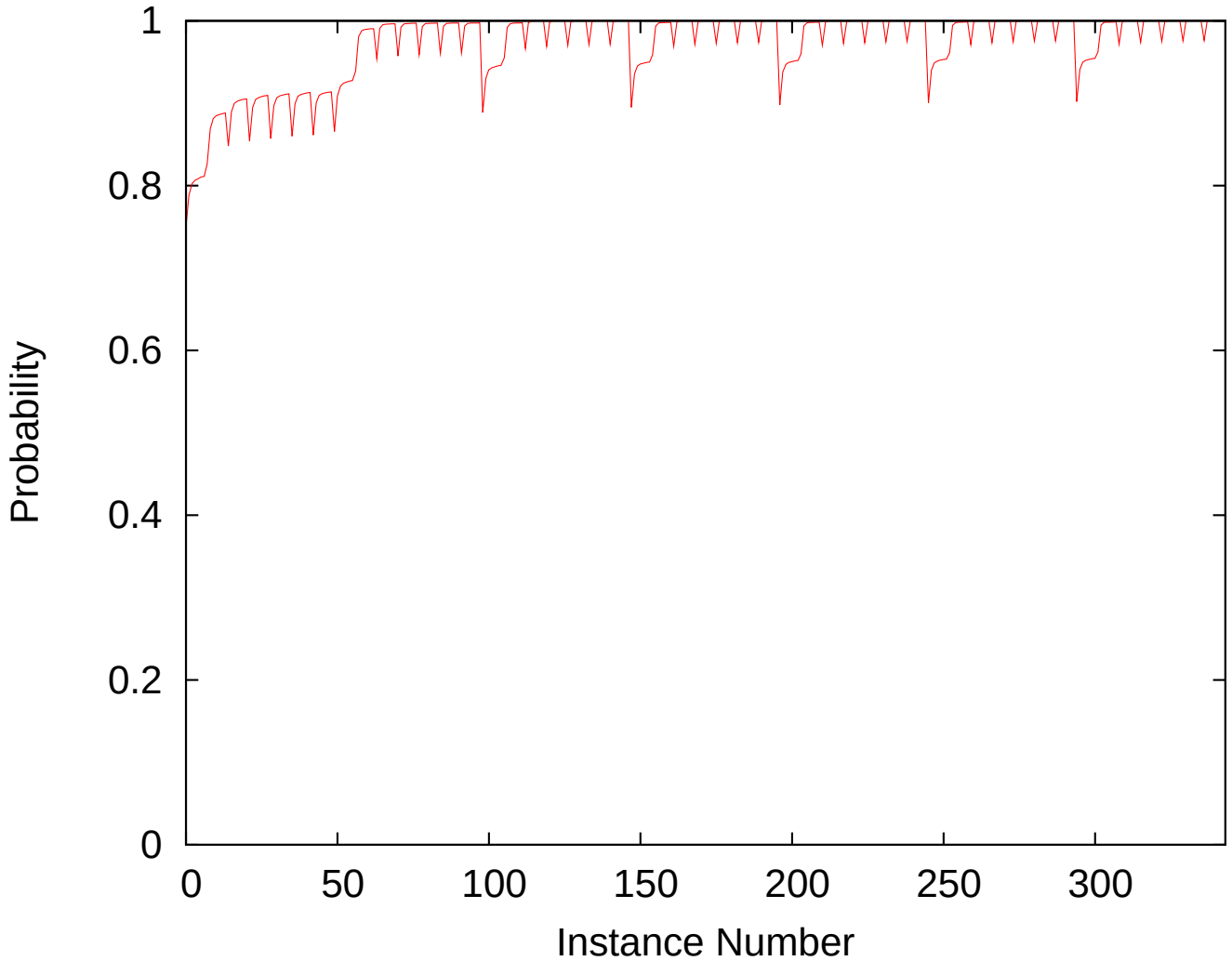
Response-time analysis at time 125



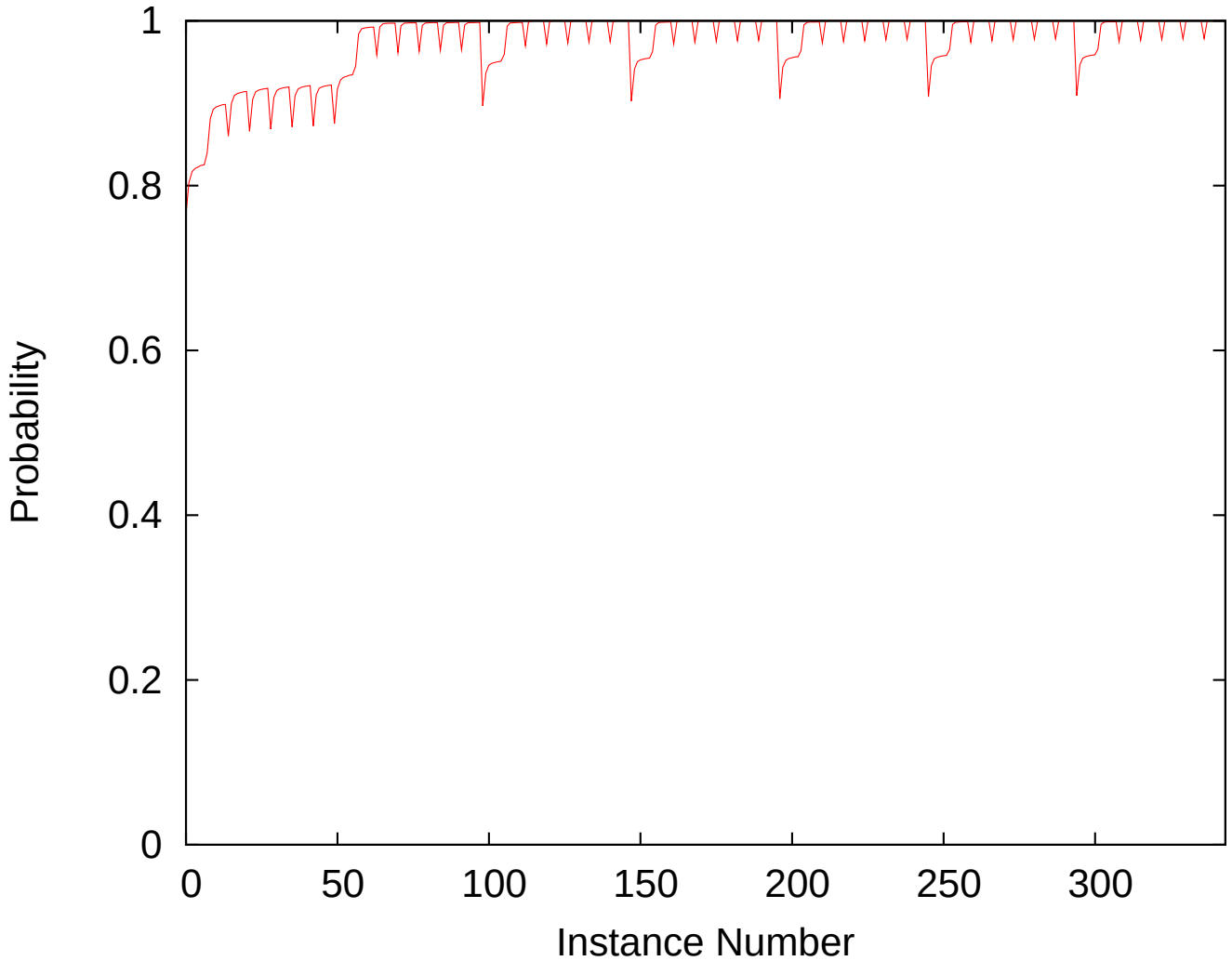
Response-time analysis at time 130



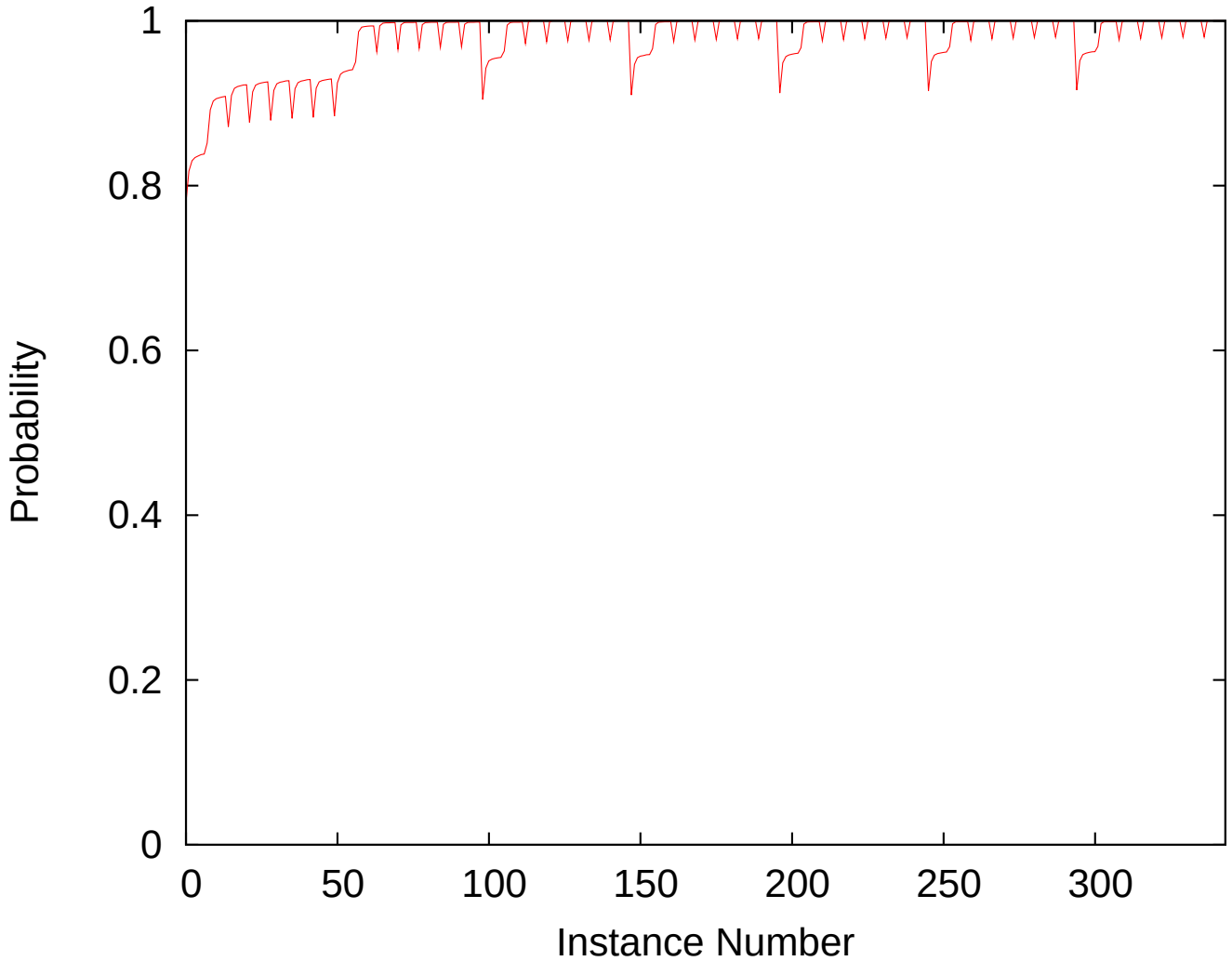
Response-time analysis at time 135



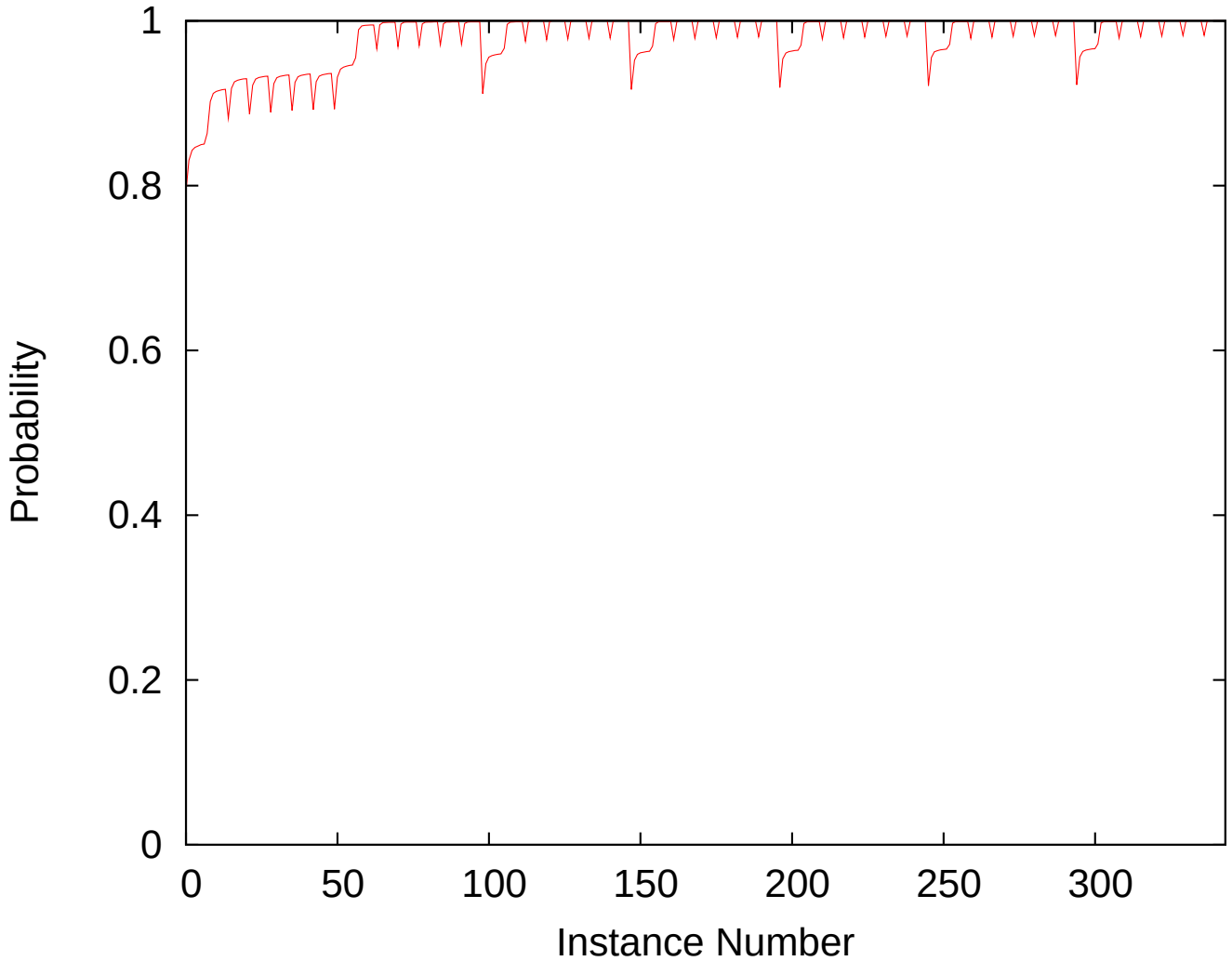
Response-time analysis at time 140



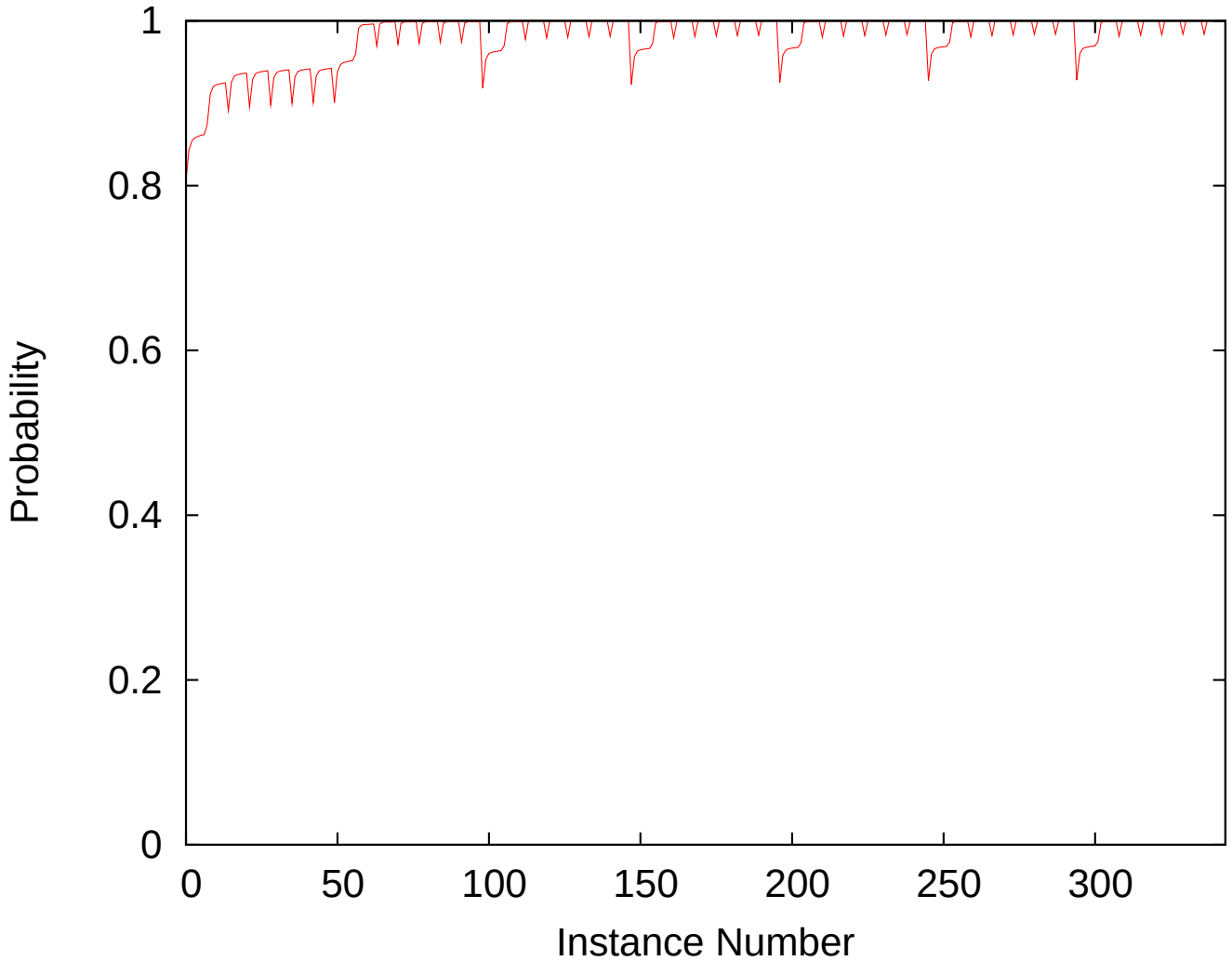
Response-time analysis at time 145



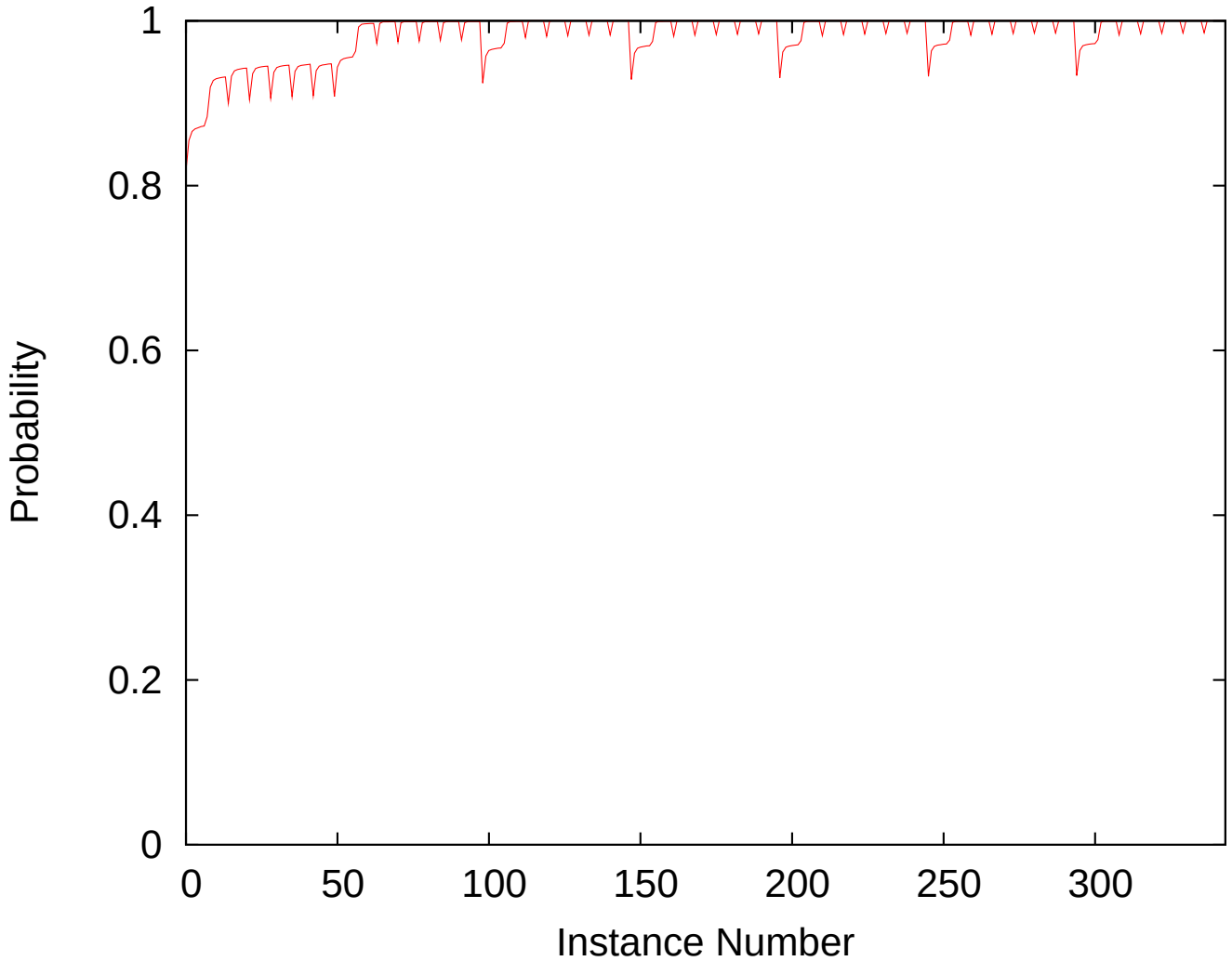
Response-time analysis at time 150



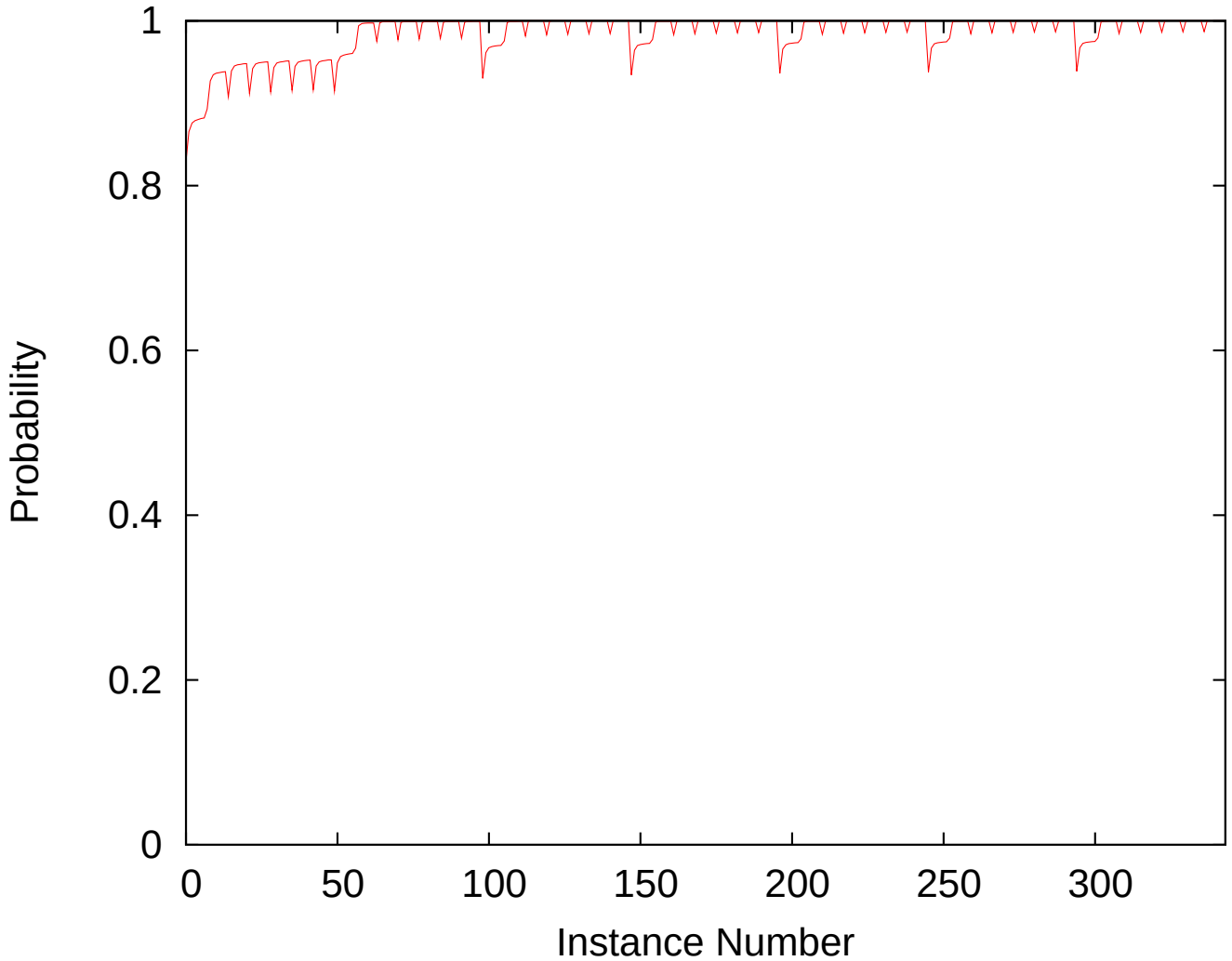
Response-time analysis at time 155



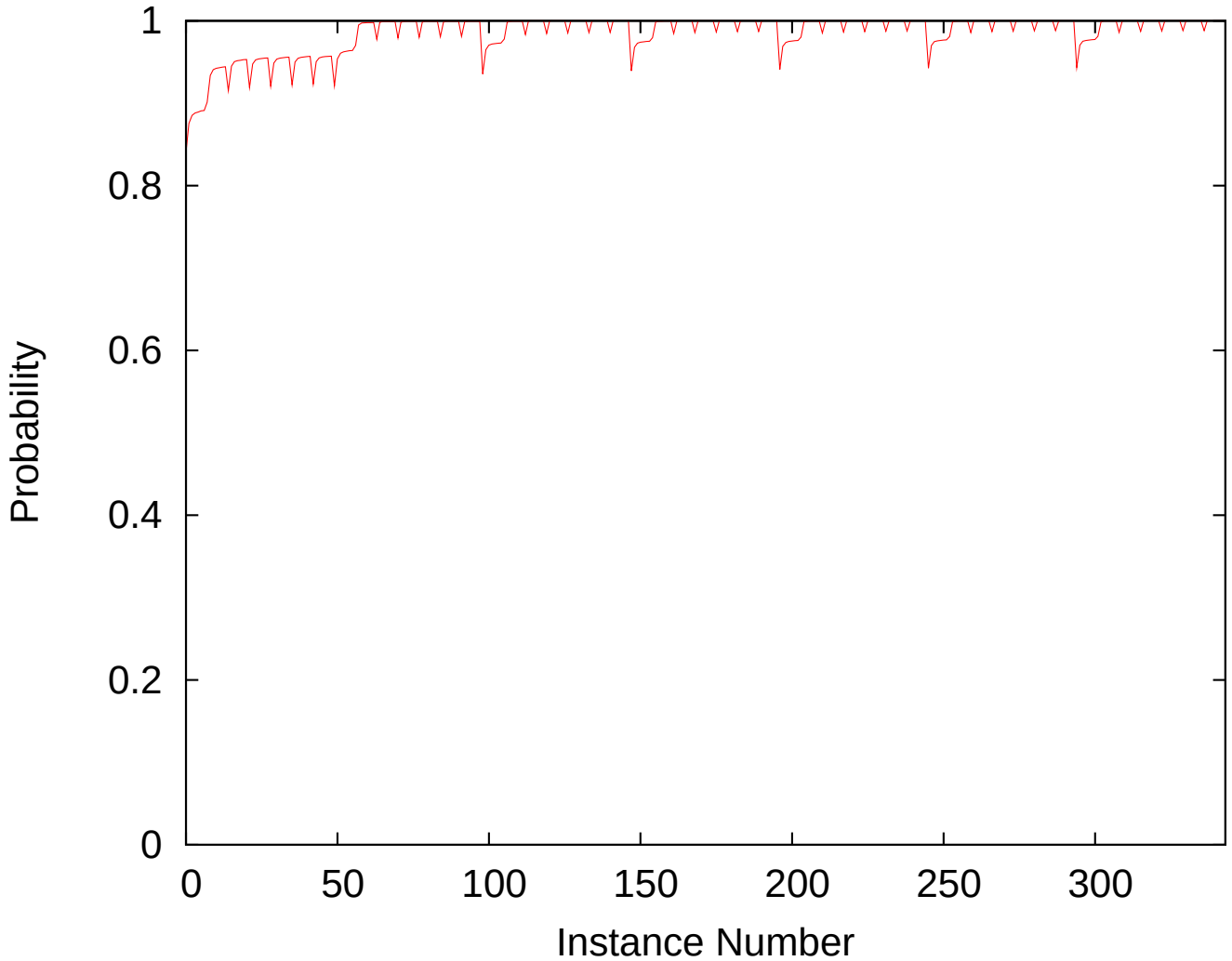
Response-time analysis at time 160



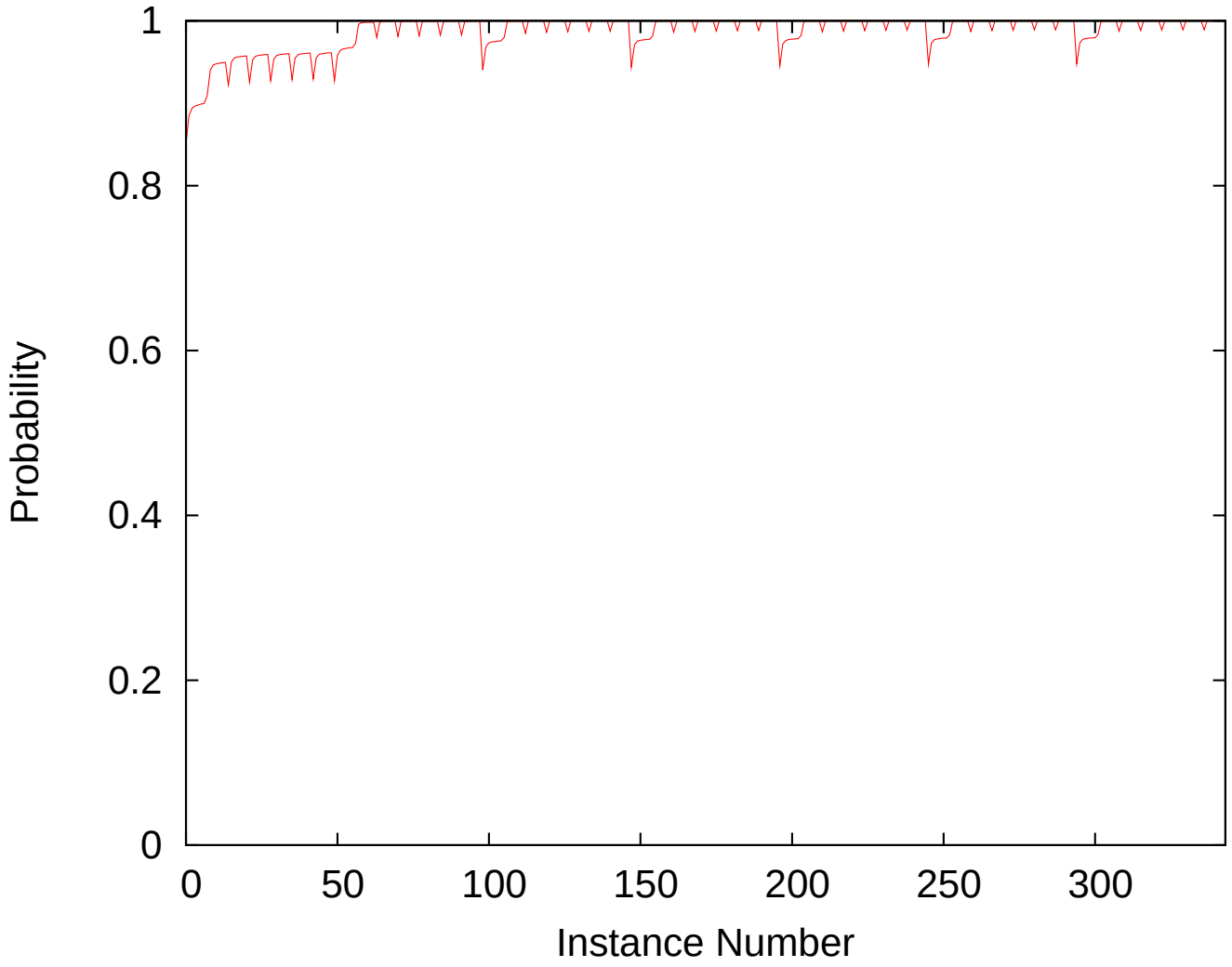
Response-time analysis at time 165



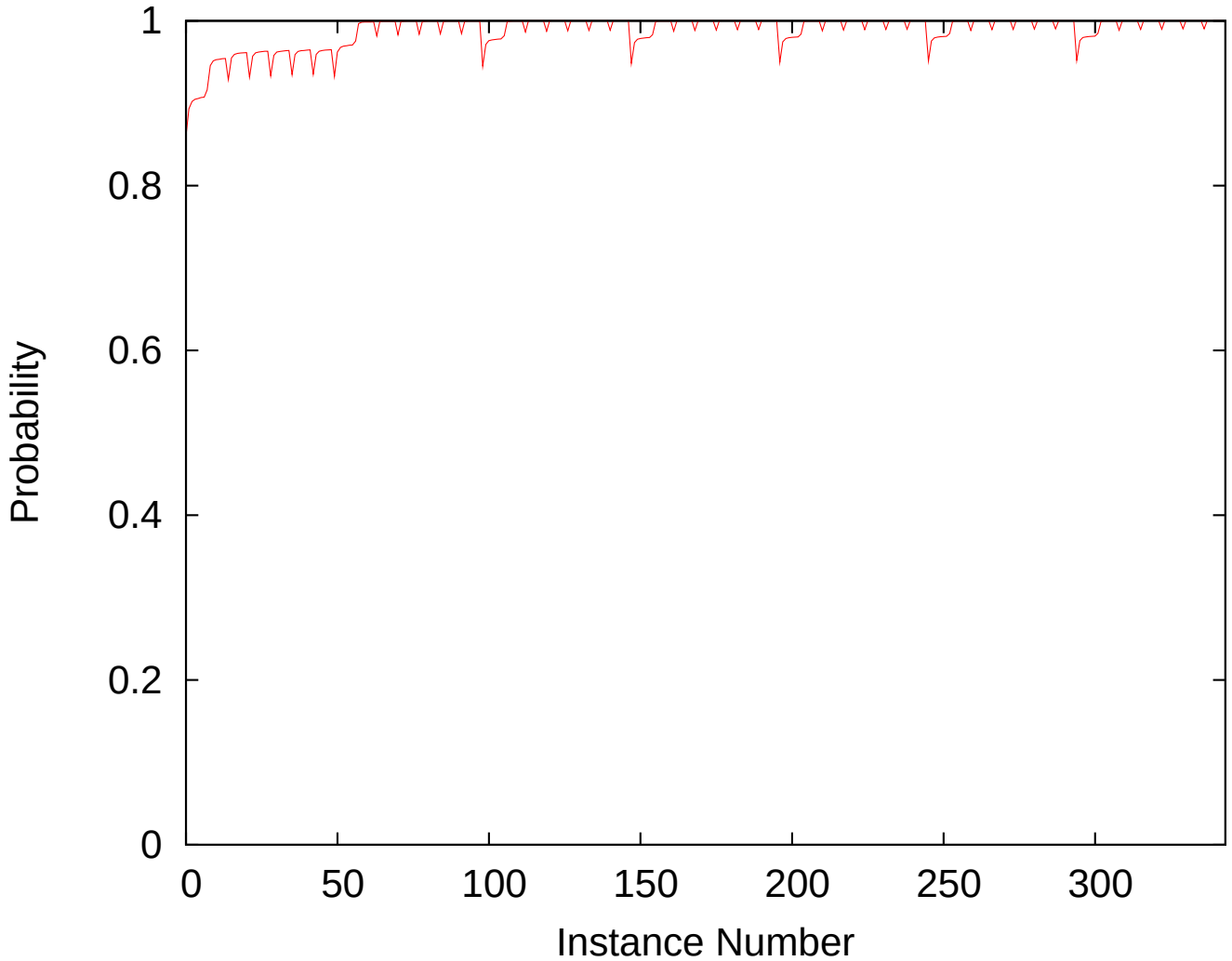
Response-time analysis at time 170



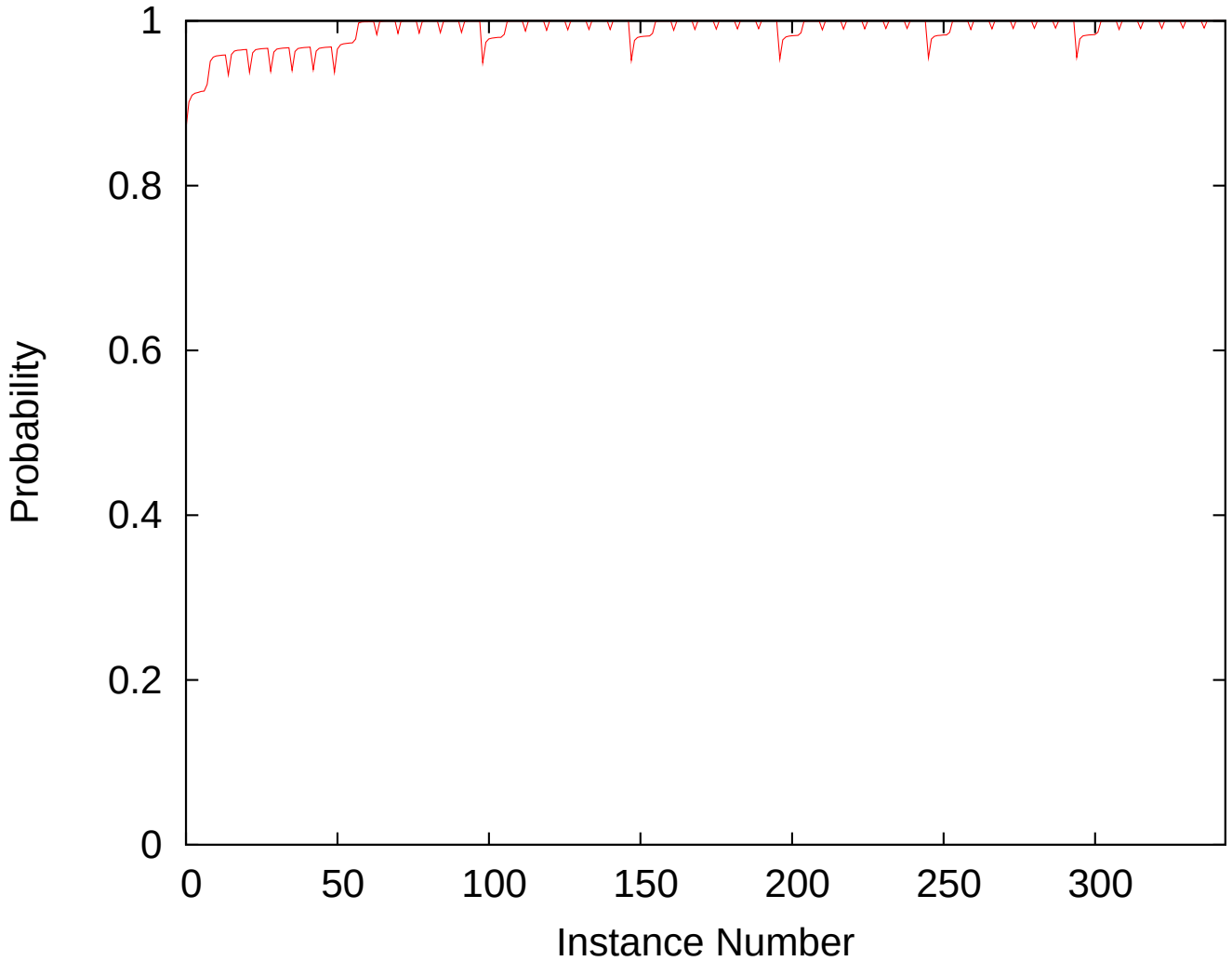
Response-time analysis at time 175



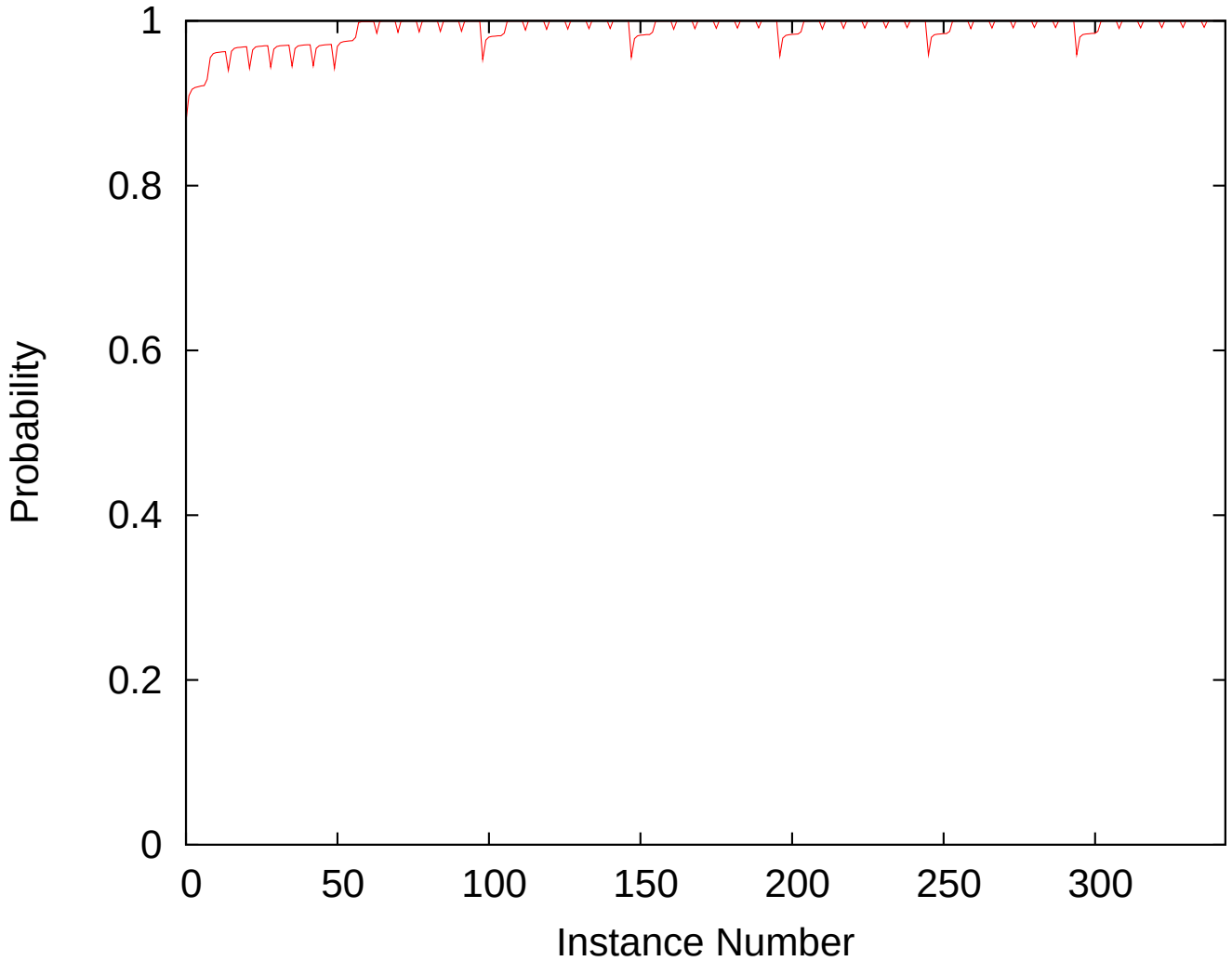
Response-time analysis at time 180



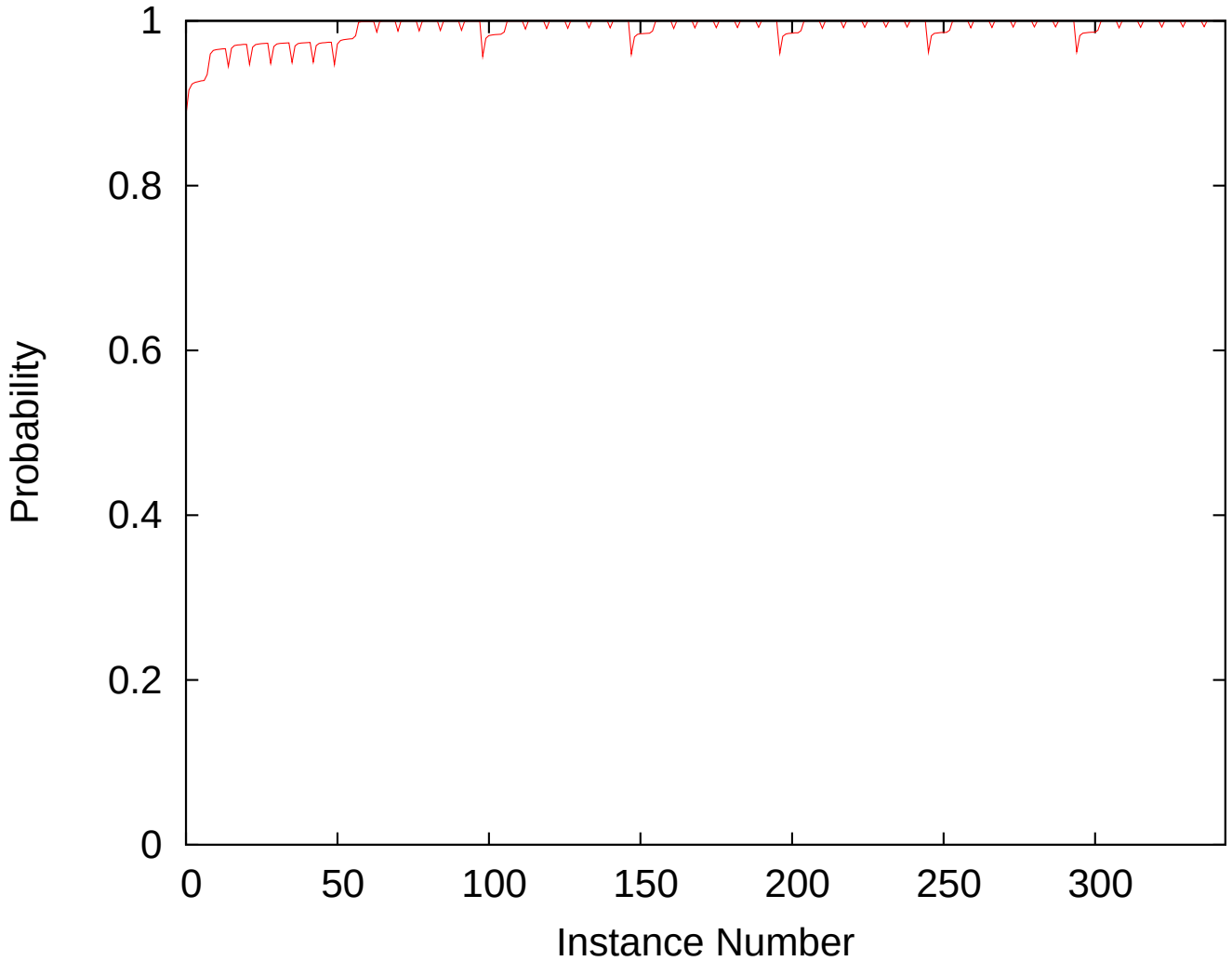
Response-time analysis at time 185



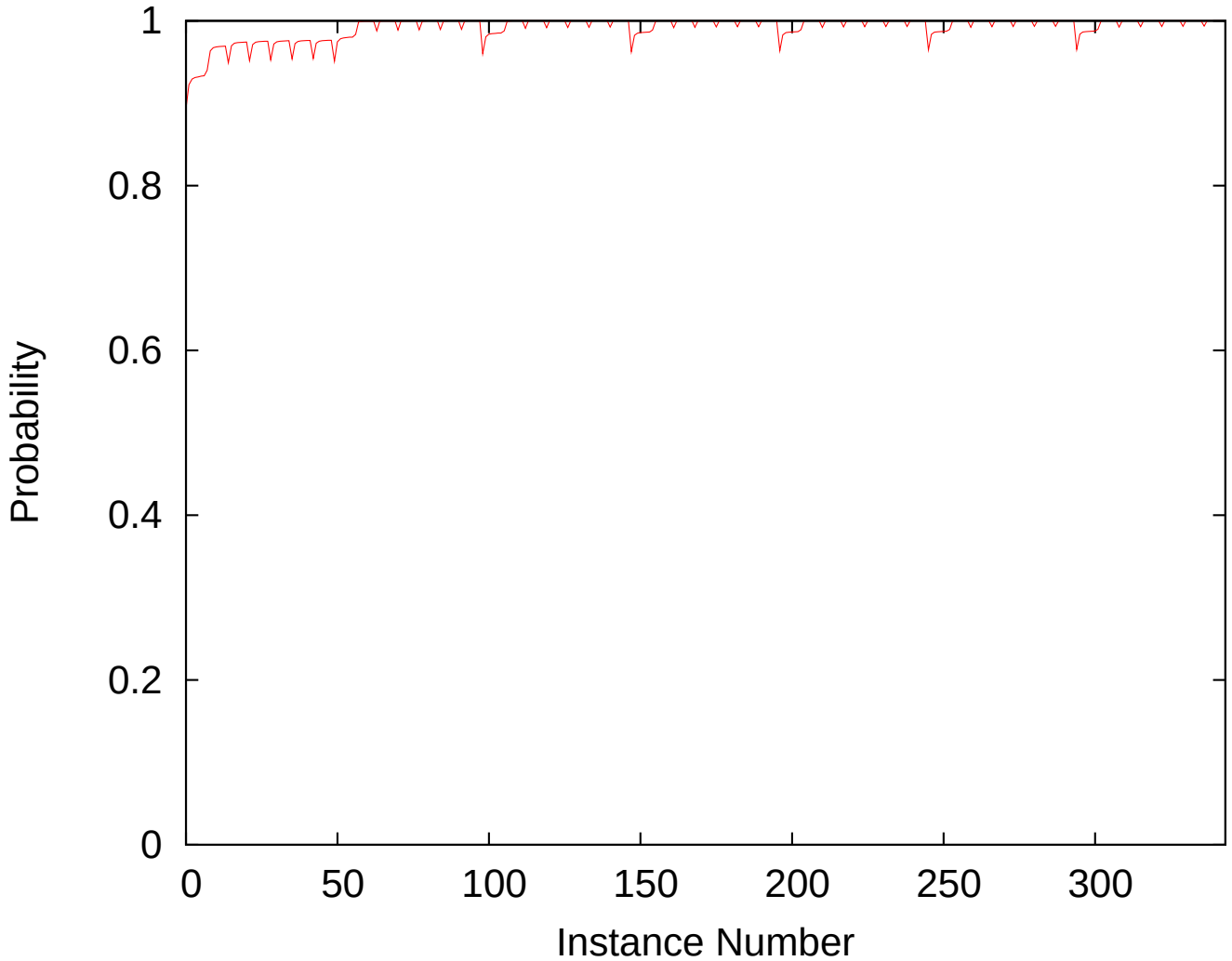
Response-time analysis at time 190



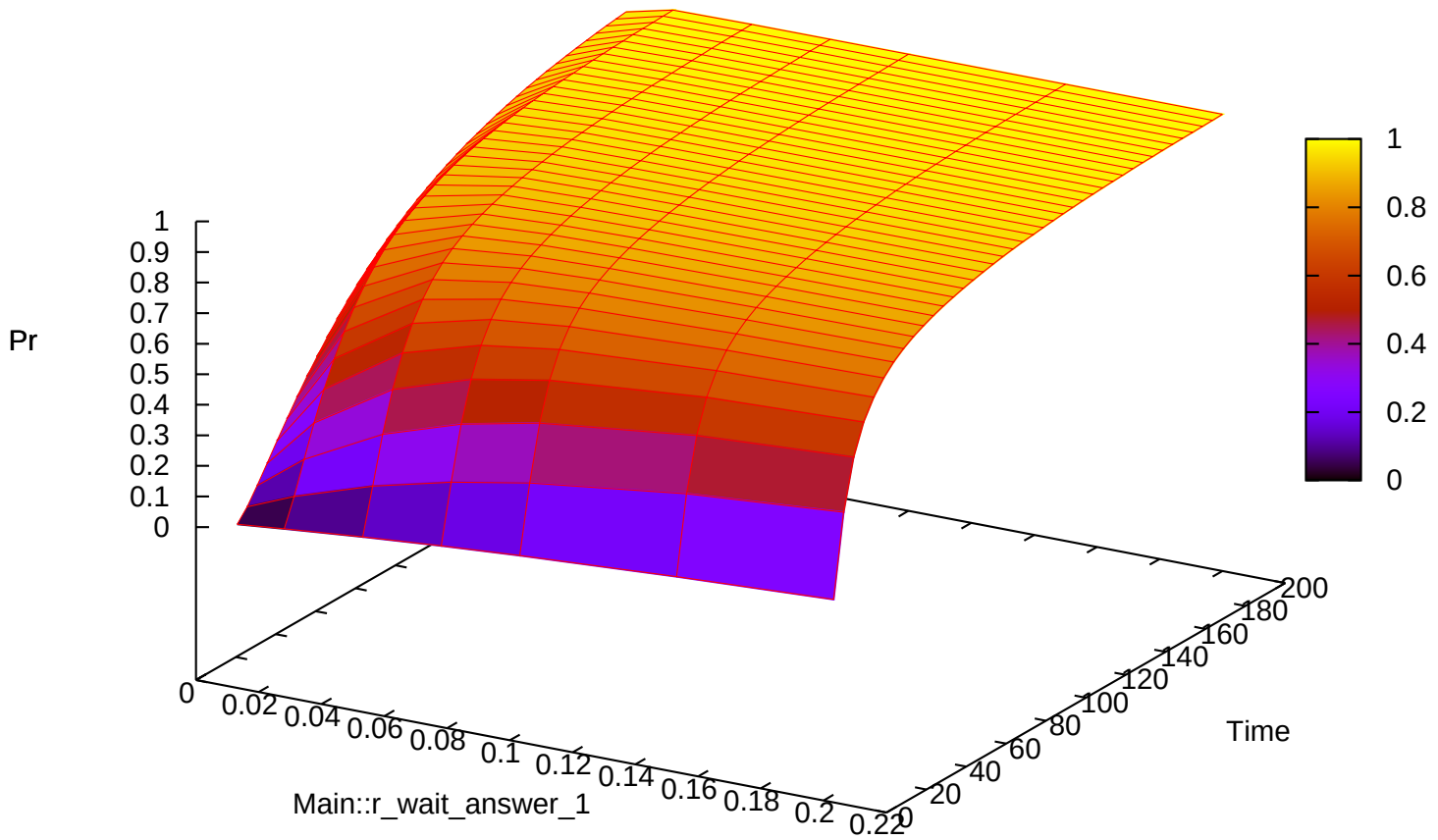
Response-time analysis at time 195



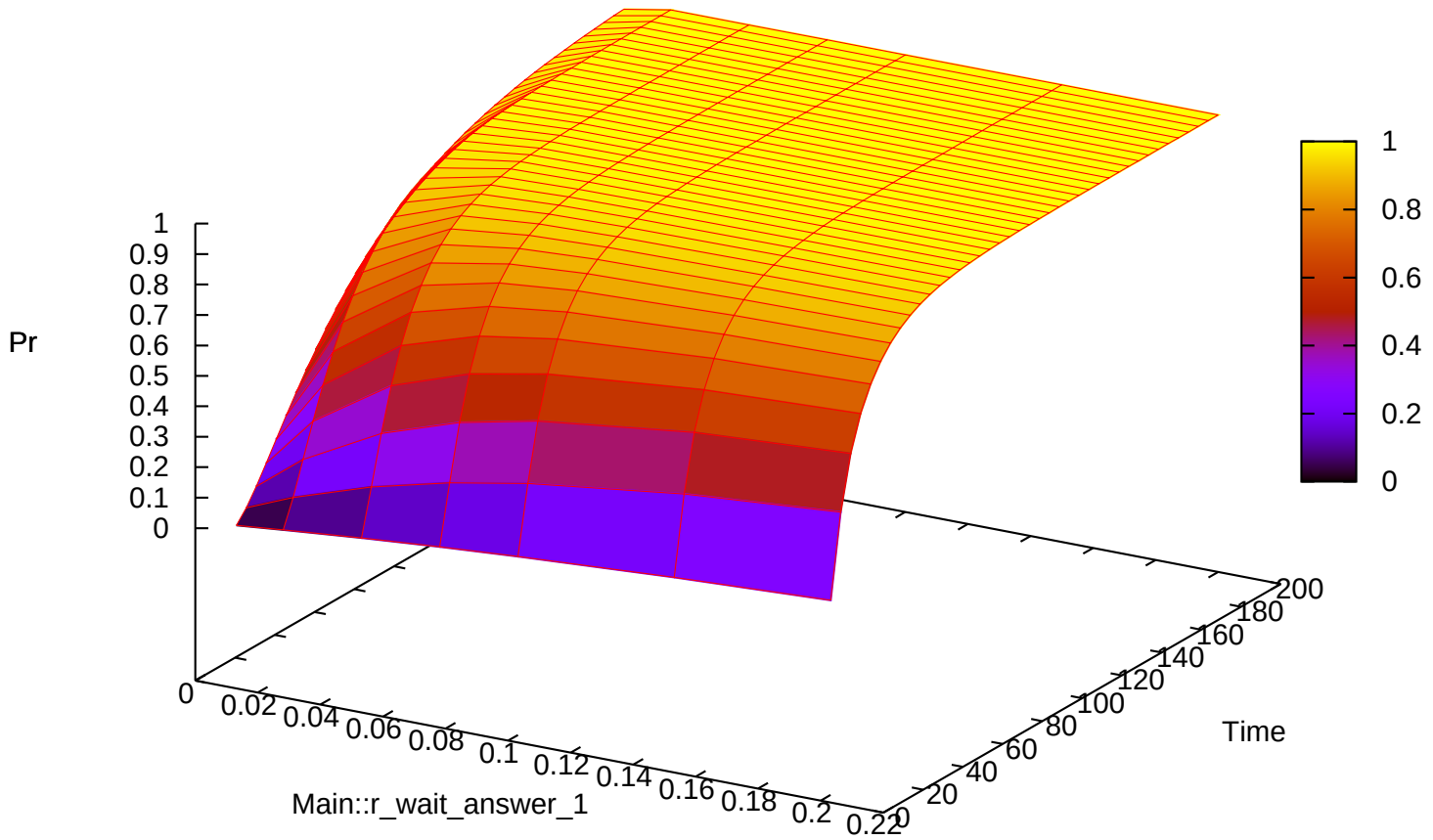
Response-time analysis at time 200



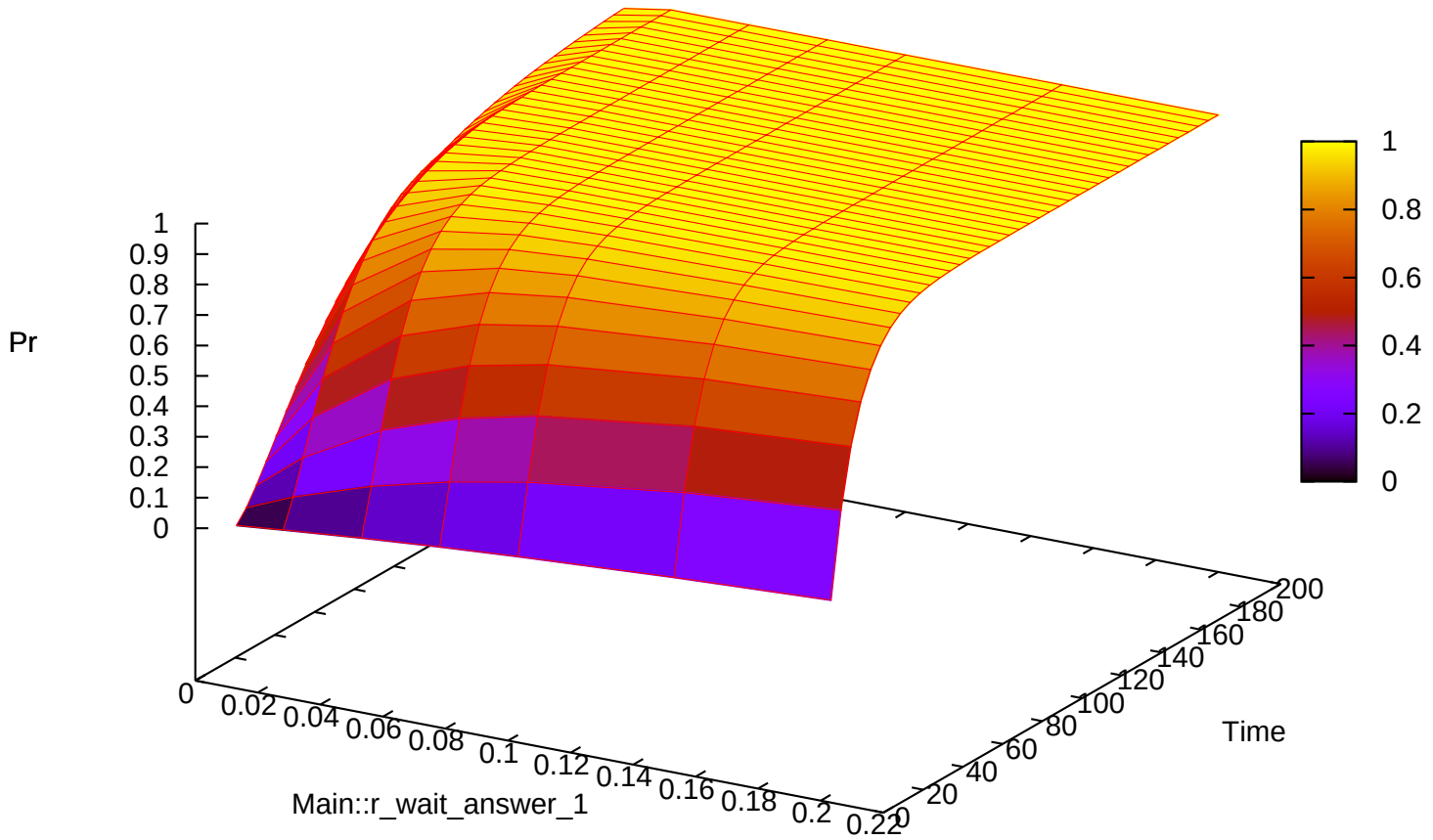
Sensitivity analysis, $r\_wait\_answer\_3 = 0.01$



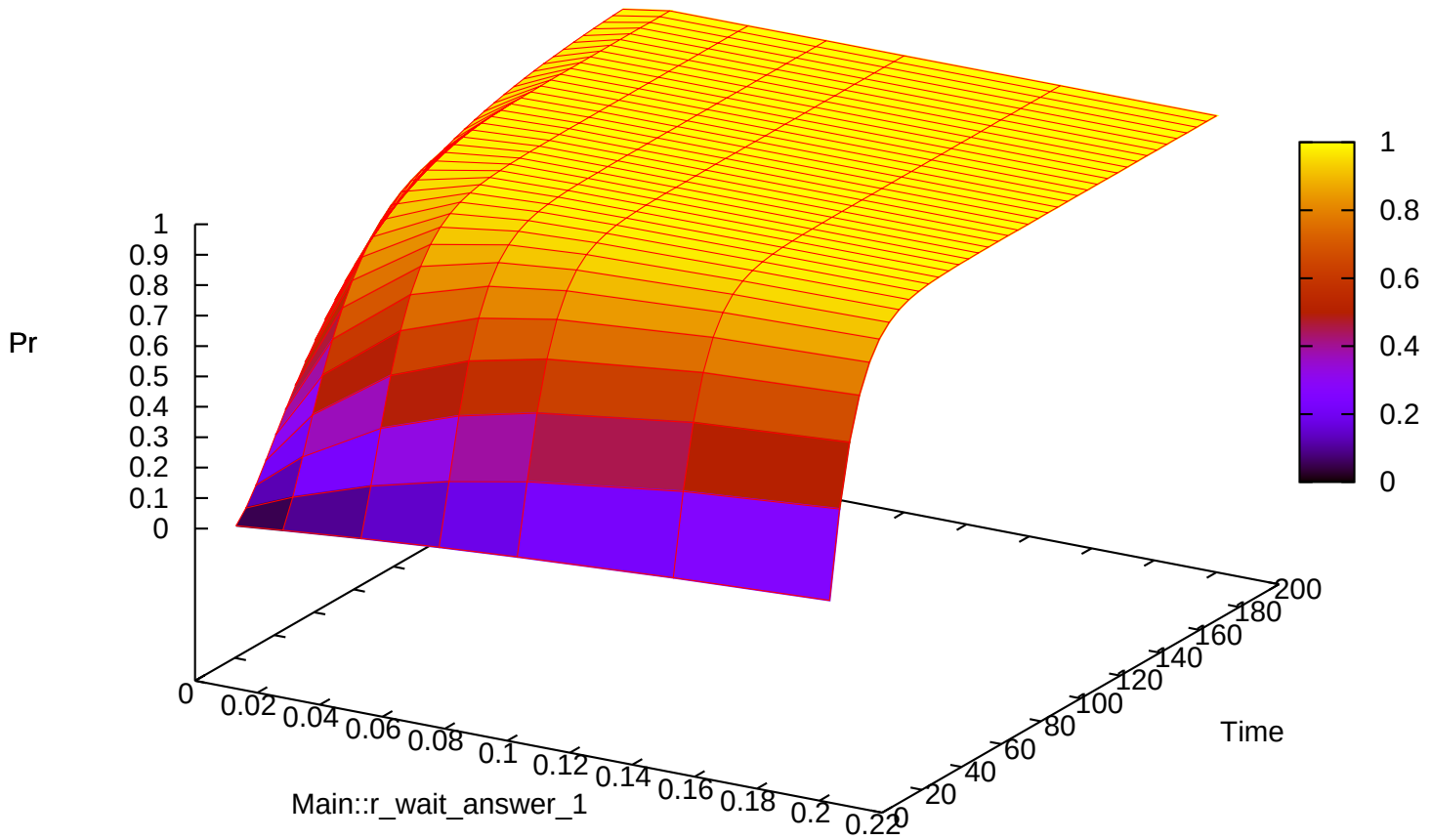
Sensitivity analysis, $r\_wait\_answer\_3 = 0.025$



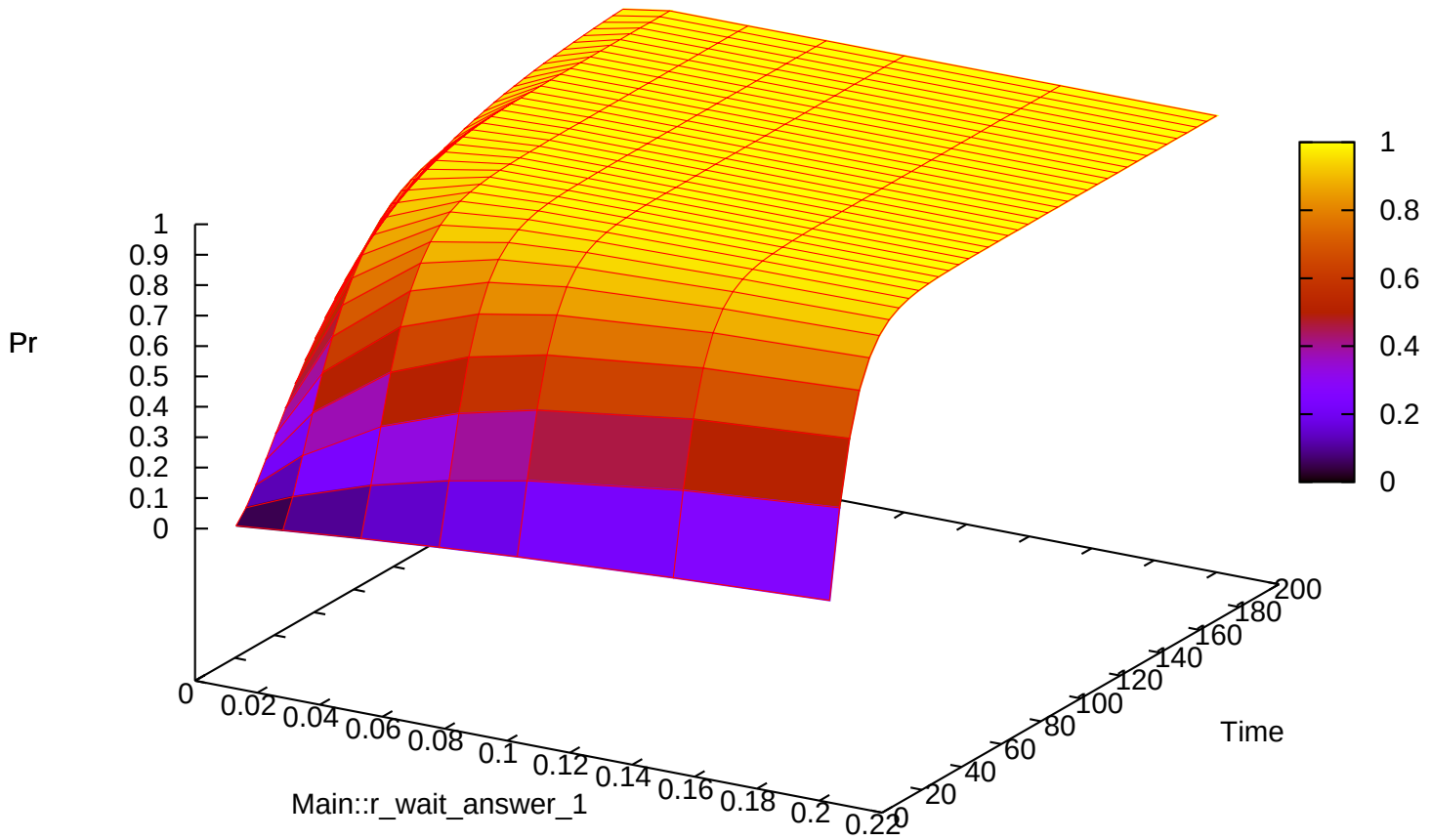
Sensitivity analysis, $r\_wait\_answer\_3 = 0.05$



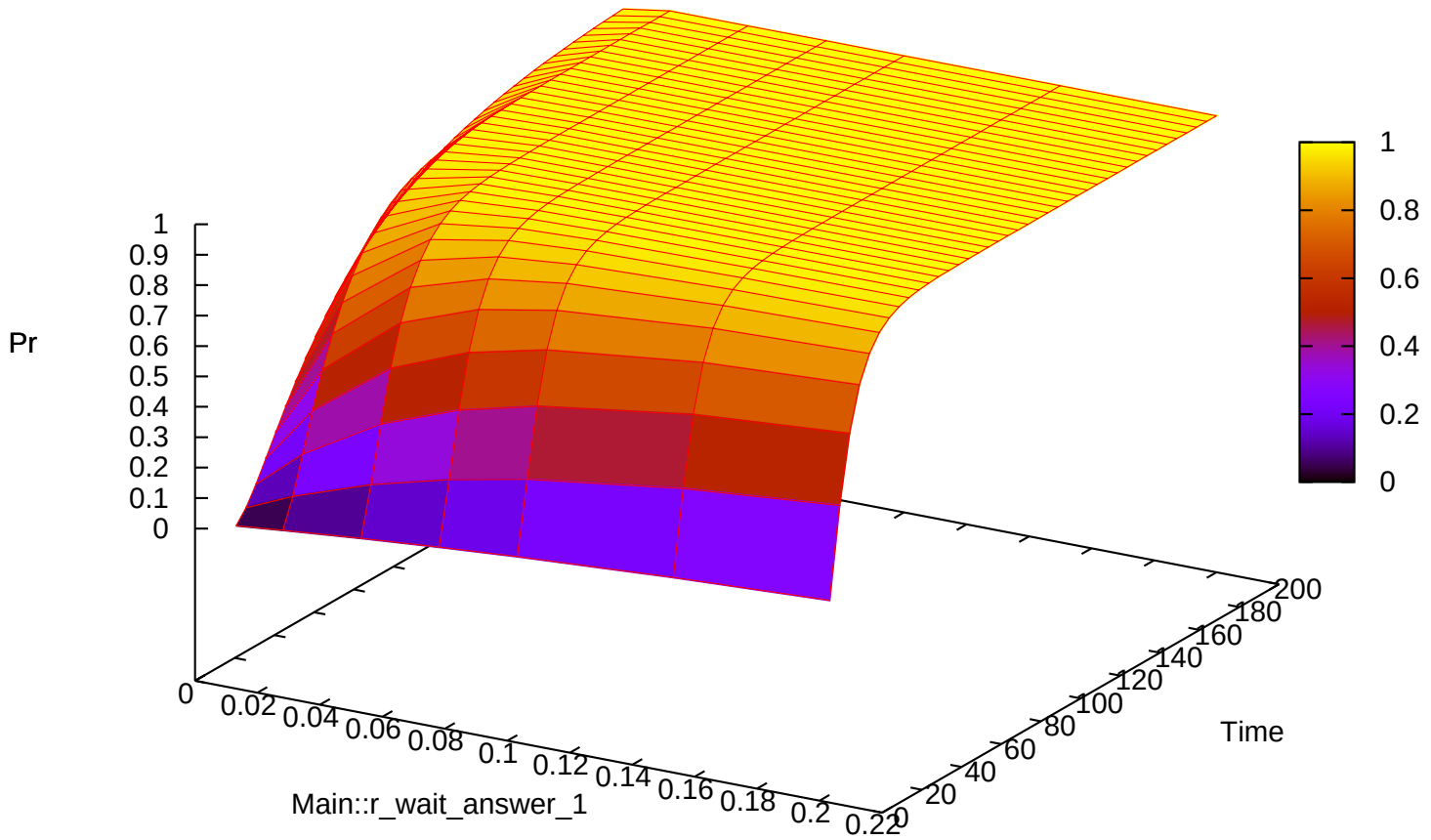
Sensitivity analysis, $r\_wait\_answer\_3 = 0.075$



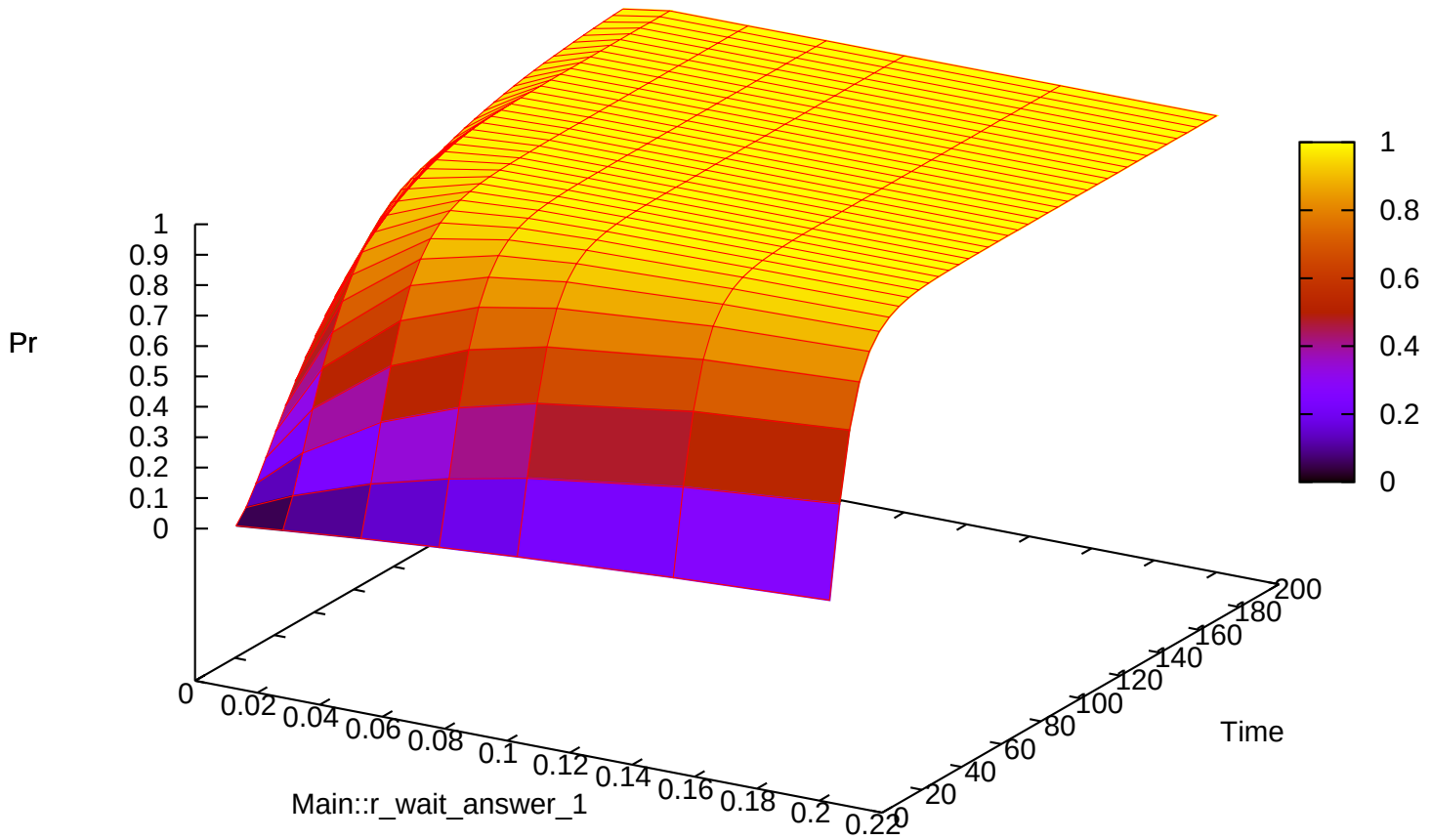
Sensitivity analysis, $r\_wait\_answer\_3 = 0.1$



Sensitivity analysis, $r\_wait\_answer\_3 = 0.15$



Sensitivity analysis, $r\_wait\_answer\_3 = 0.2$



Insight obtained

- Increasing the rate at which the final call is made has a significant impact on the probability of completion of the work of the accident assistance service by a given time bound.

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This suggests that the service would best improve its response time by waiting for less time on the second call attempt than on the first, and less time on the third than the second.

Conclusions

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Conclusions

- We completed a thorough analysis of the accident assistance service.
- Model-checking allowed us to detect errors in the model to ensure accuracy of the modelling work.
- Passage-time and sensitivity analysis allowed us to identify the most productive place in the workflow to target for improvement.
- Modelling tools hosted on a state-of-the-art modelling environment.