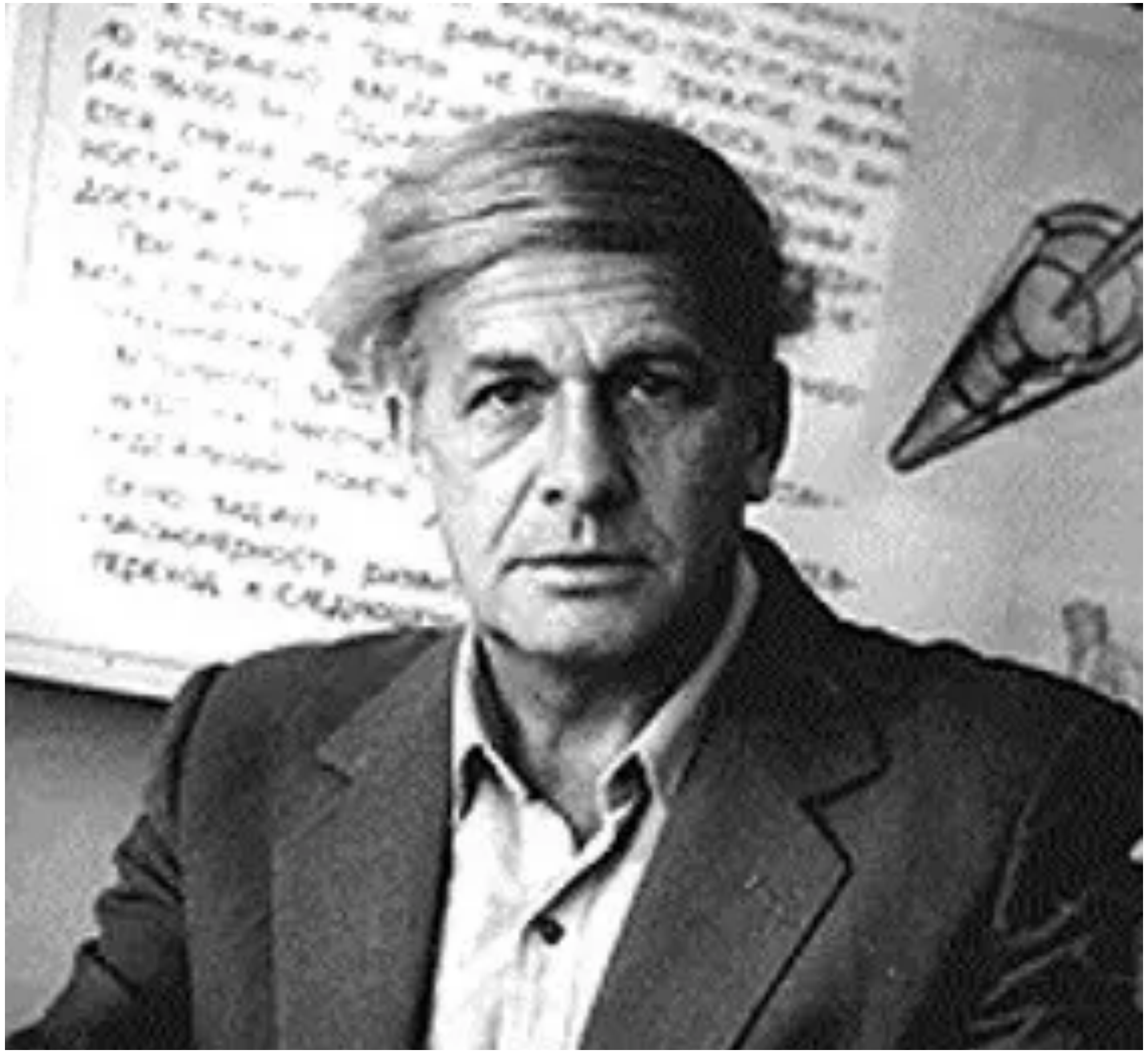
fastly®

The power of good abstractions in systems design

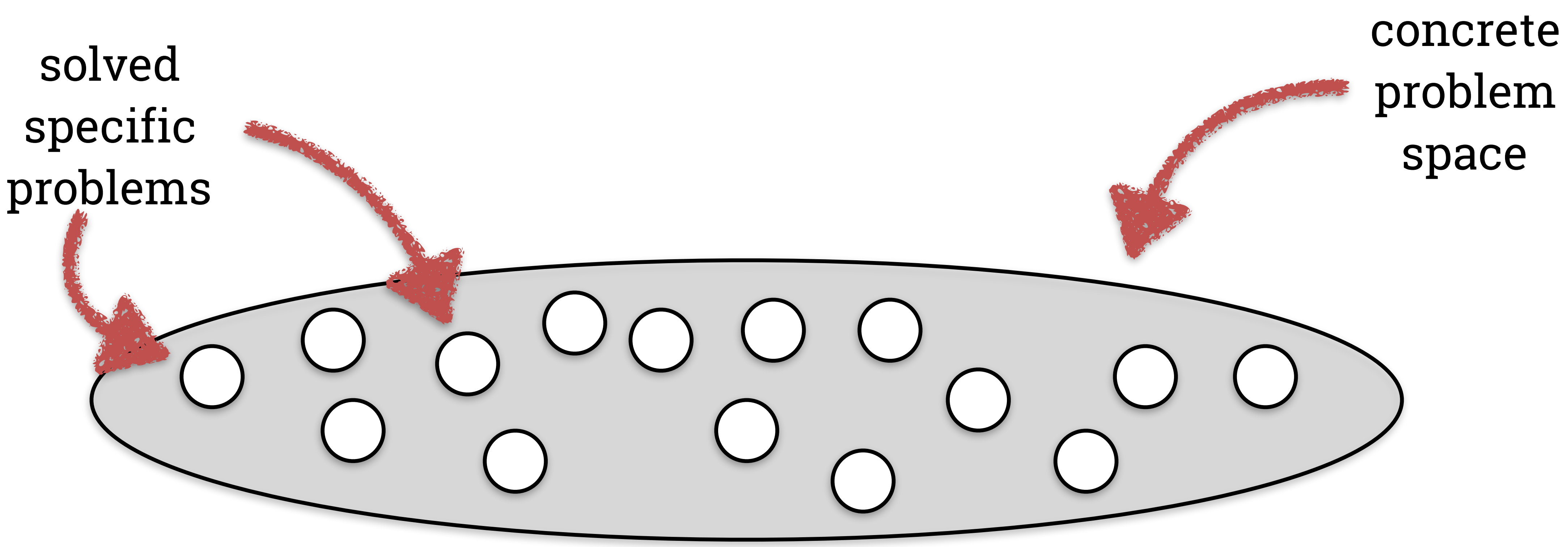
Lorenzo Saino
Engineering manager

@lorenzosaino



Genrich Altshuller
(1926 - 1998)

90% of the problems had been solved
with just 40 basic principles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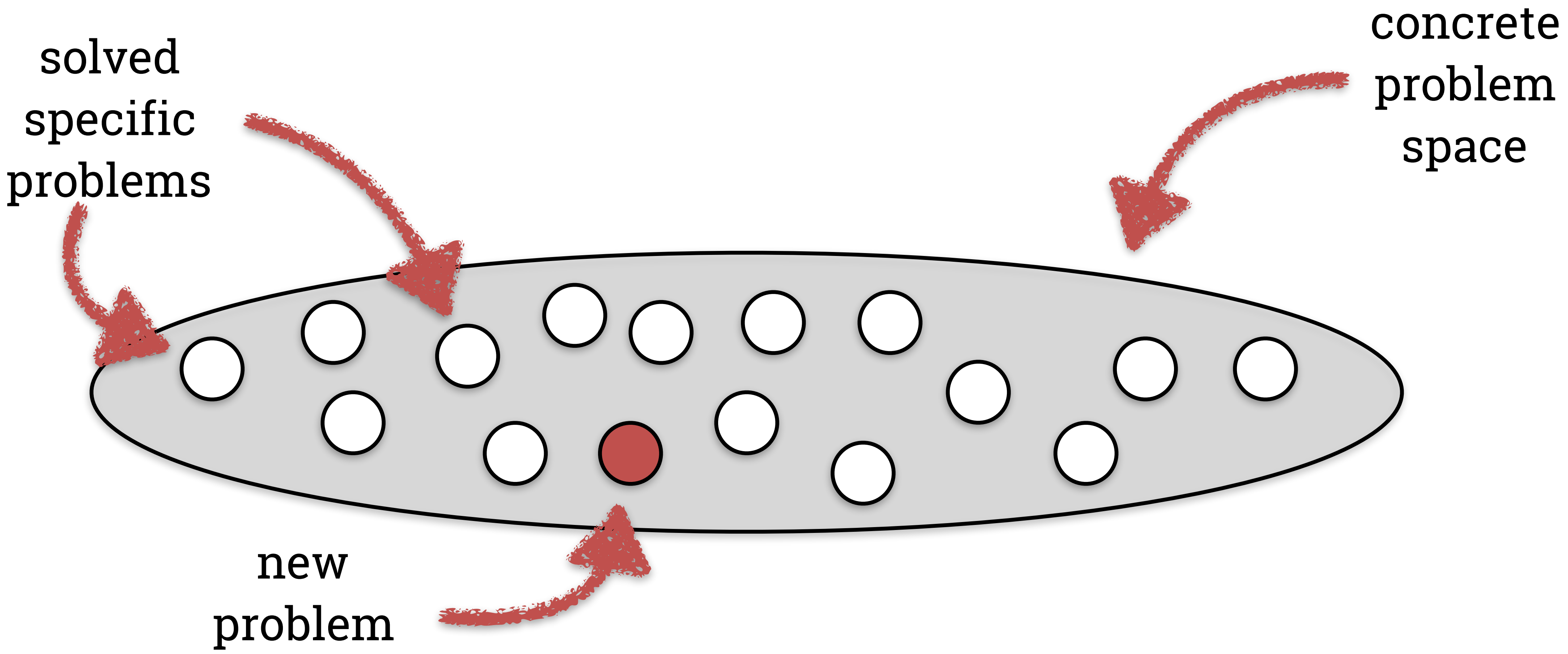
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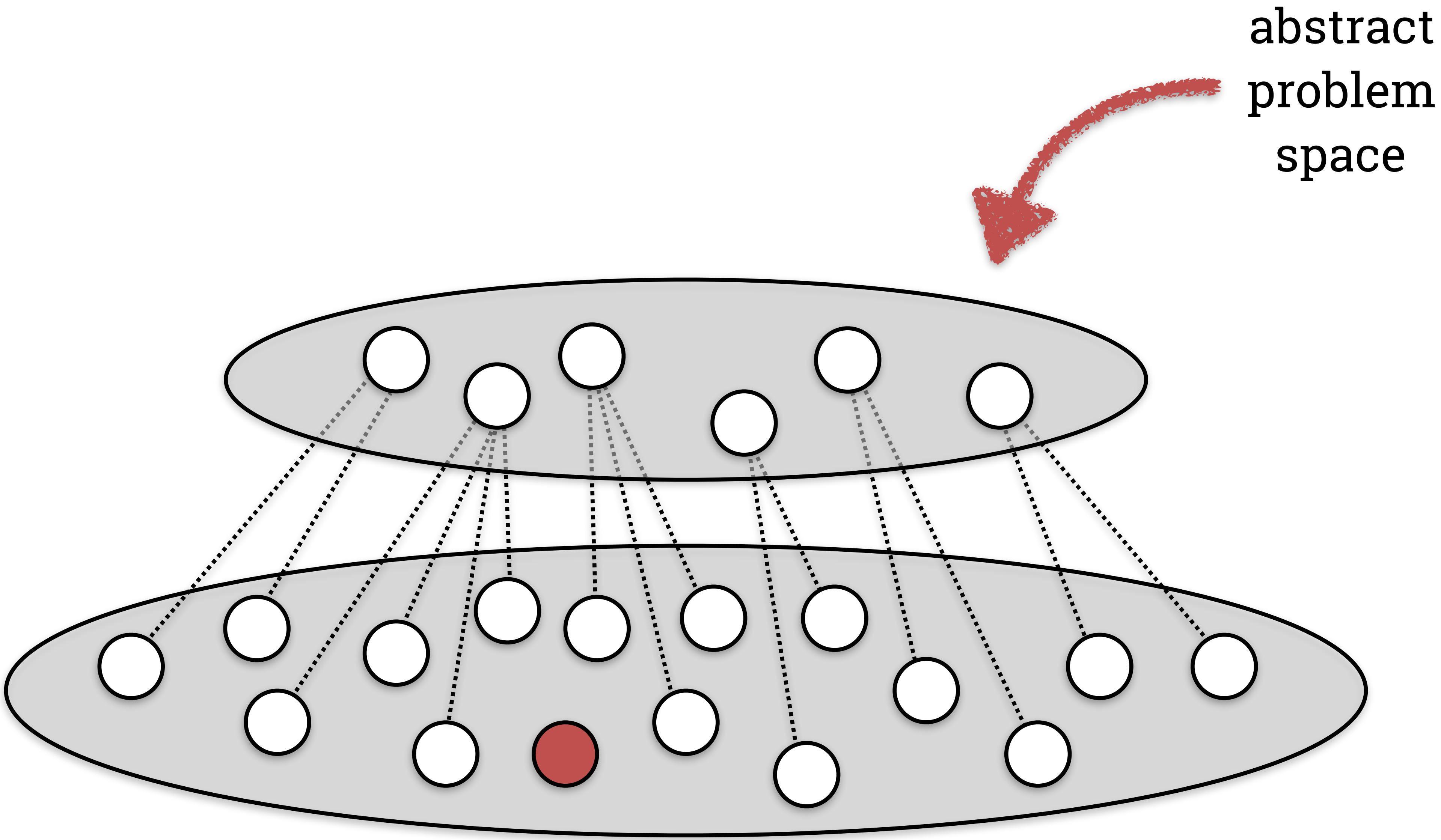
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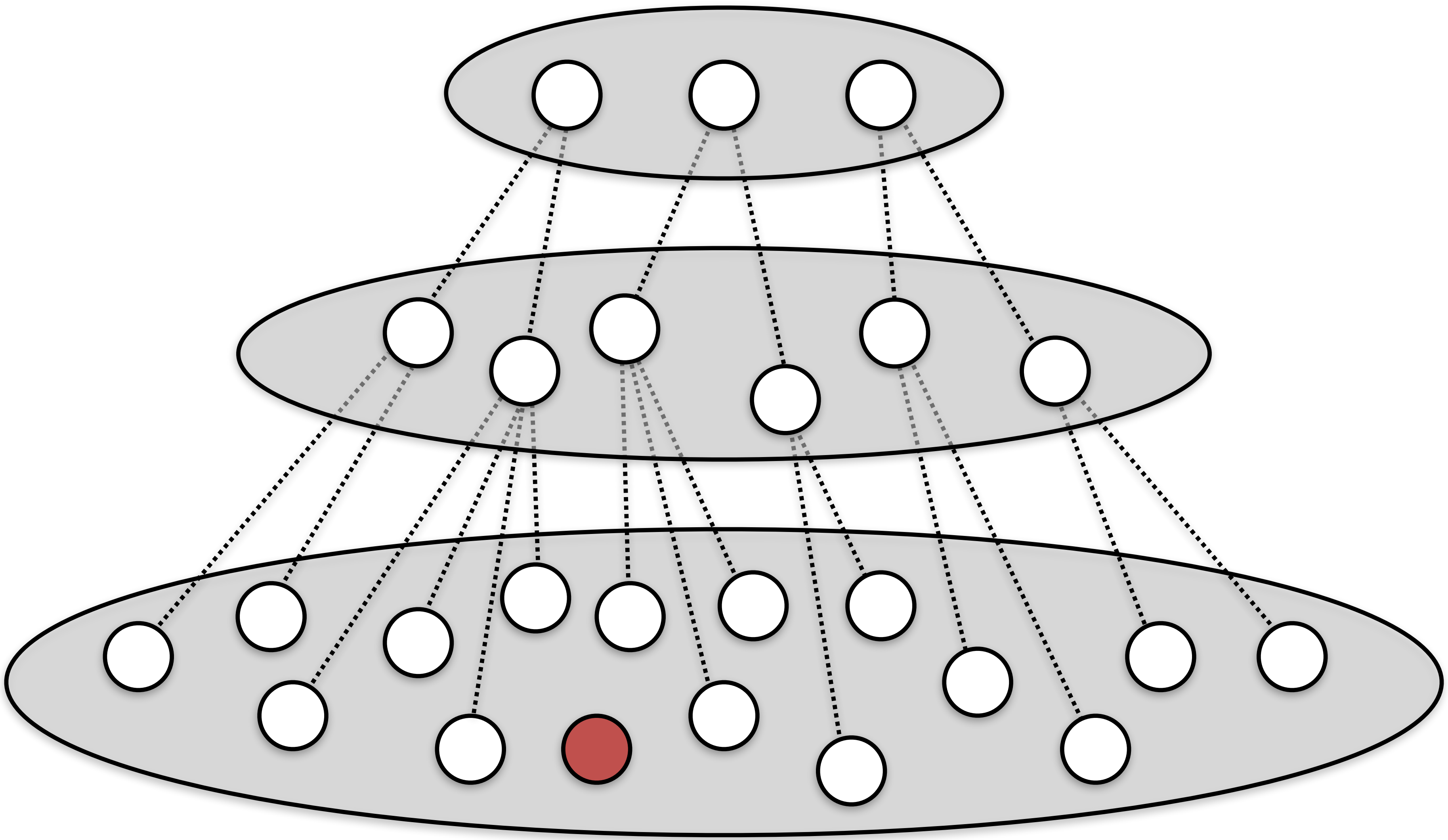
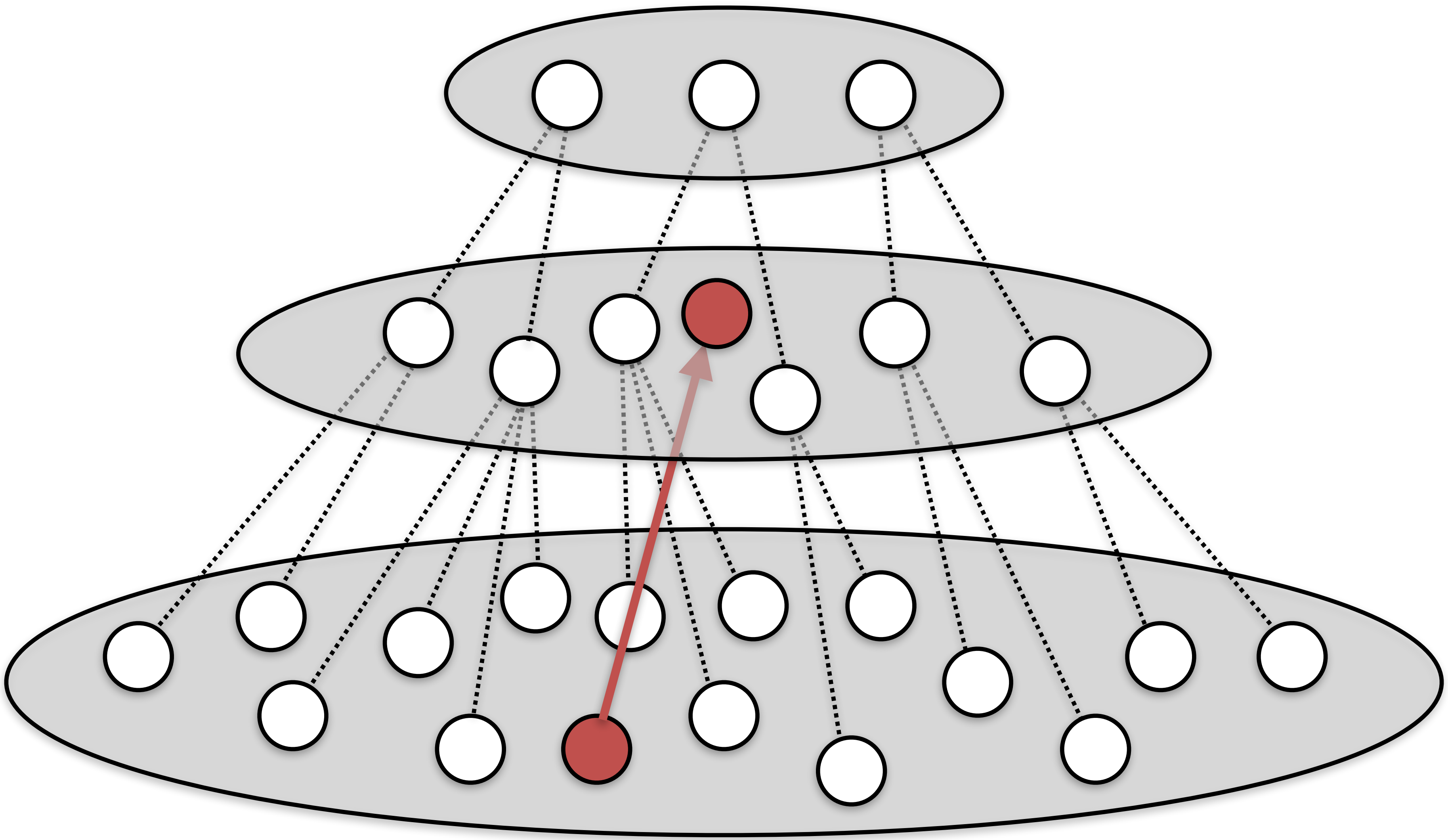
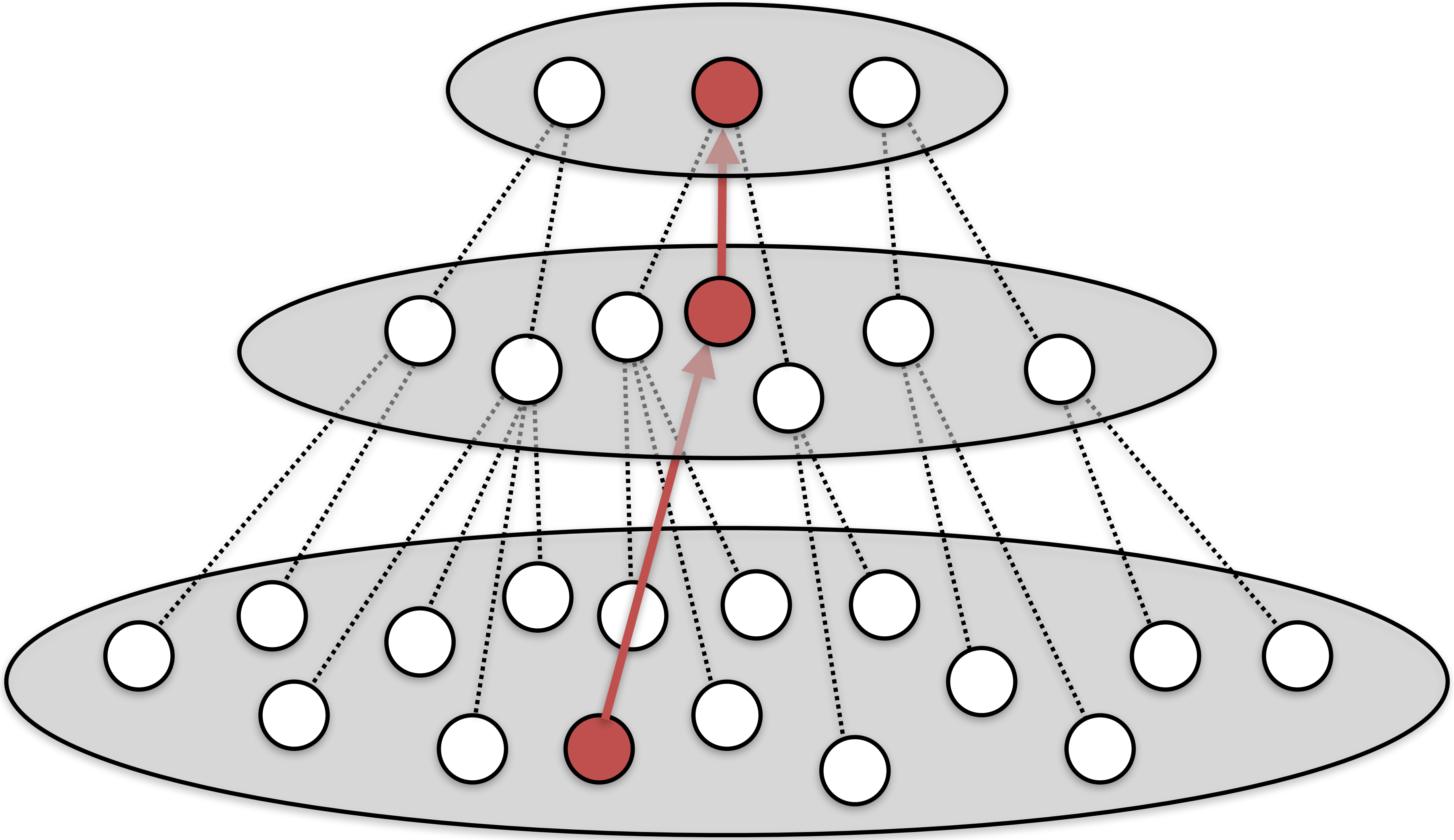
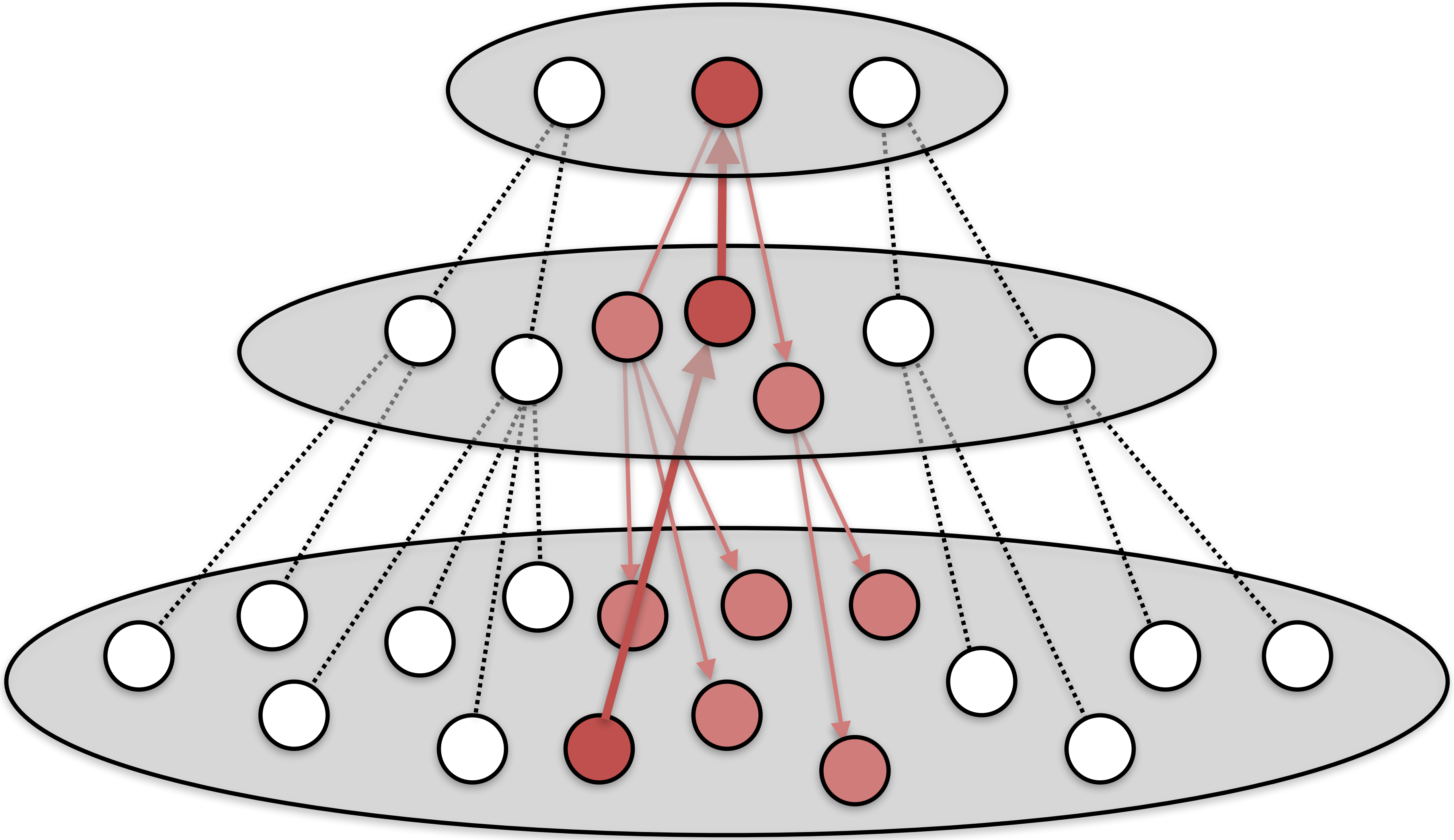








TRIZ

Theory of Inventive Problem Solving

A Mathematical Model for the Determination of Total Area Under Glucose Tolerance and Other Metabolic Curves

MARY M. TAI, MS, EDD

OBJECTIVE — To develop a mathematical model for the determination of total areas under curves from various metabolic studies.

RESEARCH DESIGN AND METHODS — In Tai's Model, the total area under a curve is computed by dividing the area under the curve between two designated values on the *X*-axis (abscissas) into small segments (rectangles and triangles) whose areas can be accurately calculated from their respective geometrical formulas. The total sum of these individual areas thus represents the total area under the curve. Validity of the model is established by comparing total areas obtained from this model to these same areas obtained from graphic method (less than ±0.4%). Other formulas widely applied by researchers under- or overestimated total area under a metabolic curve by a great margin.

RESULTS — Tai's model proves to be able to *1*) determine total area under a curve with precision; *2*) calculate area with varied shapes that may or may not intercept on one or both *X/Y* axes; *3*) estimate total area under a curve plotted against varied time intervals (abscissas), whereas other formulas only allow the same time interval; and

However, except for Wolever et al.'s formula, other formulas tend to under- or overestimate the total area under a metabolic curve by a large margin.

RESEARCH DESIGN AND METHODS

Tai's mathematical model

Tai's model was developed to correct the deficiency of under- or overestimation of the total area under a metabolic curve. This formula also allows calculating the area under a curve with unequal units on the *X*-axis. The strategy of this mathematical model is to divide the total area under a curve into individual small segments such as squares, rectangles, and triangles, whose areas can be precisely determined according to existing geometric formulas. The area of the individual segments are then added to obtain the total area under the curve. As shown in Fig. 1, the total area can be expressed as:

Total area = triangle a + rectangle b + triangle c + rectangle d + triangle e + rectangle f + triangle g + rectangle h + . . .

If y = height, x = width

Area (square) = x^2 or y^2 ($x = y$);

Area (rectangle) = xy;

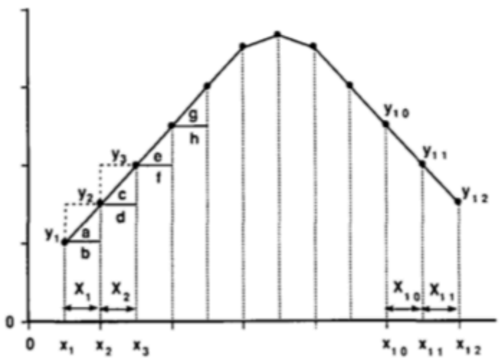


Figure 1—*Total area under the curve is the sum of individual areas of triangles a, c, e, and g and rectangles b, d, f, and h.*

$$\text{Area} = \frac{1}{2}\sum_{i=1}^{n} X_{i-1}(y_{i-1} + y_i)$$

(Tai's formula)

When the curve passes the origin: $x_0 = y_0 = 0$, $X_0 = x_1 - 0$;
When the curve intercepts *Y*-axis at y_0: $X_0 = x_1 - 0$
When the curve neither passes the origin nor intercepts at y-axis: $X_0 = y_0 = 0$

Example using Tai's model:
Blood glucose determined at six time periods: (6)

time (min)	0	30	60	90	120

formulas to a standard (true value), which is obtained by plotting the curve on graph paper and counting the number of small units under the curve. The sum of these units represents the actual total area under the curve. Results are presented in Table 1. From Table 1, it is evident that total area I can not be obtained from Alder's formula. Total area II has underestimated the total area under a metabolic curve by a large margin. Total area III corresponds well (− 6.1%) with the actual area estimated from the plot (total area V). However, this formula only permits a single *t* value, which means the time interval has to be the same.

CONCLUSIONS

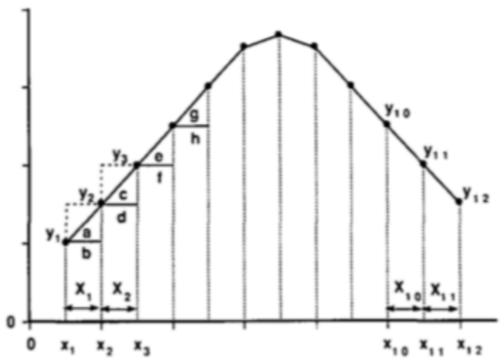
Verification of Tai's mathematical model

From Table 1, it is clear that Tai's formula (total area IV) has the most accurate estimation of the total area under a curve. Total area IV agrees extremely well with actual total area obtained from the graph (+ 0.1%). Because no statistically significant differences were found between areas from these two methods, the validity of Tai's model can thus be established.

This formula also permits accurate determination of total area under the curve when the curve intercepts with *Y*-axis, as well as when the curve passes the origin. Furthermore, in this formula, values on *X*-axis do not have to be the same as the *t* in Wolever et al.'s formula. It allows flexibility in experimental conditions, which means, in the case of glucose-response curve, samples can be taken with differing time intervals and the total area under the curve can still be determined with precision. Thus, if different authors estimate the total area under a curve from

Table 1—***Summary of results: (% area: % of total area V)***

Total area	I	II	III	IV	V
Test					
Glucose	N.A.*	480 (3.3%)	13517 (94.3%)	14400 (100.4%)	14337
TEF (SM)	N.A.*	336 (3.2%)	9588 (92.6%)	10326 (99.8%)	10349
TEF (LM)	N.A.*	452 (3.2%)	13367 (94.7%)	14163 (100.3)	14115



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Integral

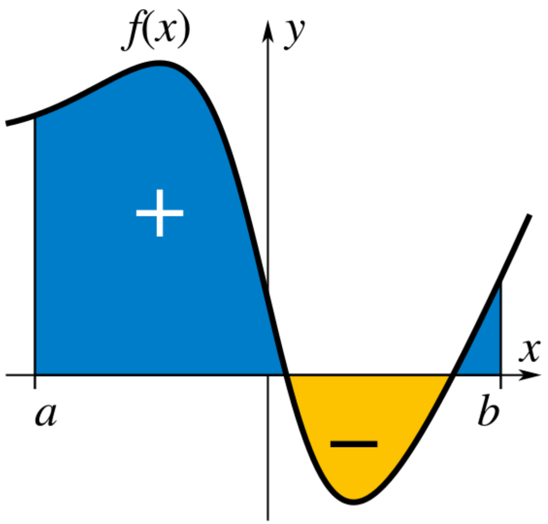
This article is about the concept of definite integrals in calculus. For the indefinite integral, see antiderivative. For the set of numbers, see integer. For other uses, see Integral (disambiguation).

"Area under the curve" redirects here. For the pharmacology integral, see Area under the curve (pharmacokinetics).

In mathematics, an **integral** assigns numbers to functions in a way that can describe displacement, area, volume, and other concepts that arise by combining infinitesimal data. Integration is one of the two main operations of calculus, with its inverse operation, differentiation, being the other. Given a function f of a real variable x and an interval $[a, b]$ of the real line, the **definite integral**

$$\int_a^b f(x)\,dx$$

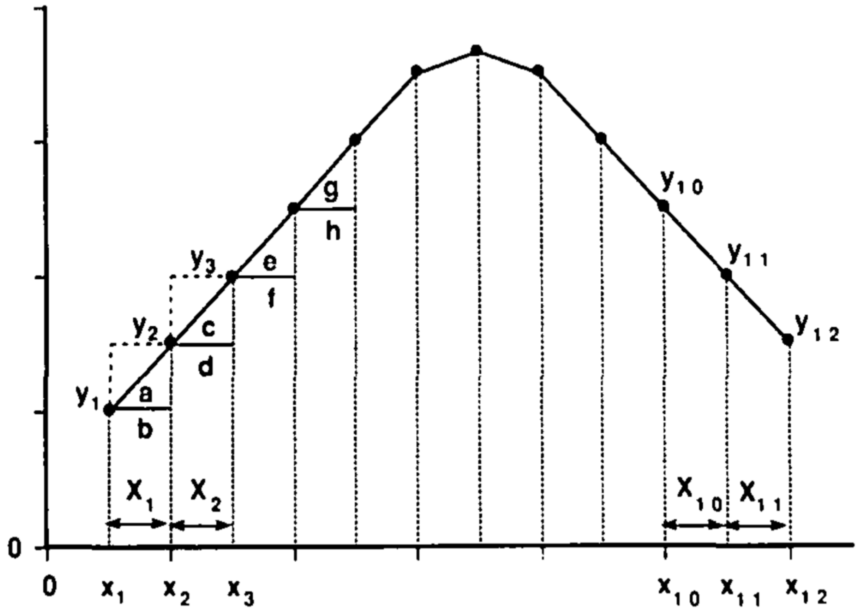
is defined informally as the signed area of the region in the xy-plane that is bounded by the graph of f, the x-axis and the vertical lines $x = a$ and $x = b$. The area above the x-axis adds to the total and that below the x-axis subtracts from the total.



A definite integral of a function can be represented as the signed area of the region bounded by its graph.

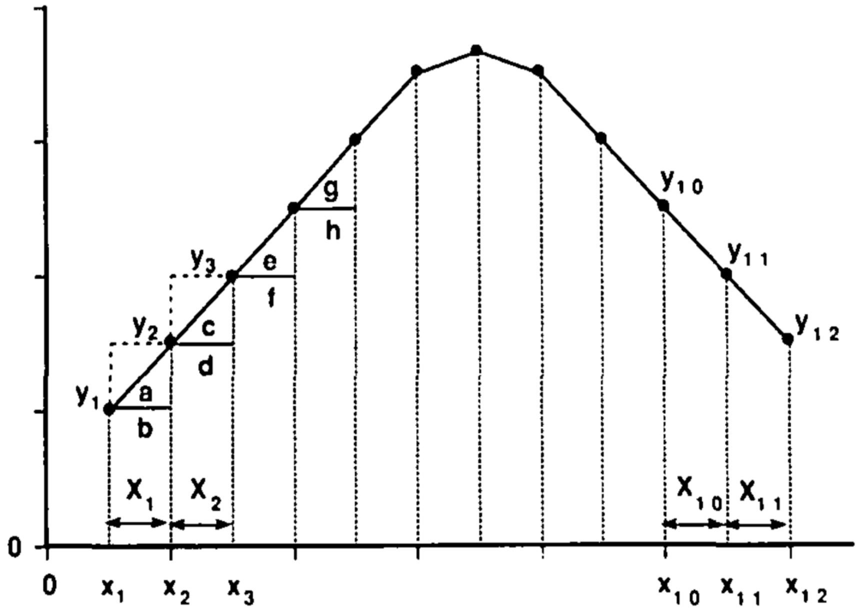
The operation of integration, up to an additive constant, is the inverse of the operation of differentiation. For this reason, the term *integral* may also refer to the related notion of the antiderivative, a function F whose derivative is the given function f. In this case, it is called an indefinite integral and is written:

$$F(x) = \int f(x)\,dx.$$



Tai’s model
1994
endocrinology

Left: Mary M Tai, A Mathematical Model for the Determination of Total Area Under Glucose Tolerance and Other Metabolic Curves, Diabetes Care Feb 1994, 17 (2) 152-154



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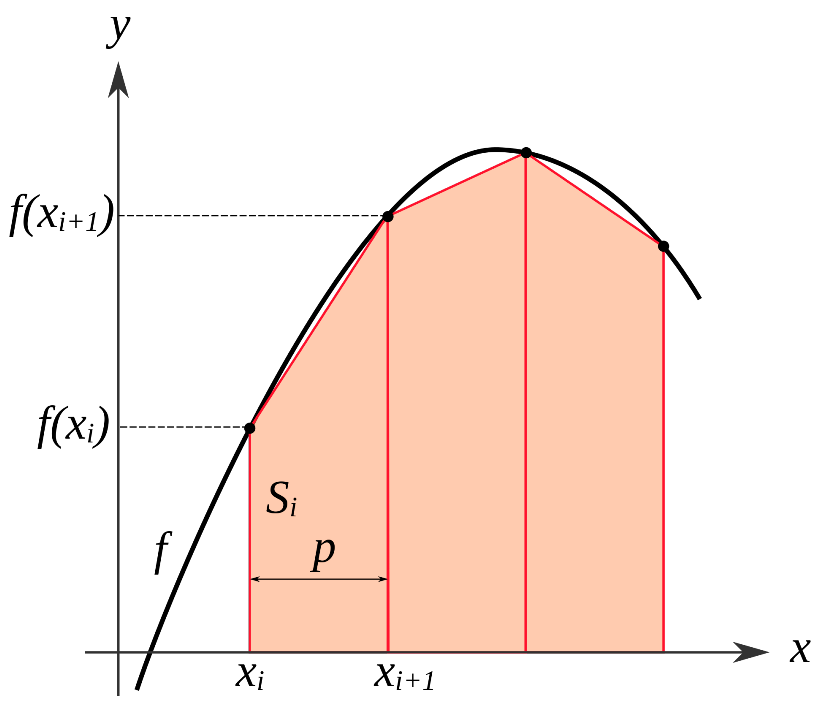

Trapezoidal rule

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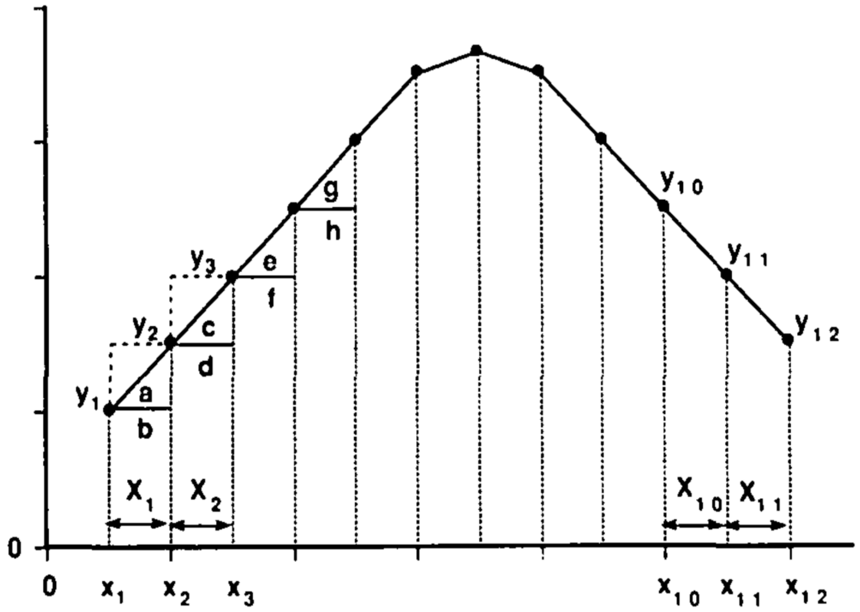
Right: Explanatory diagram of numerical integration with the trapezoidal rule, Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Int%C3%A9gration_num_trap%C3%A8zes.svg



Tai’s model
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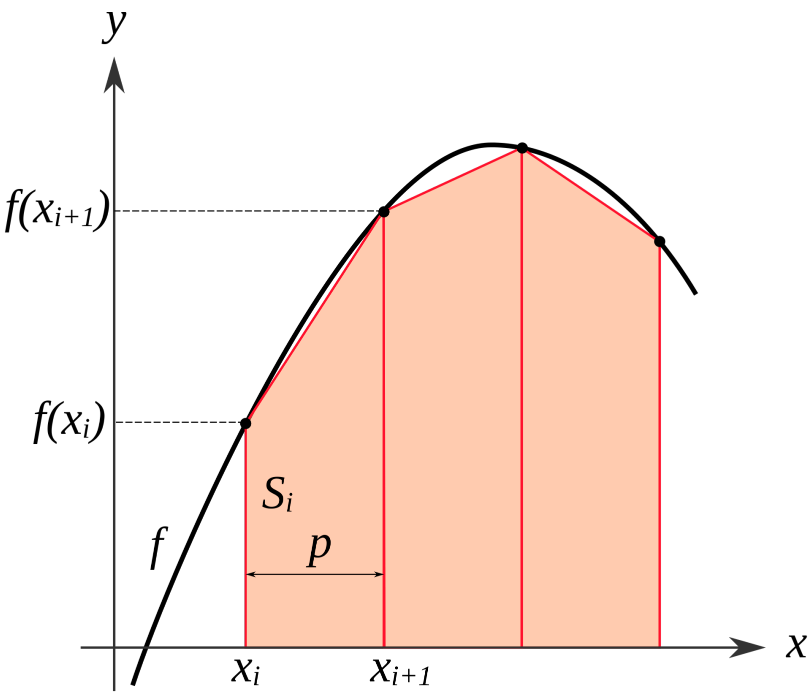
endocrinology



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50 BC
astronomy

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MM Tai - Diabetes care, 1994 - Am Diabetes Assoc

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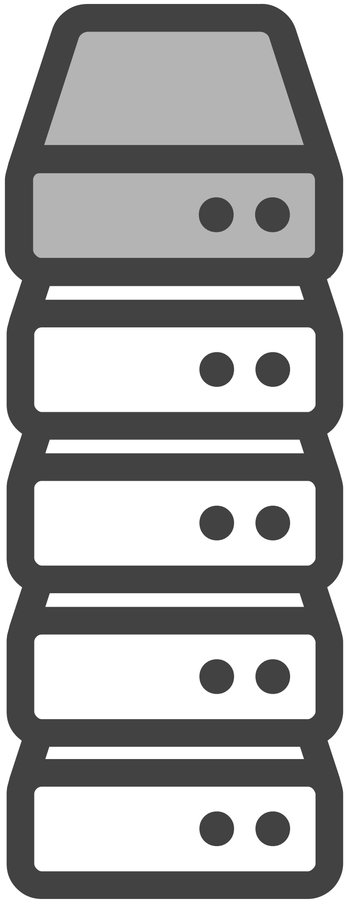
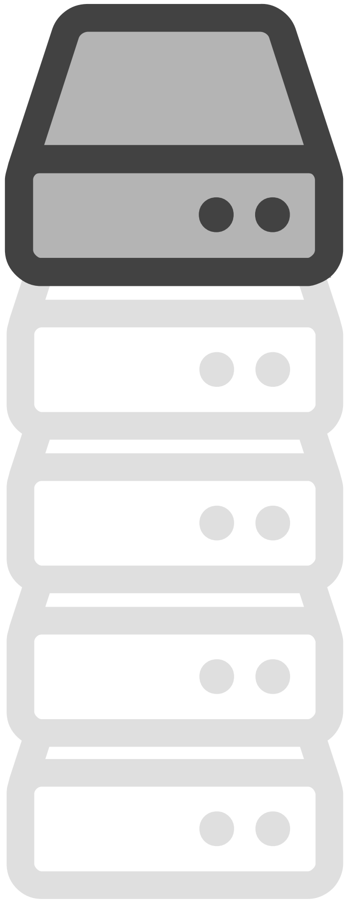
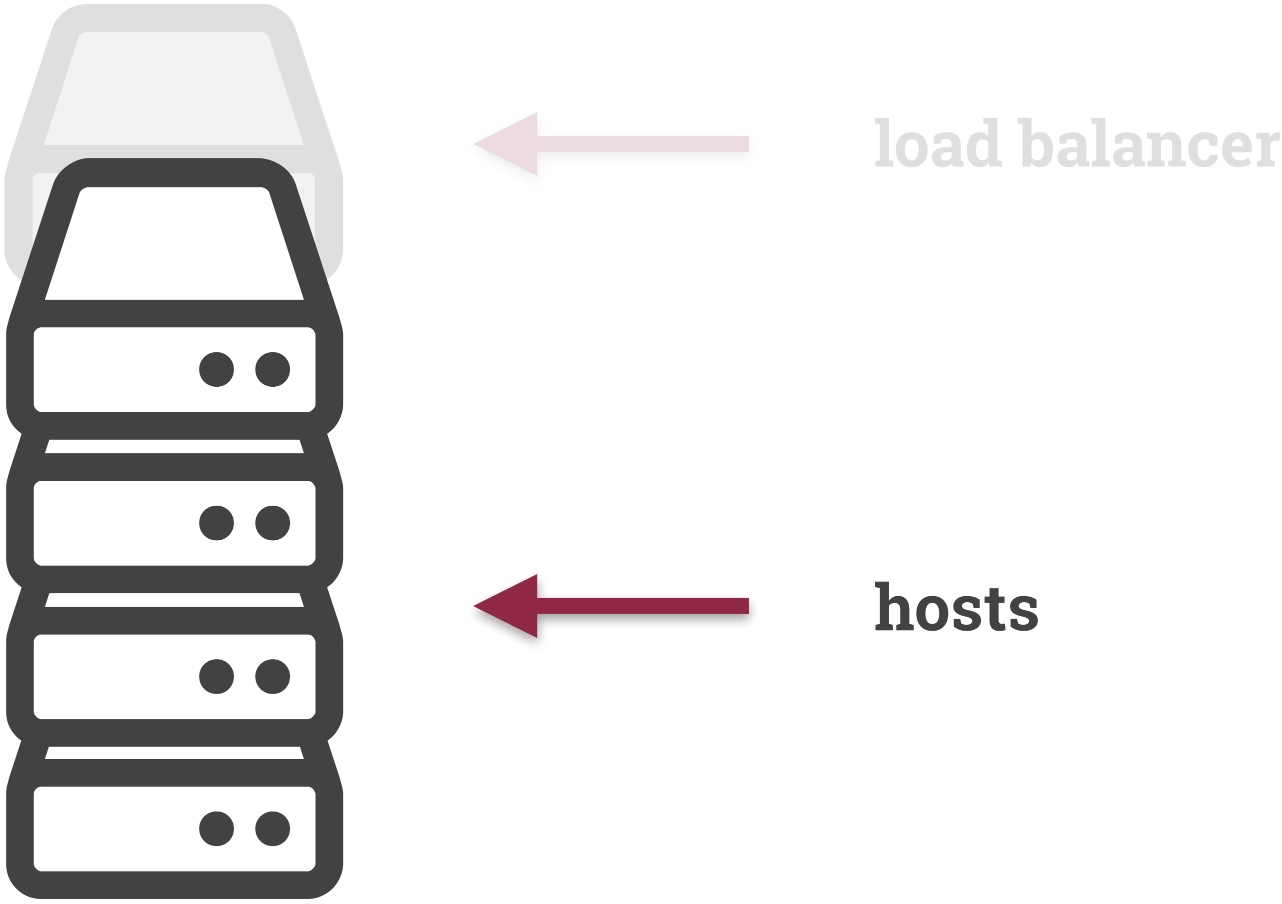




load balancer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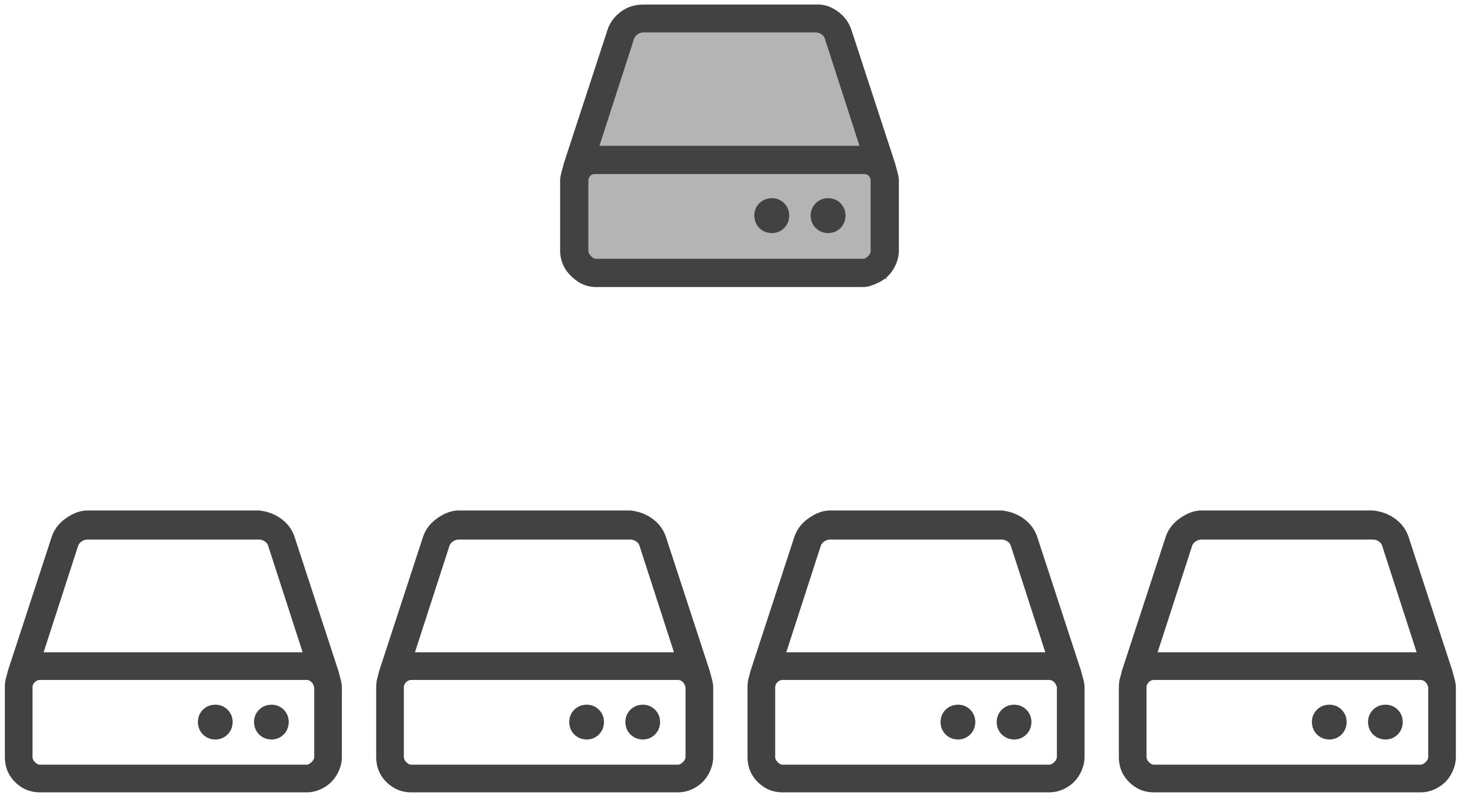
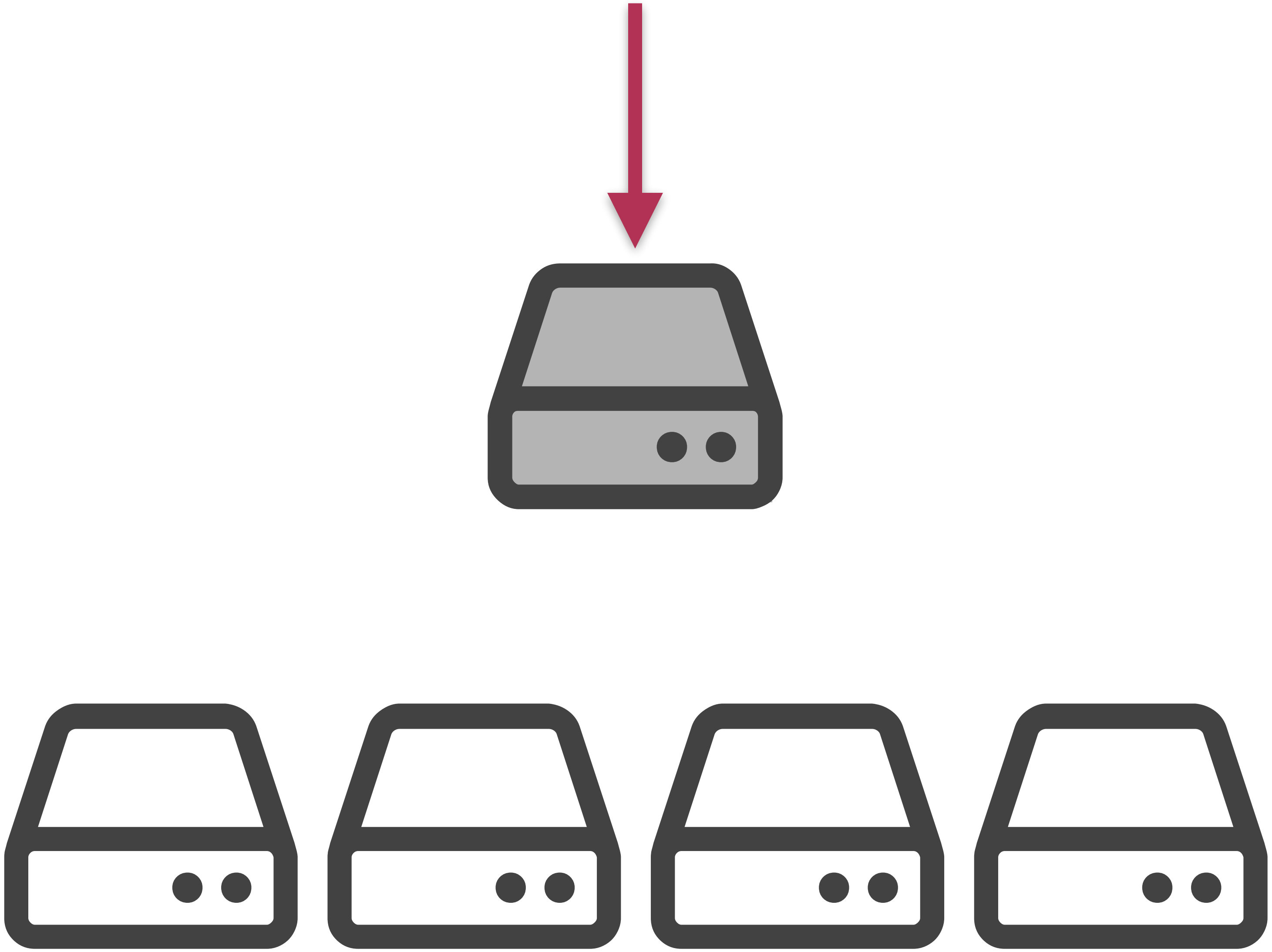
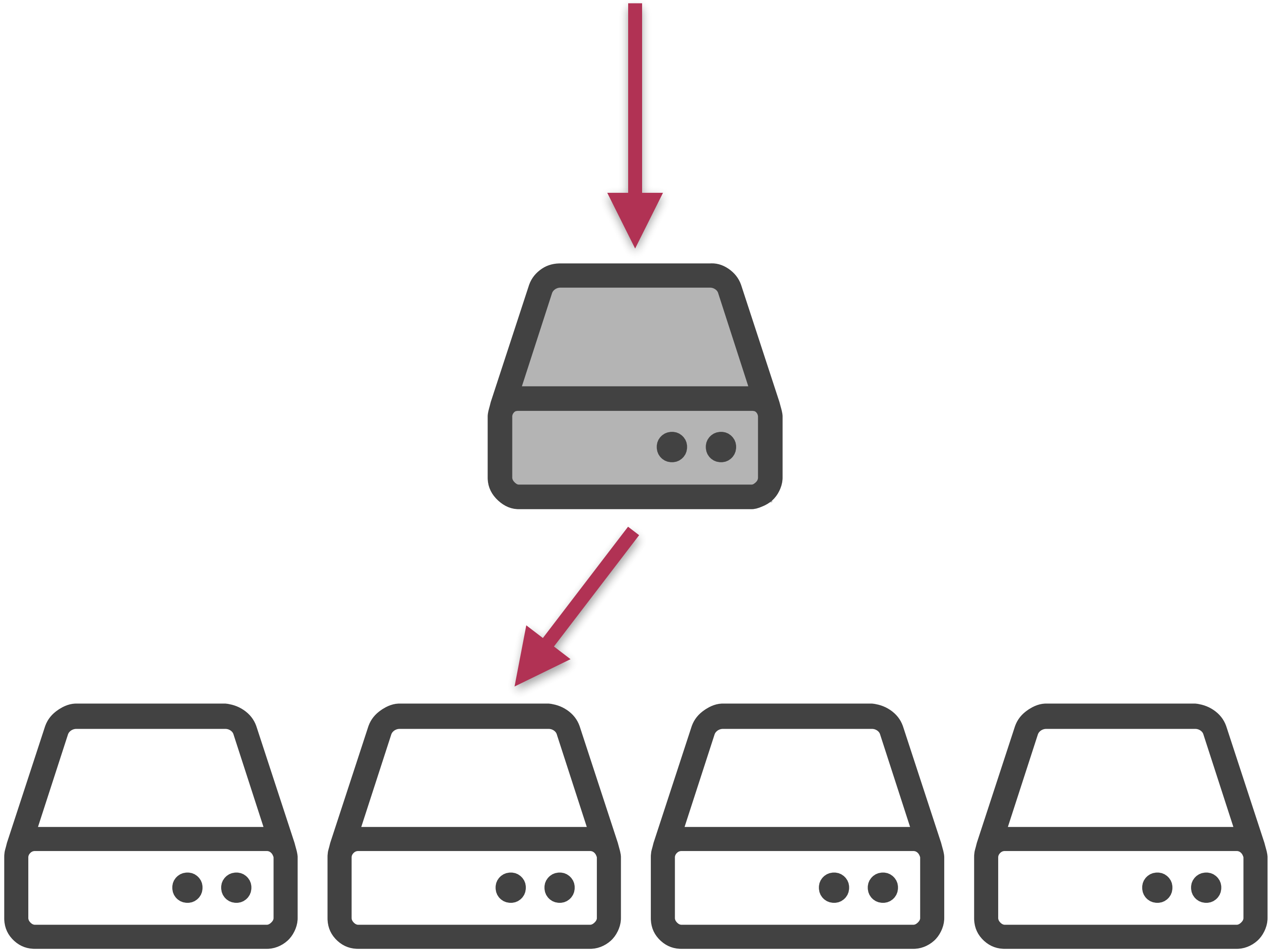
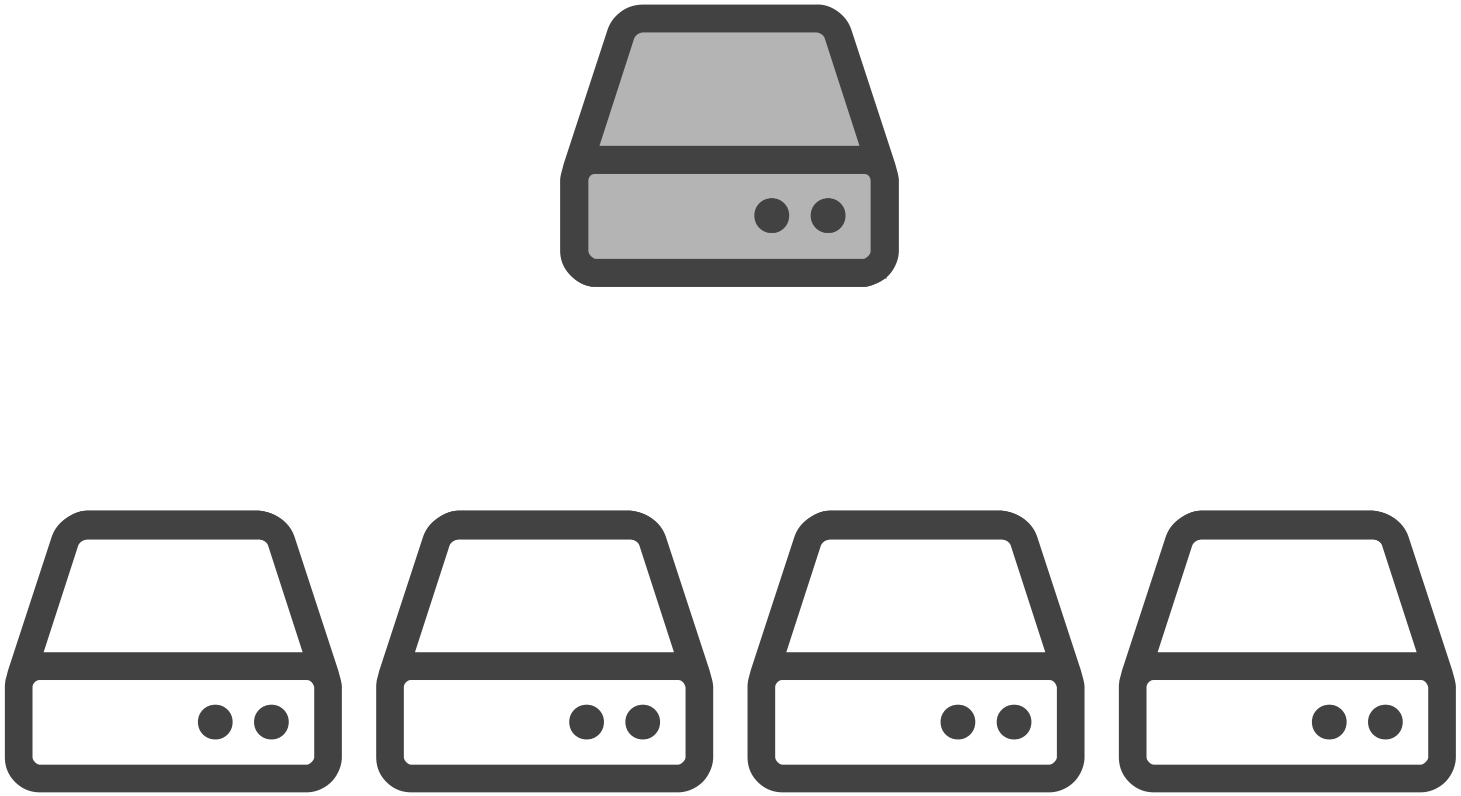
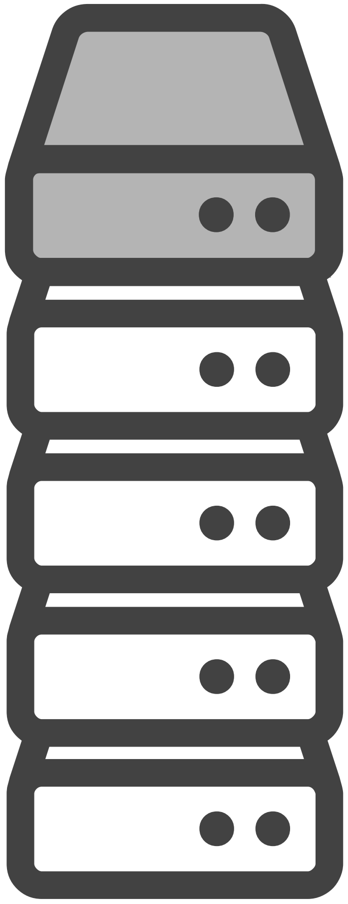
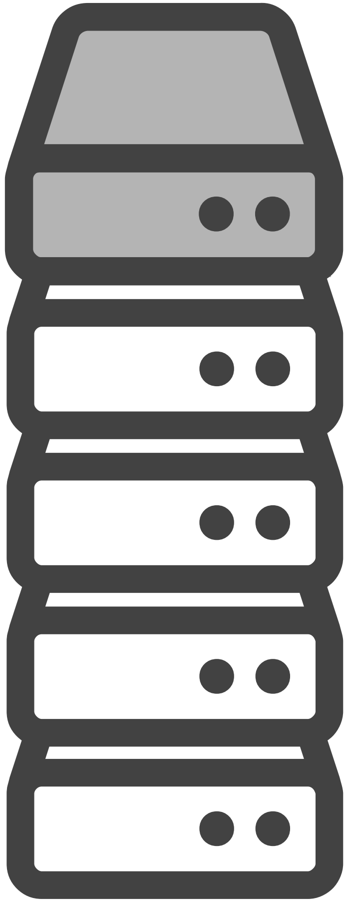






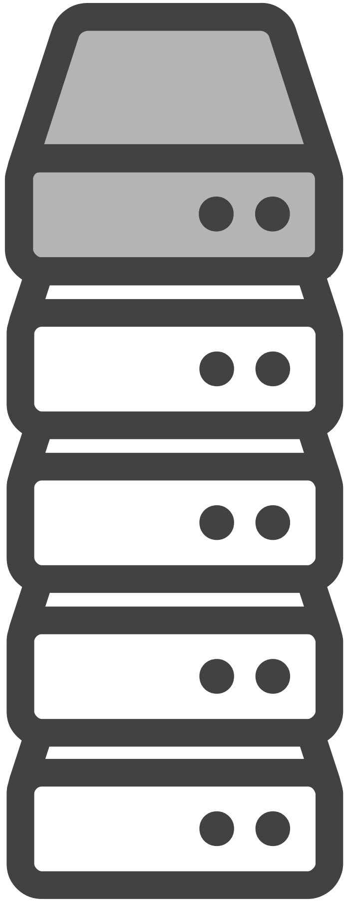






Space and power are at a premium

Careful considerations in design and HW selection



Space and power are at a premium

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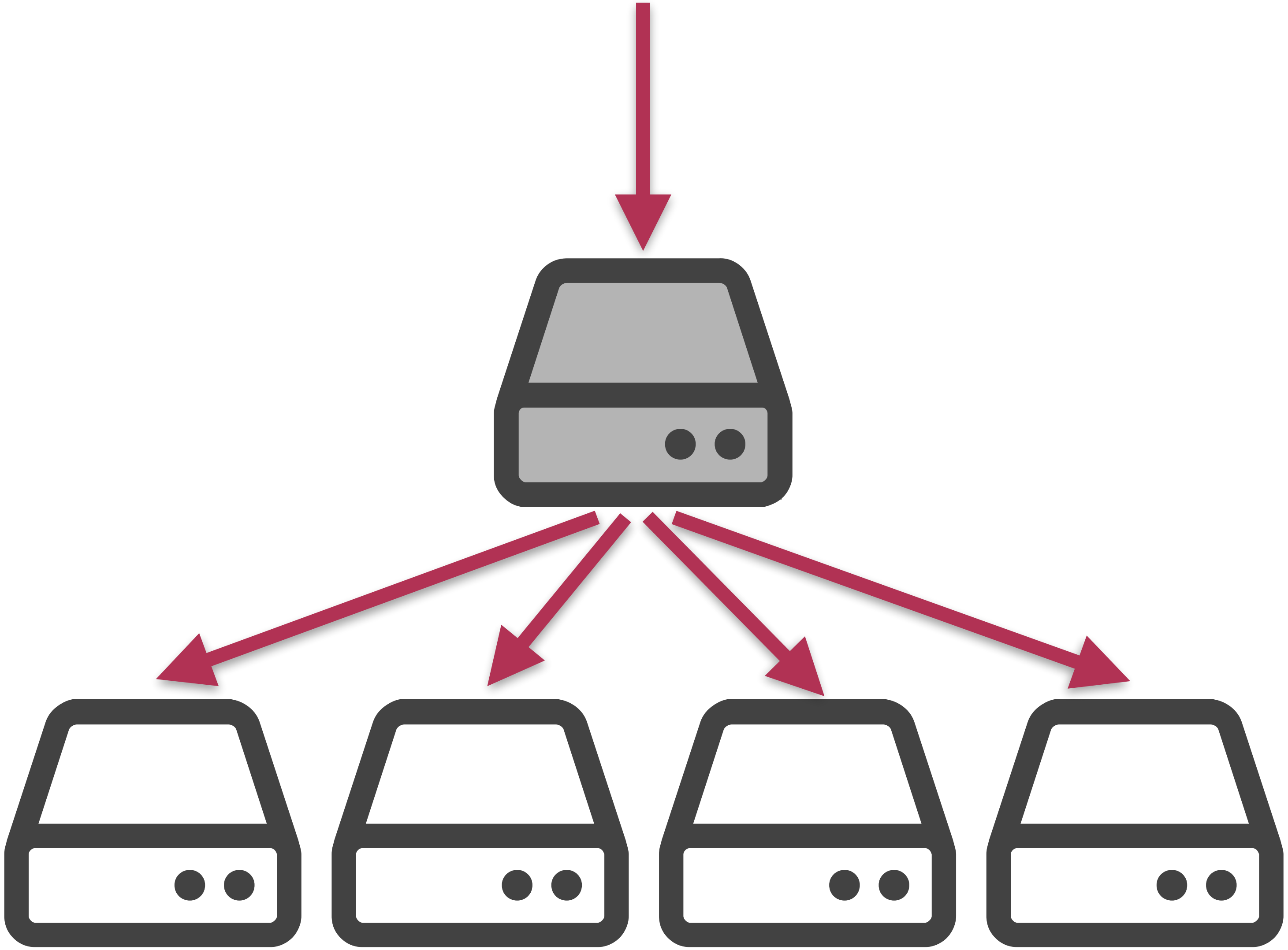
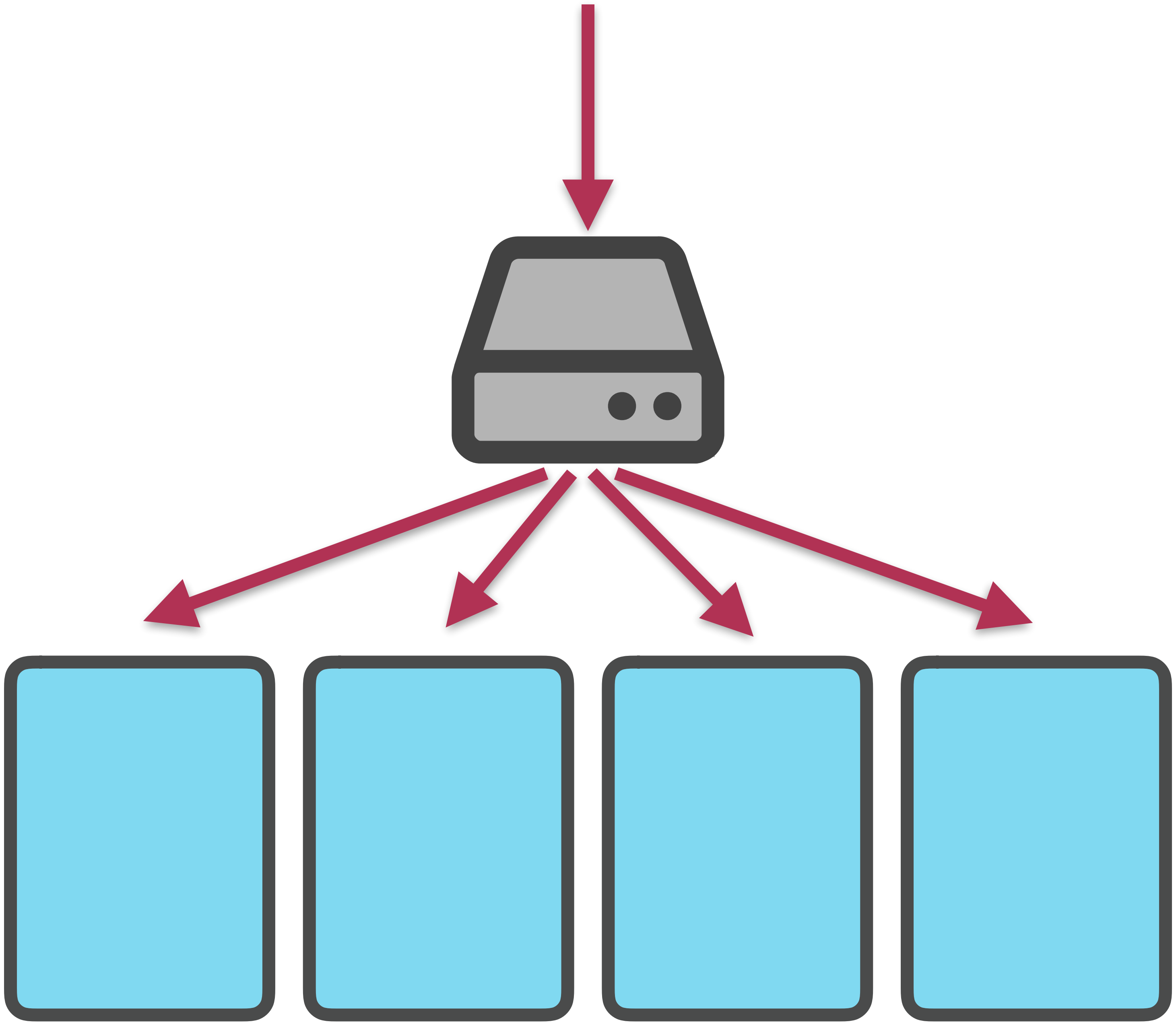
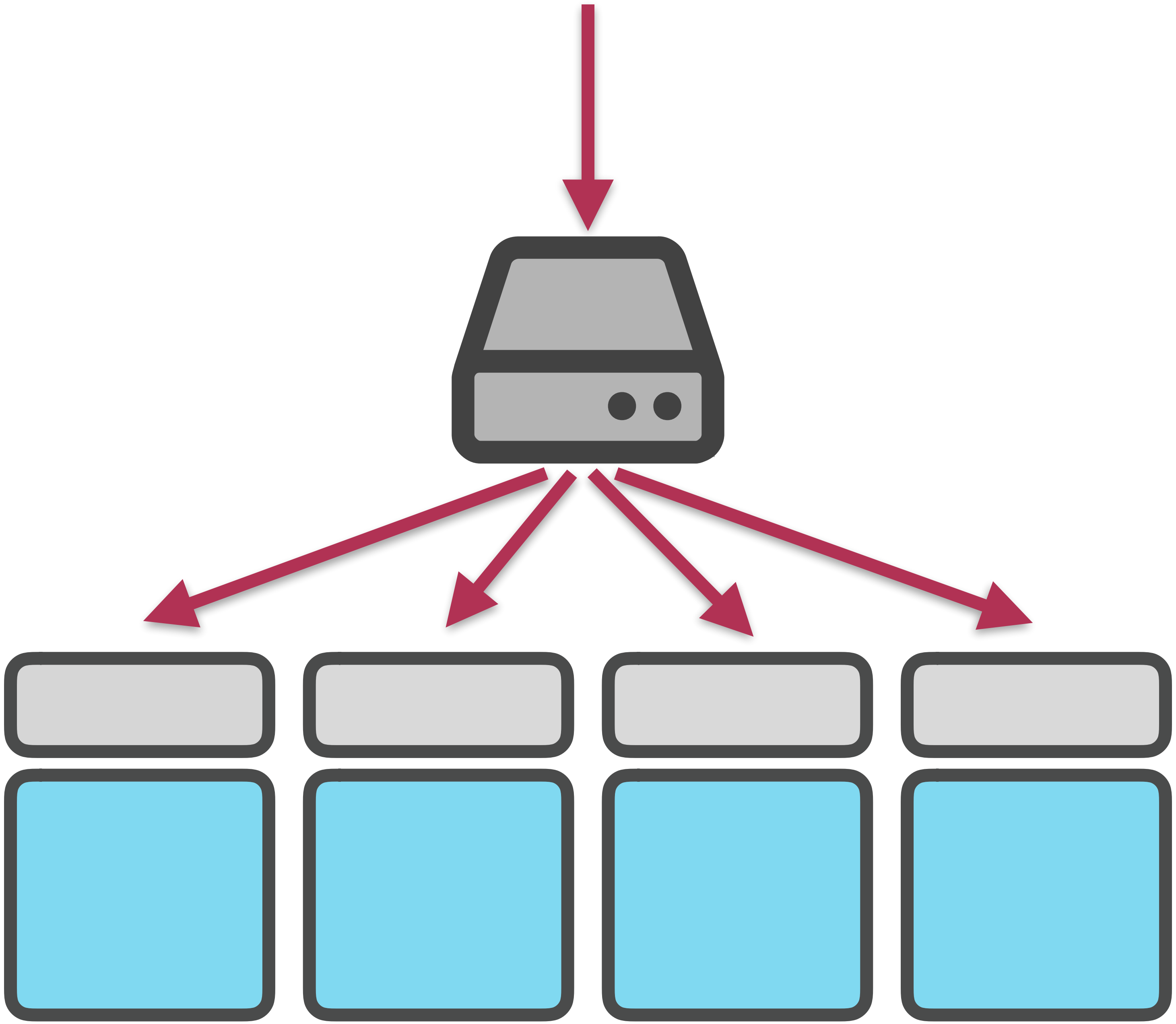
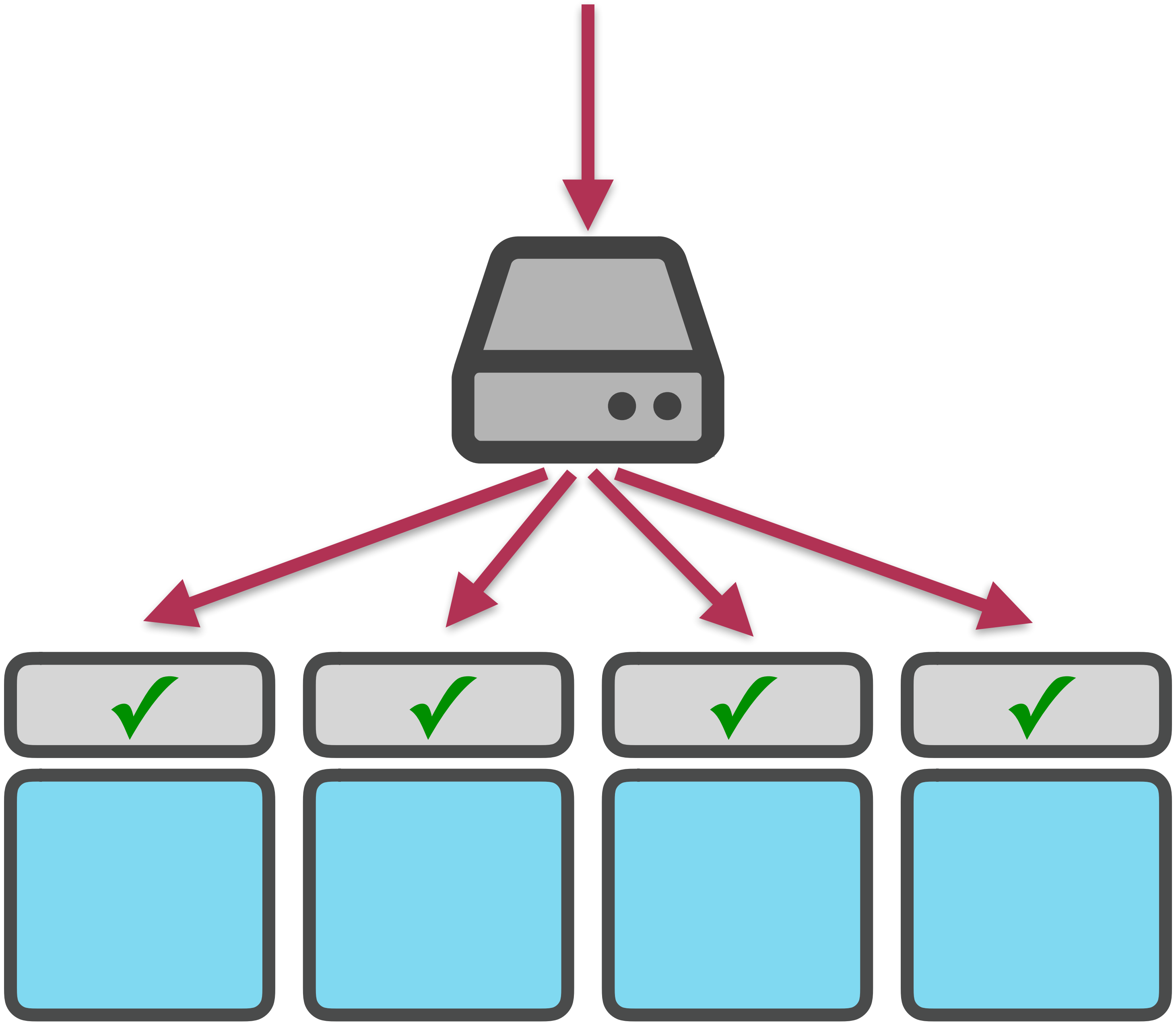
Limited scalability

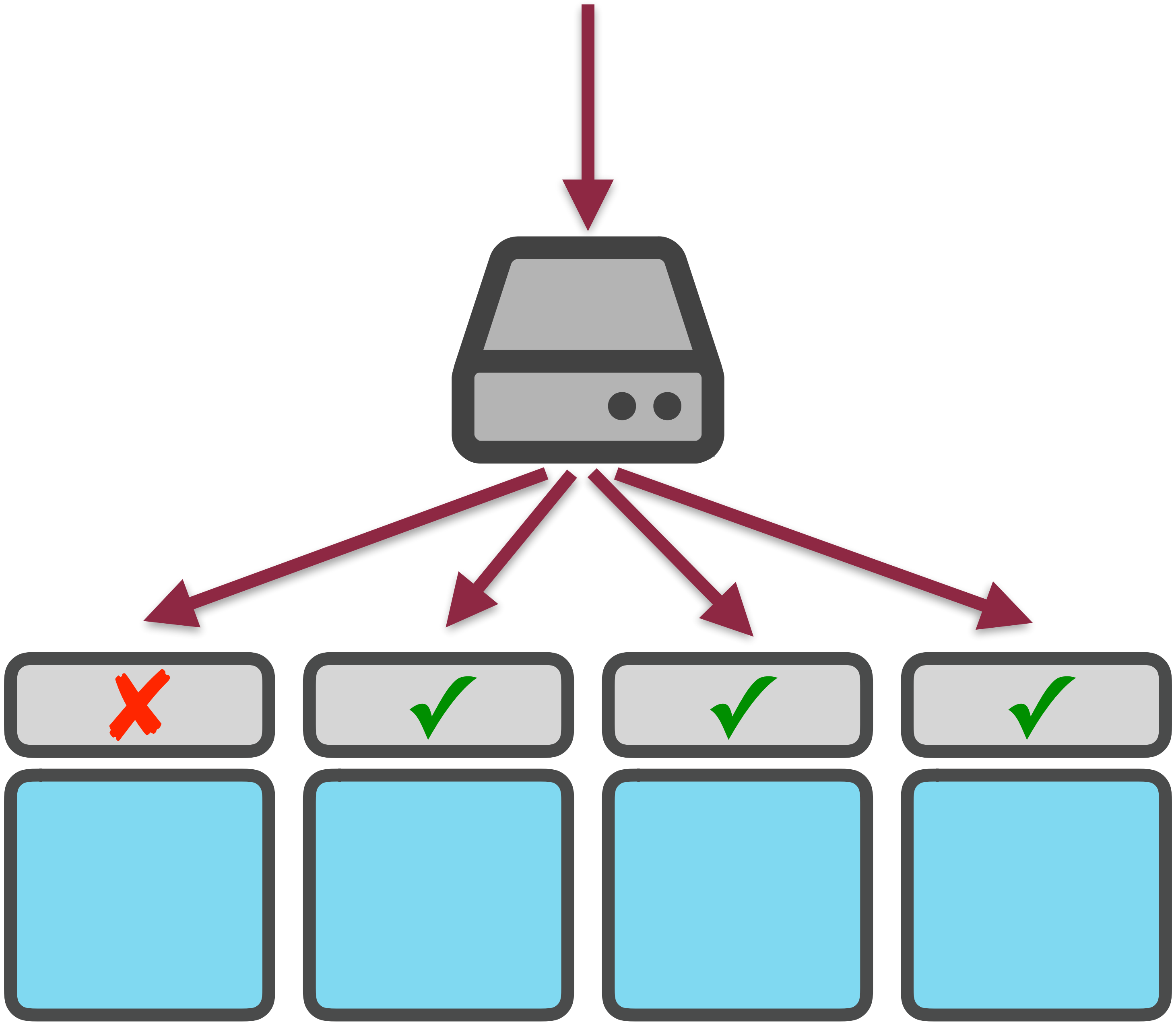
Scaling capacity requires racking new servers

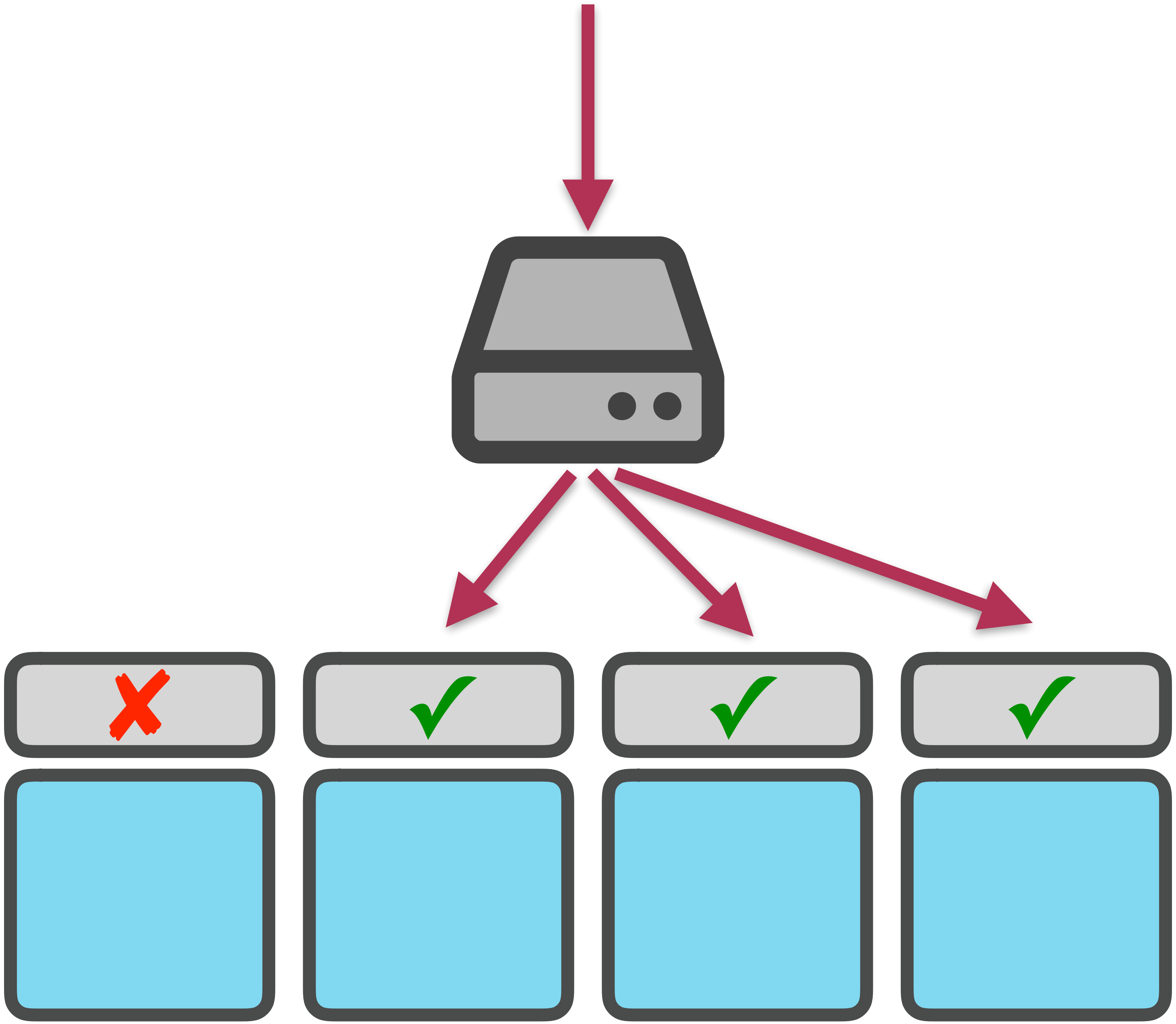


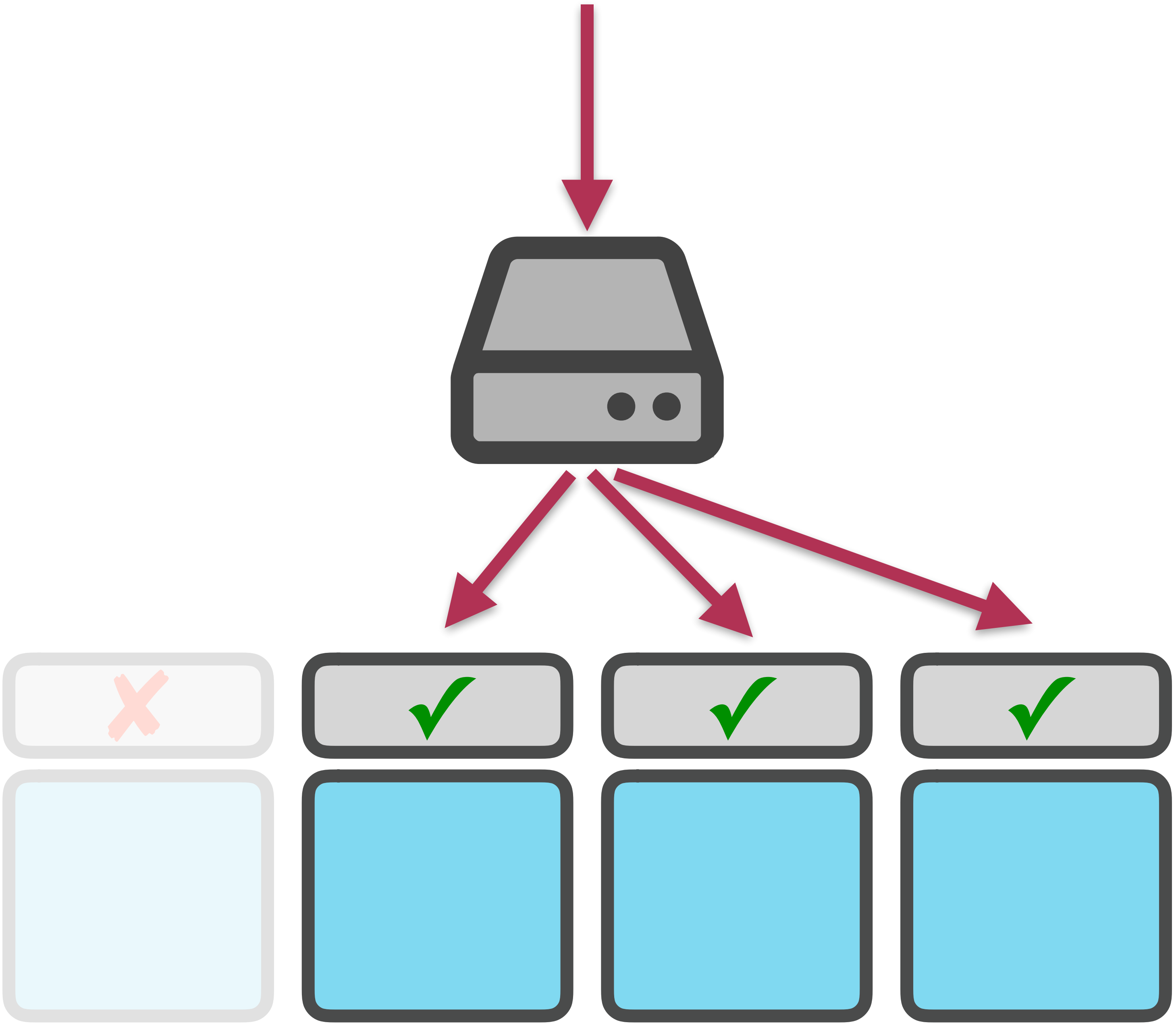


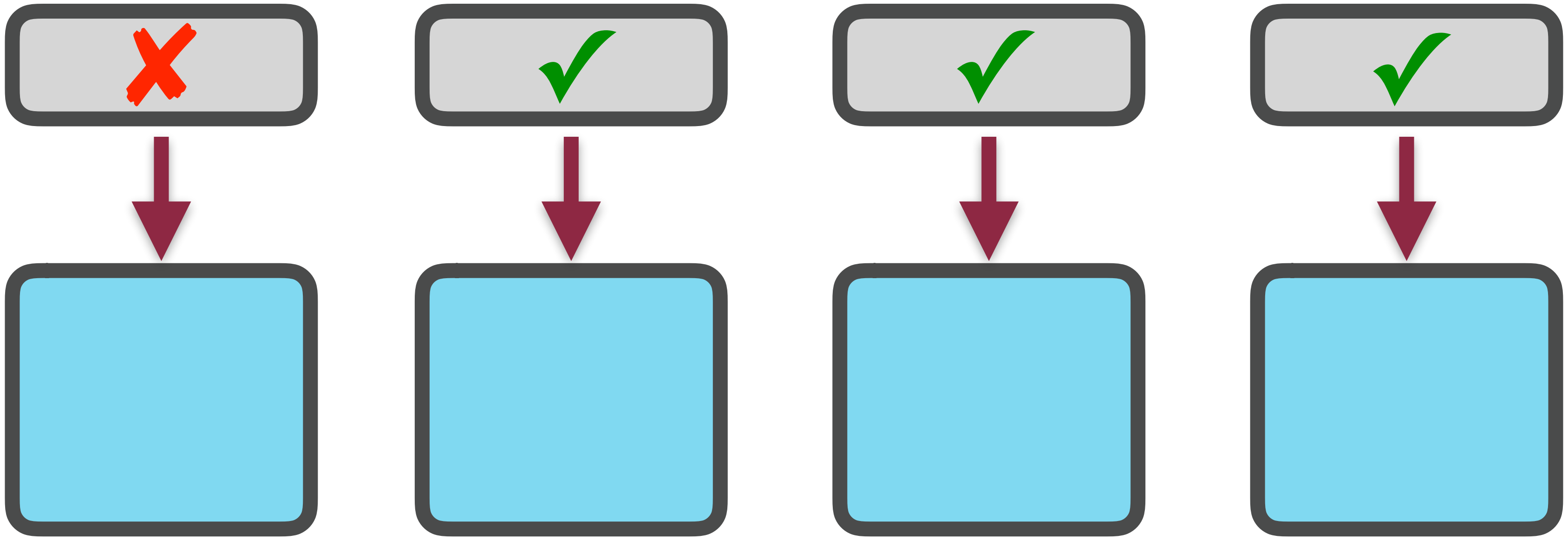


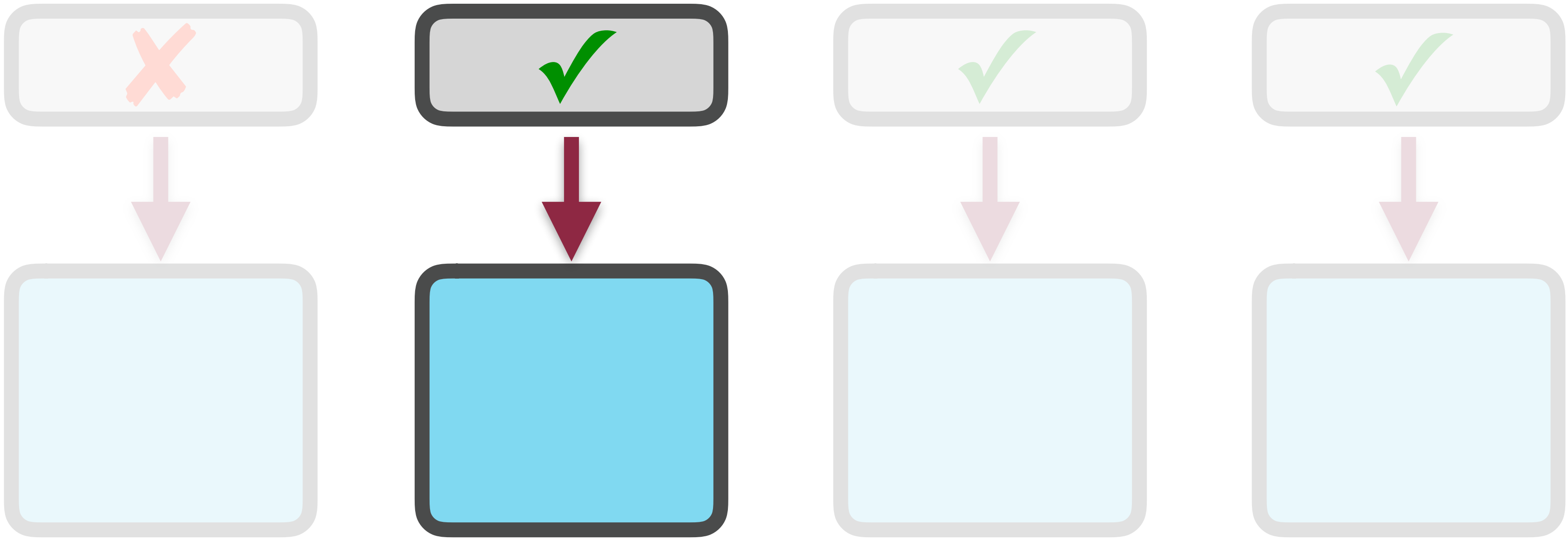


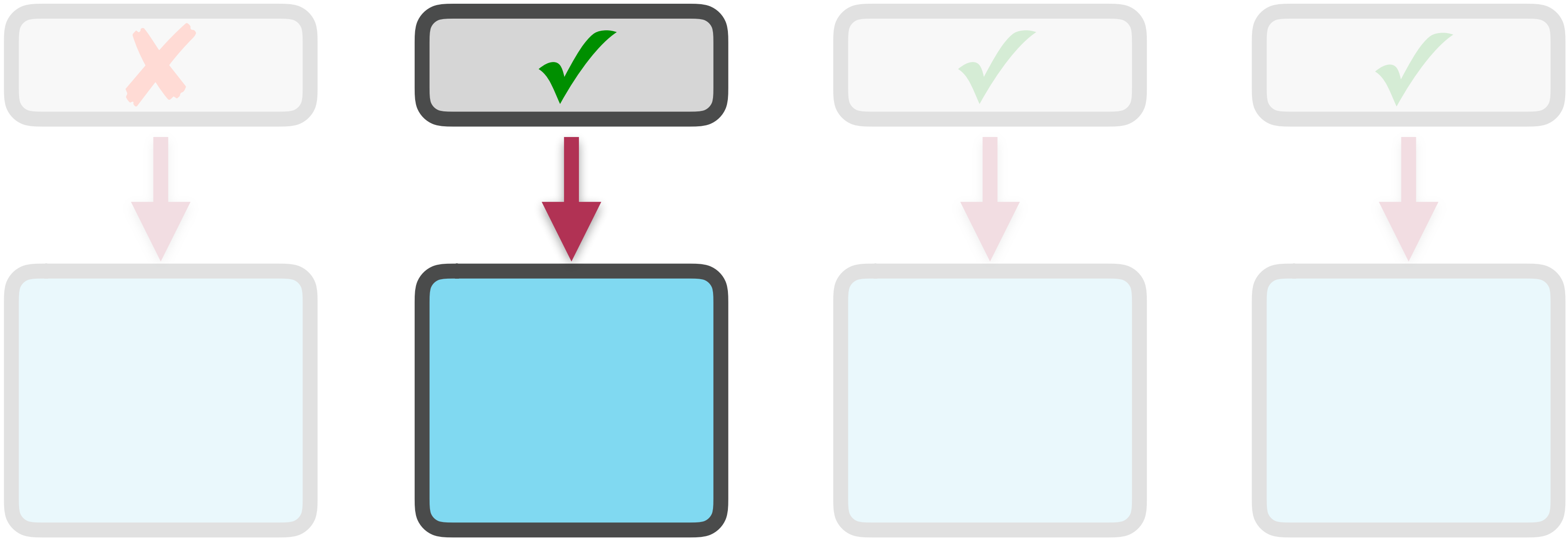


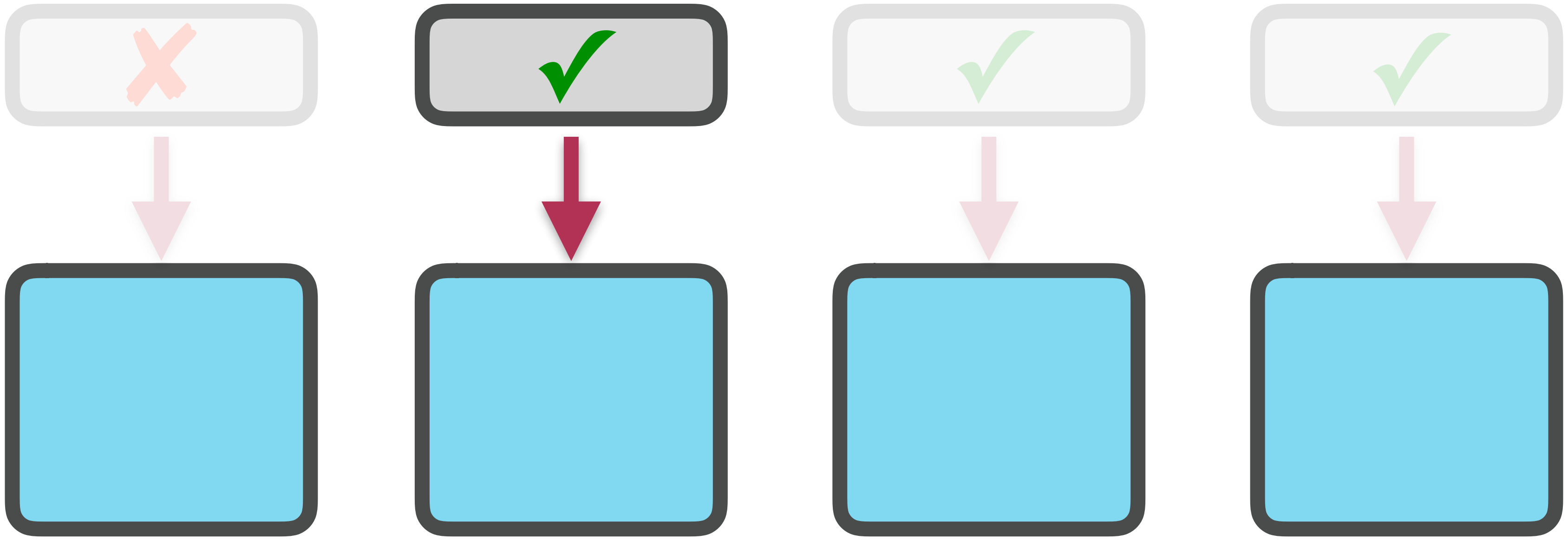


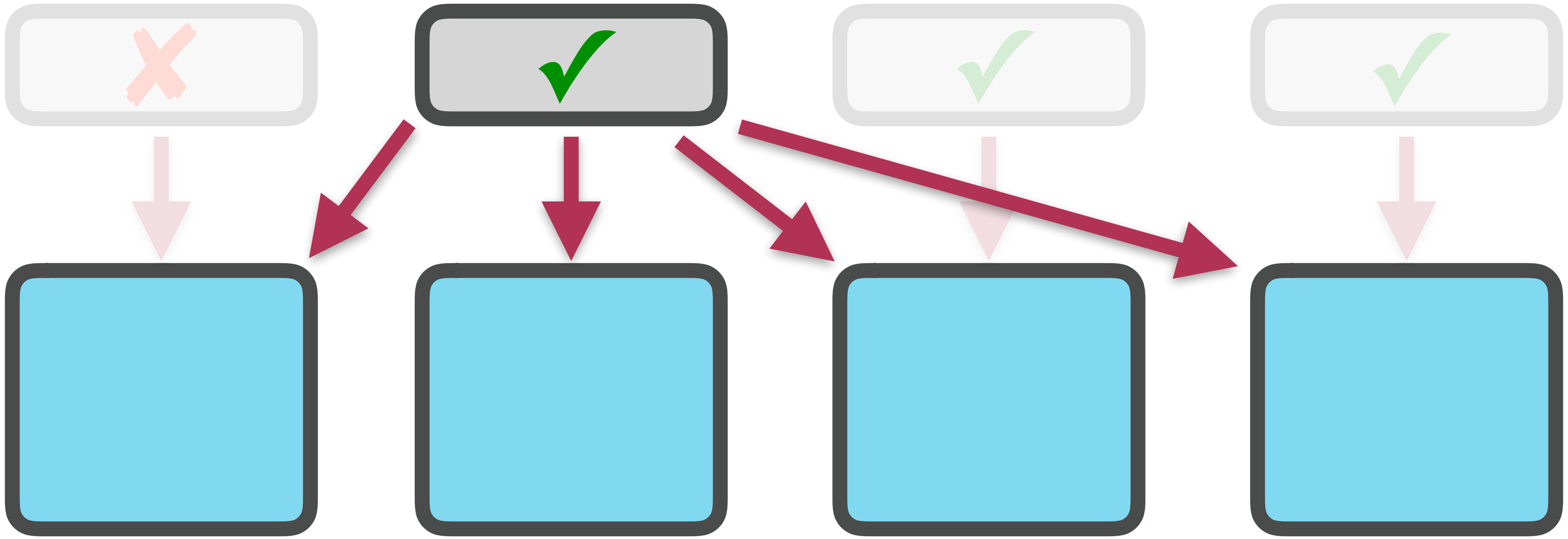


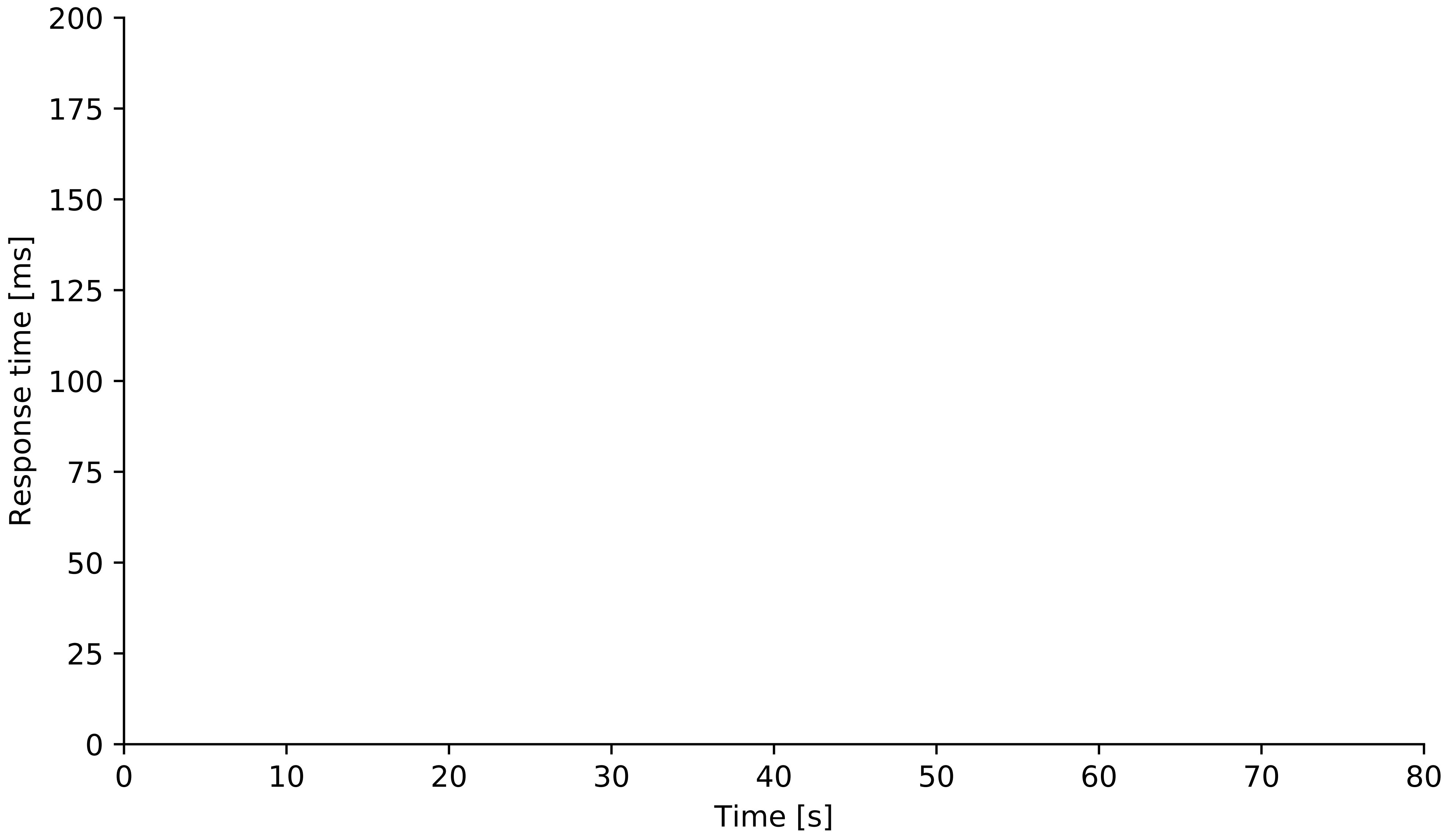












Response time [ms]
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175
150
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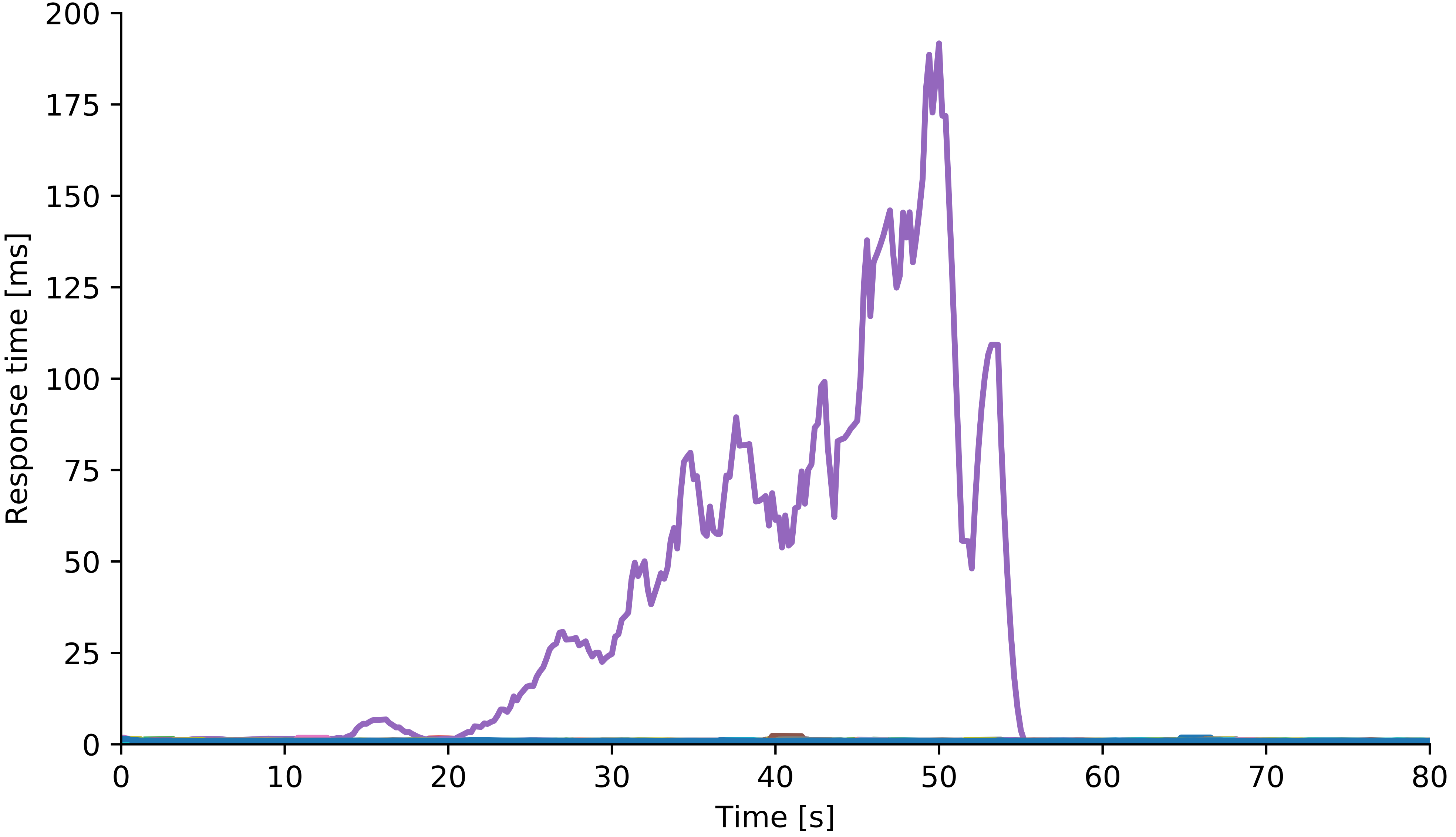
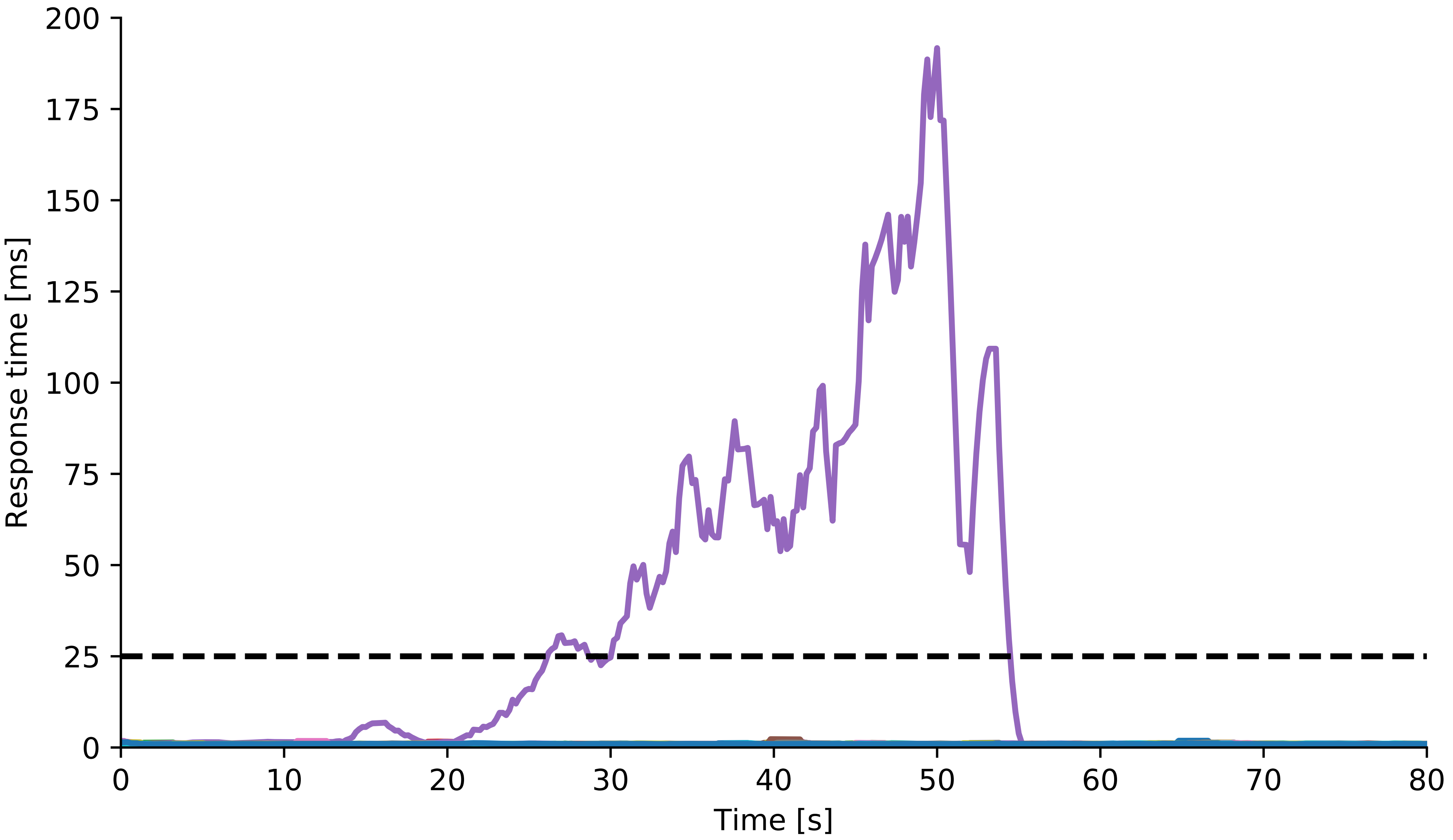
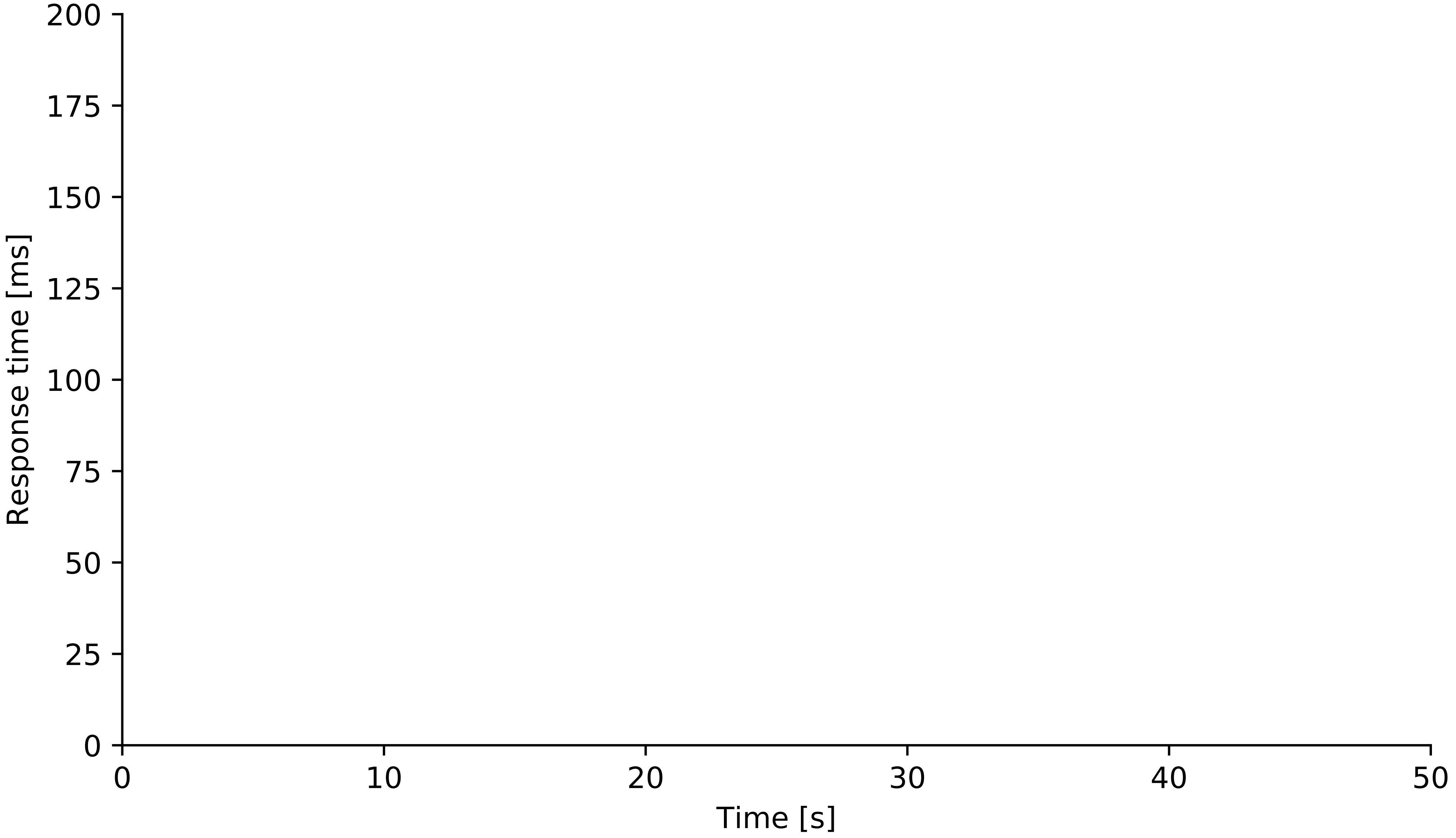
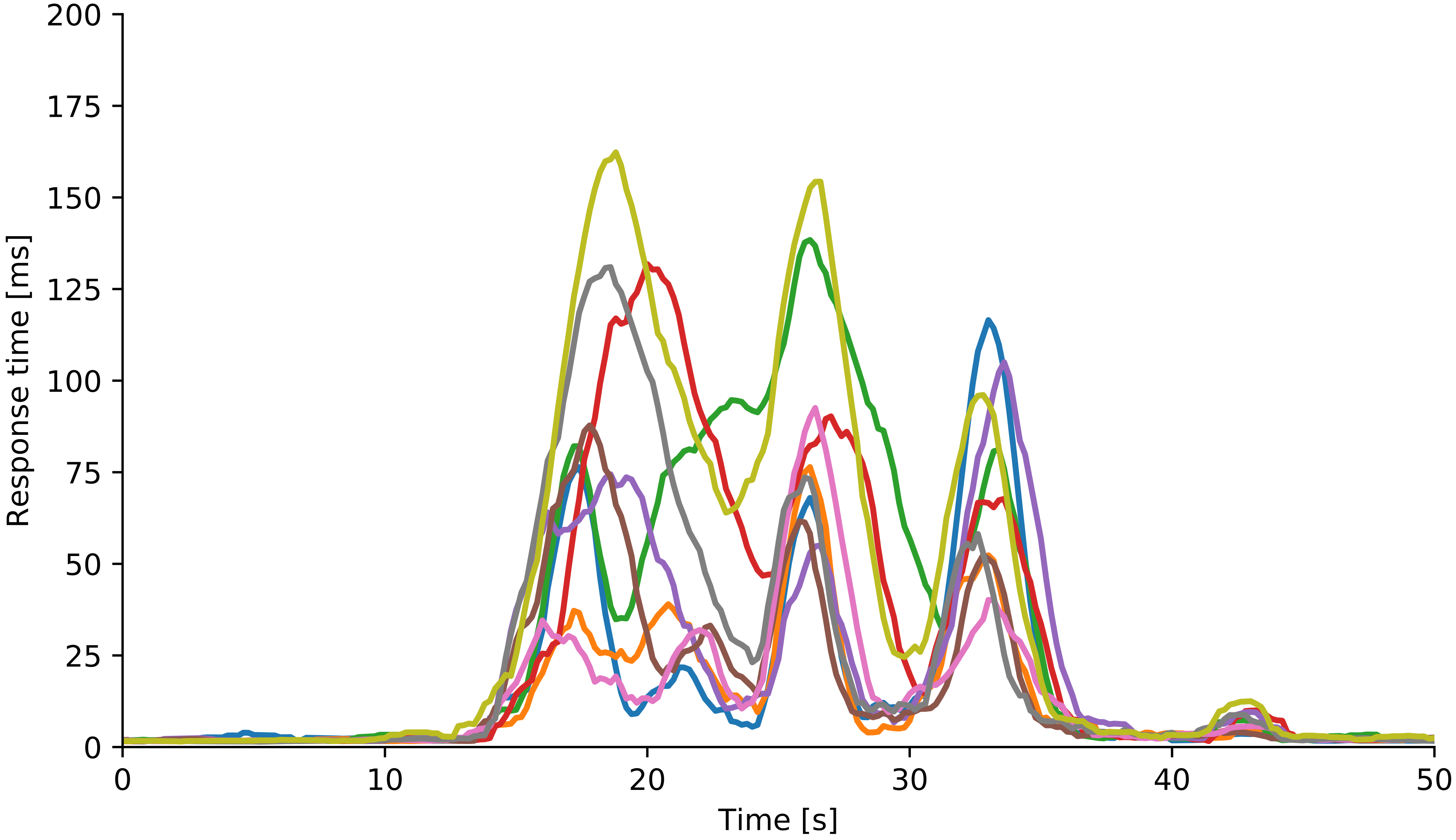
60
70
80
Time [s]

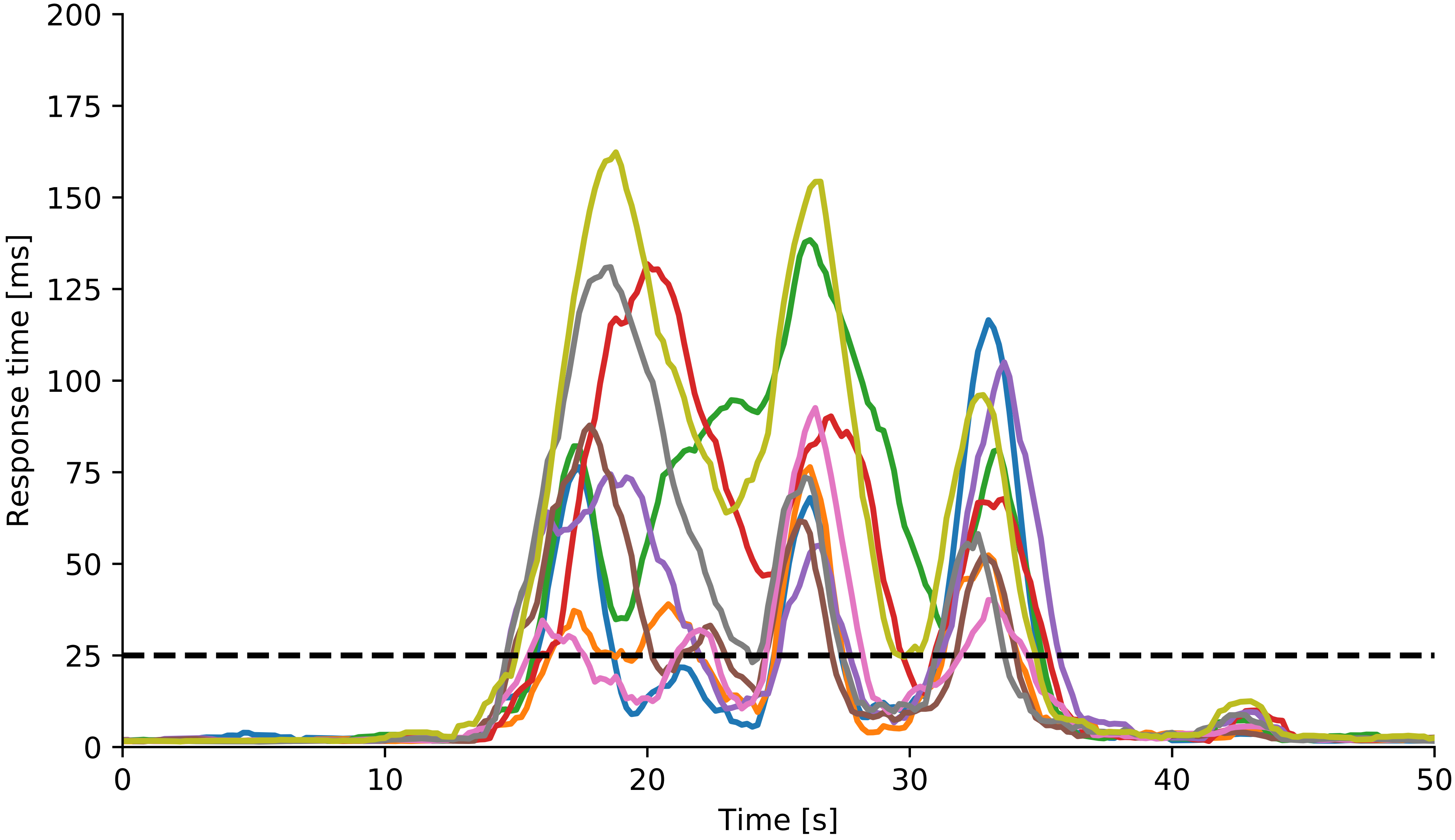


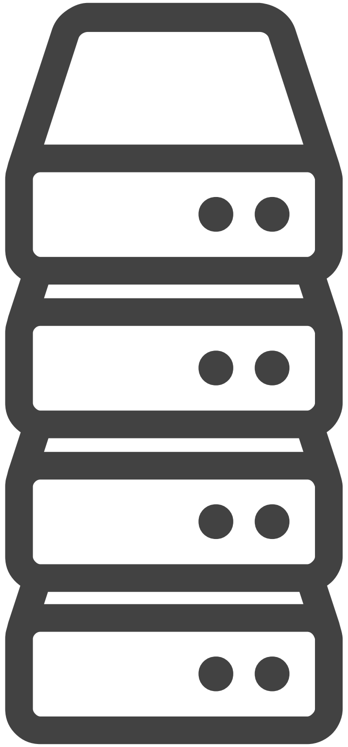
Response time [ms]
200
175
150
125
100
75
50
25
0
0
10
20
30
40
50
60
70
80
Time [s]

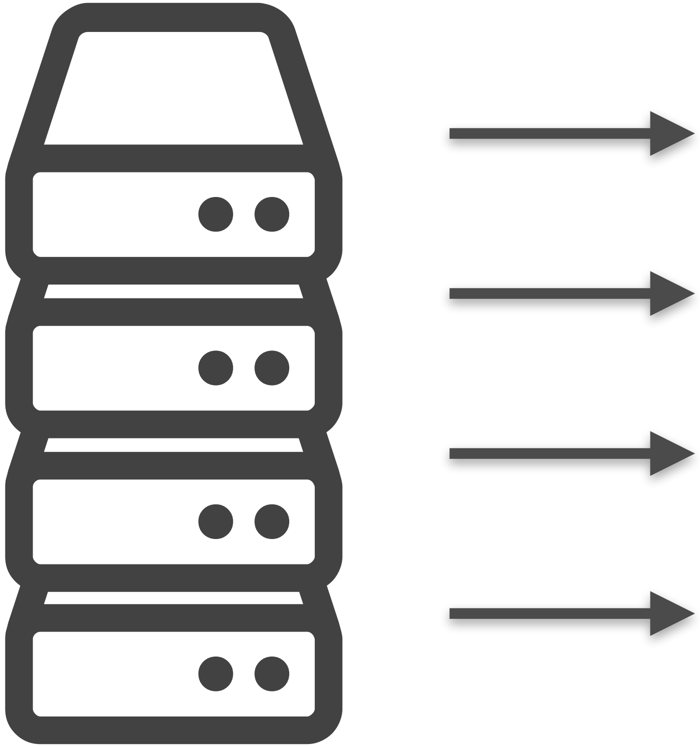

Response time [ms]
200
175
150
125
100
75
50
25
0
0
10
20
30
40
50
60
70
80
Time [s]


200
175
150
125
100
75
50
25
0
Response time [ms]
0
10
20
30
40
50
Time [s]


Response time [ms]
200
175
150
125
100
75
50
25
0
0
10
20
30
40
50
Time [s]

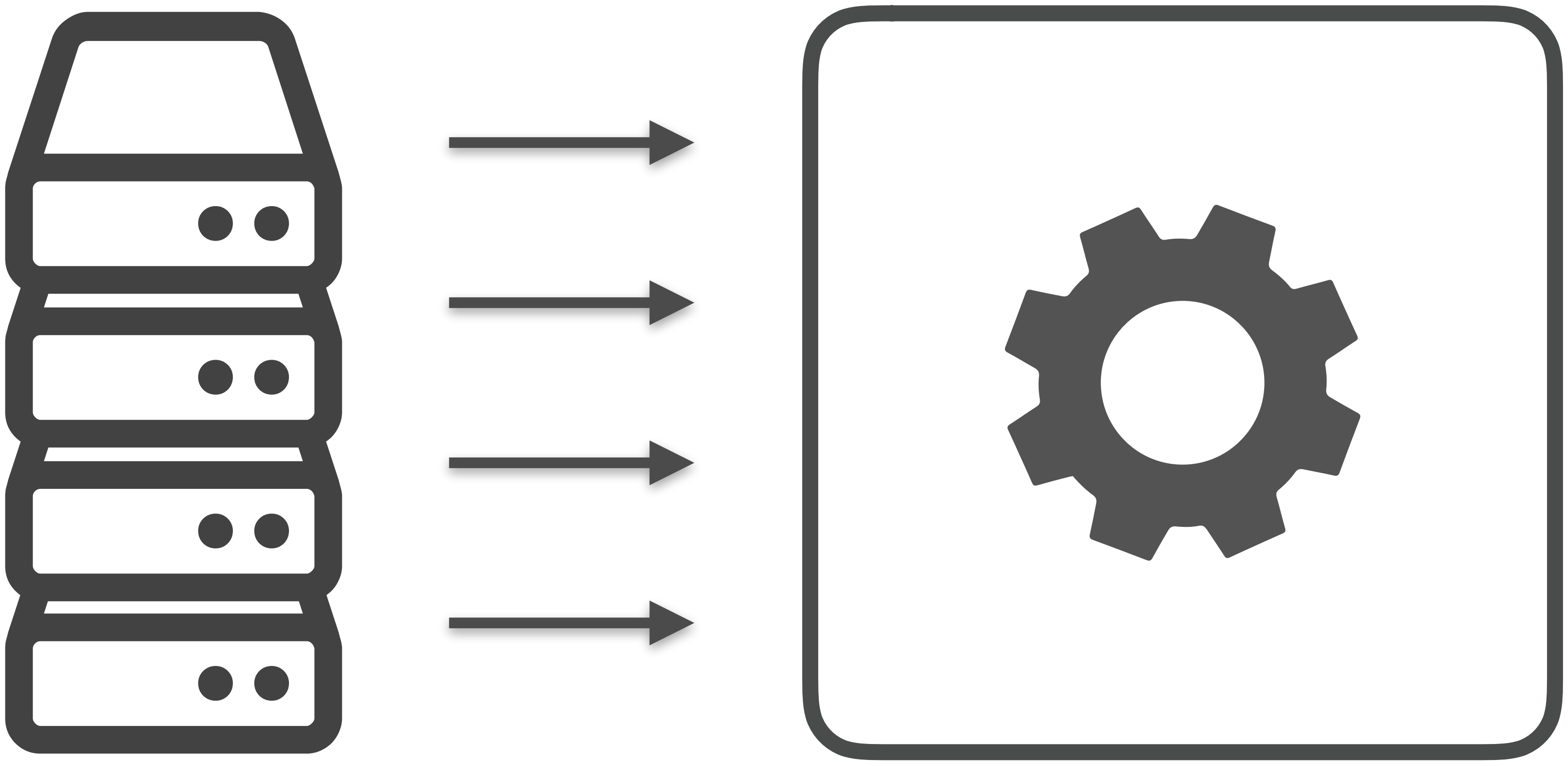

200
175
150
125
100
75
50
25
0
Response time [ms]
0
10
20
30
40
50
Time [s]

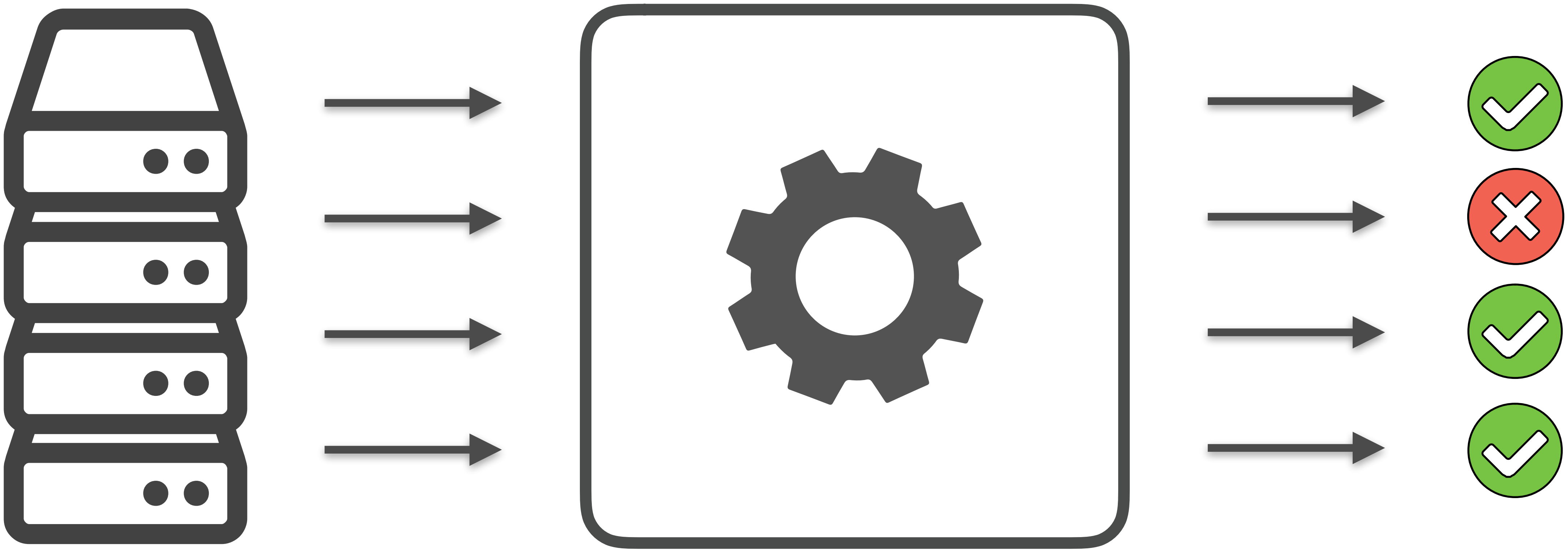


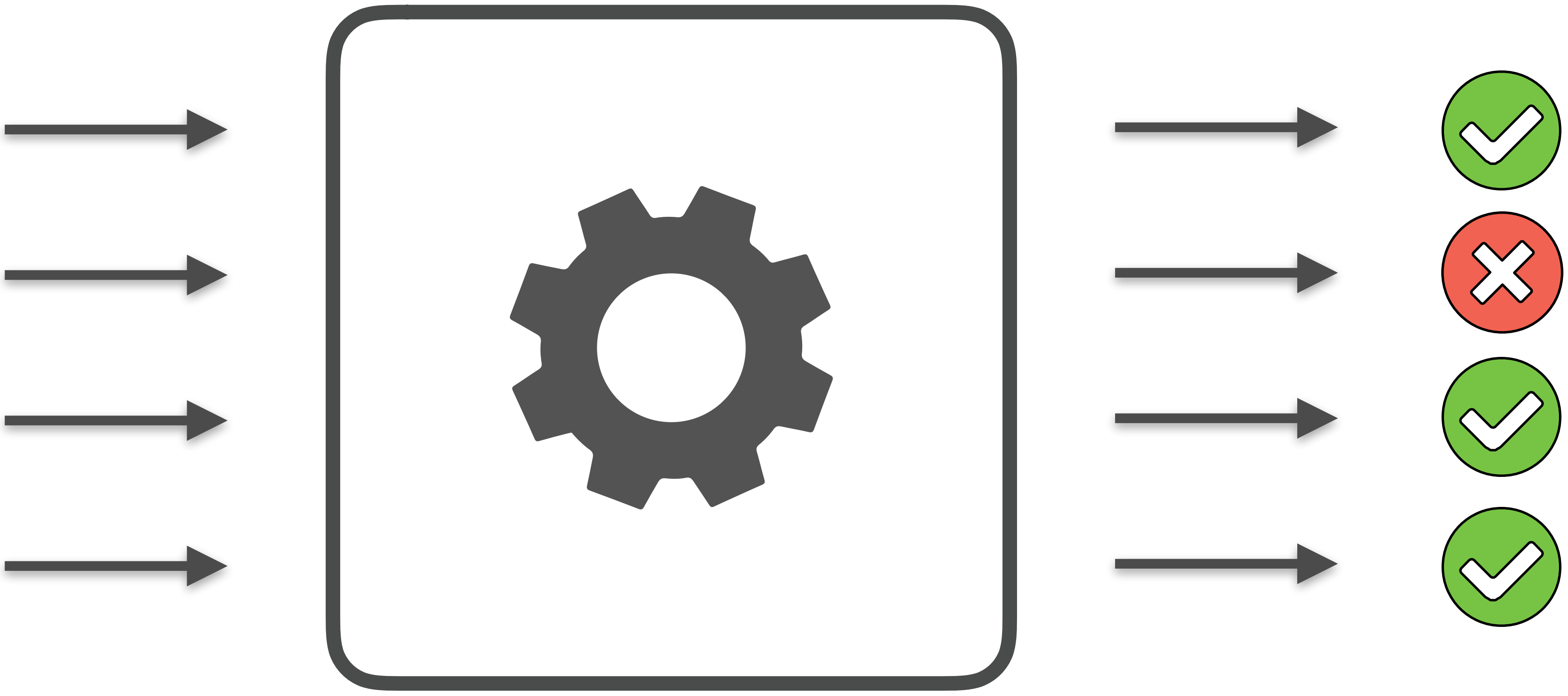


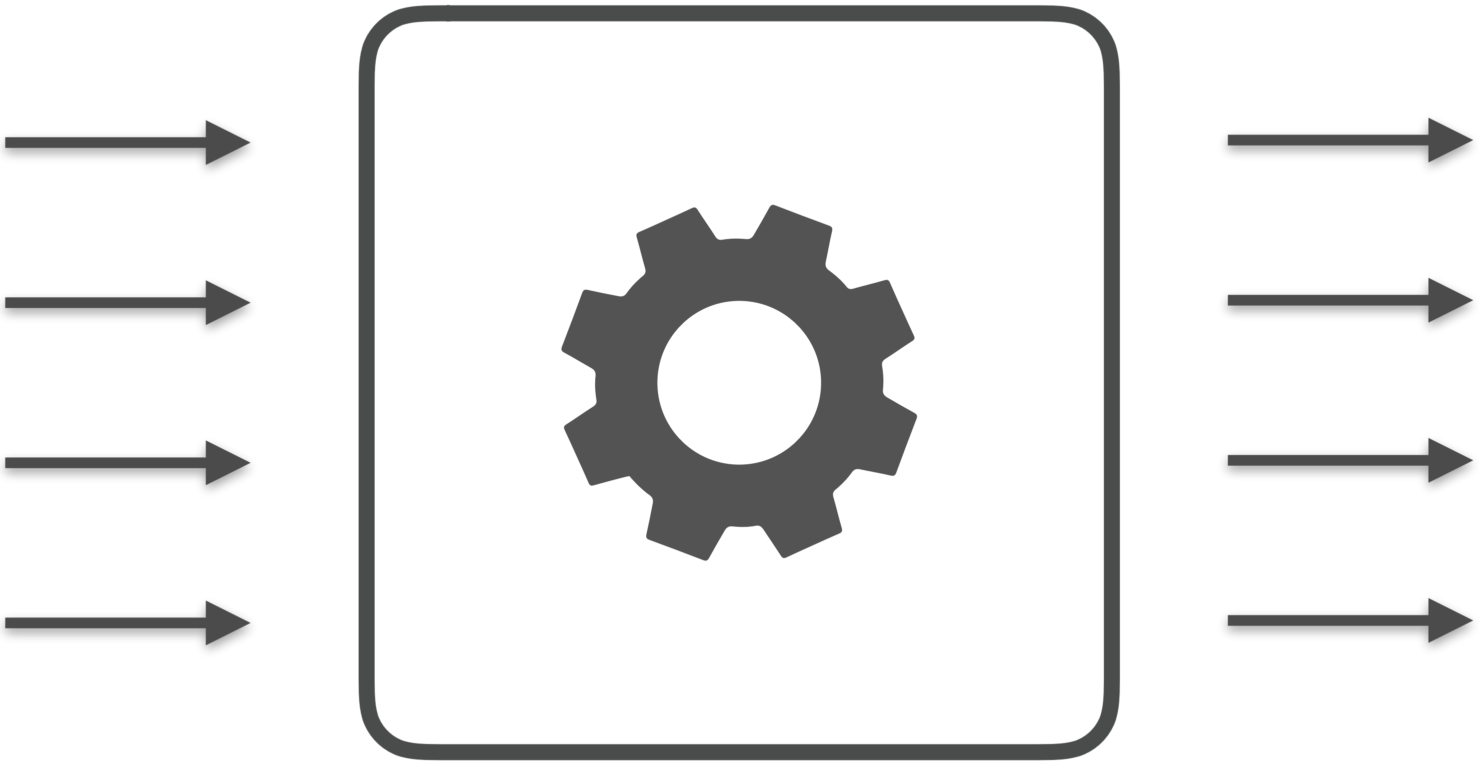
Collect observable signals:

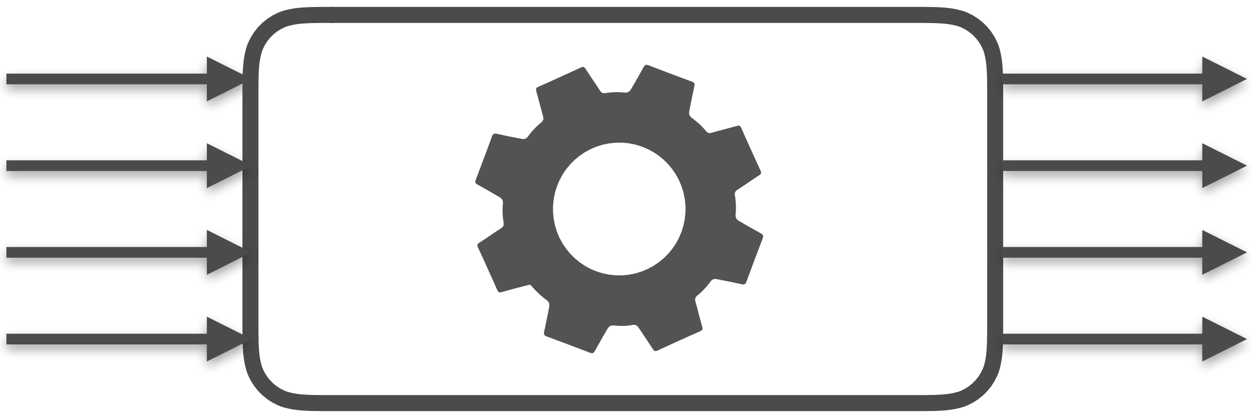
- service error rate
- service response time
- process uptime
- CPU load
- available memory
- rate of requests served
- ...

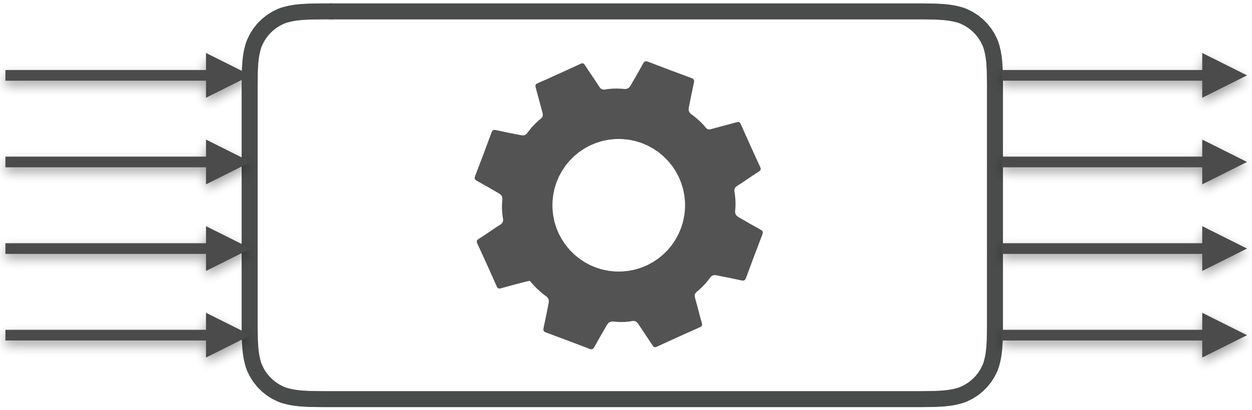




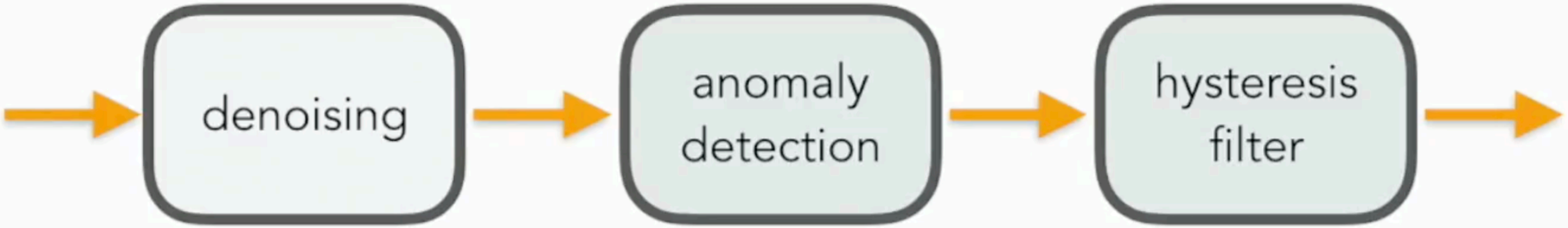








Field	Concept
Machine learning	Classifier
Signal processing	Filter
Control theory	Controller



- **Moving Average (MA)**
- Weighted MA
- Low-pass filtering
- Rolling quantile
- Karhunen-Loève transform
- Subspace projection

- **Simple thresholding**
- Hypothesis testing
- Conditional entropy
- Distributional thresholding
- Pattern matching/Clustering

- **Sharp hysteresis**
- Continuous hysteresis
- Finite State Machine
- Fuzzy logic program

Stable and accurate health-checking of horizontally-scaled services

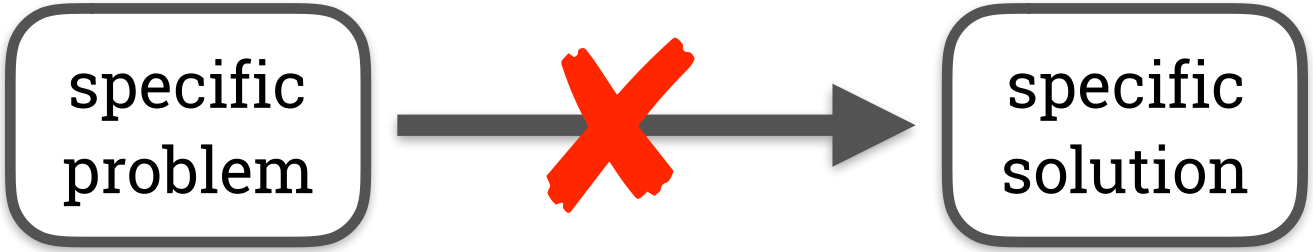
USENIX SREcon18 Americas

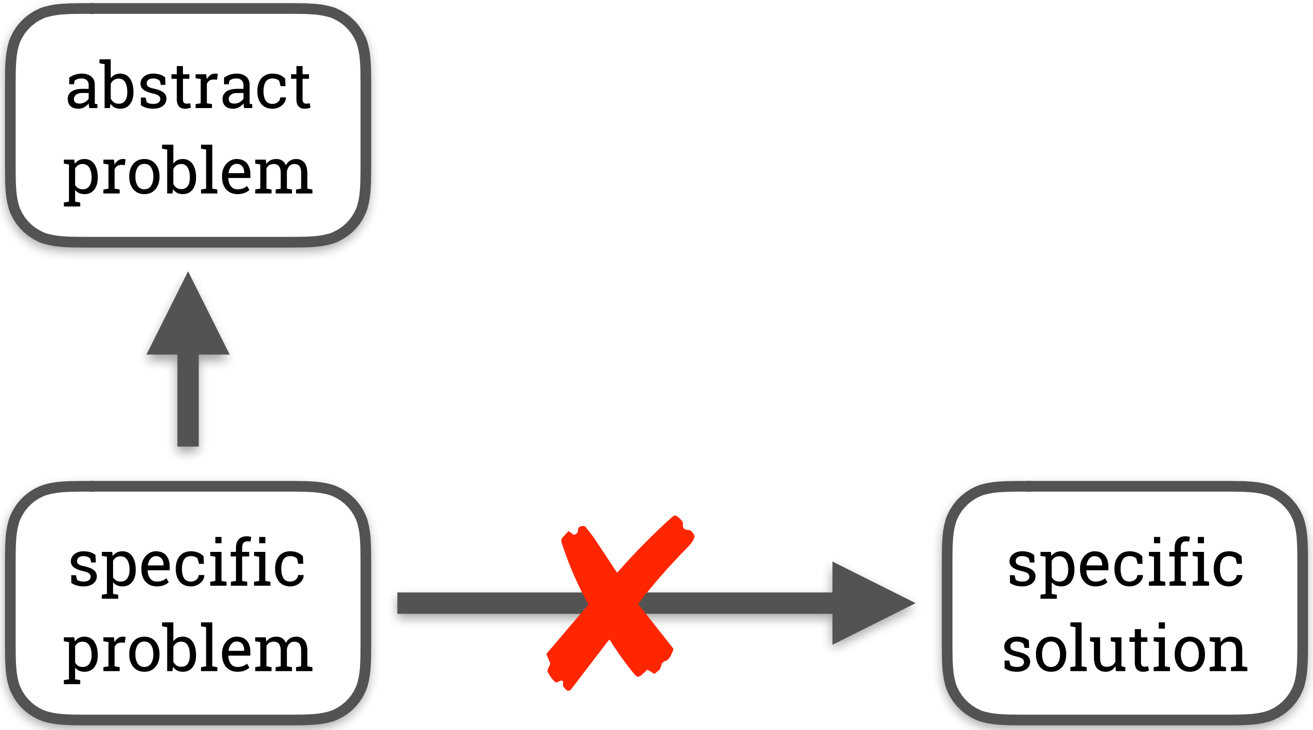
Solve abstract problems

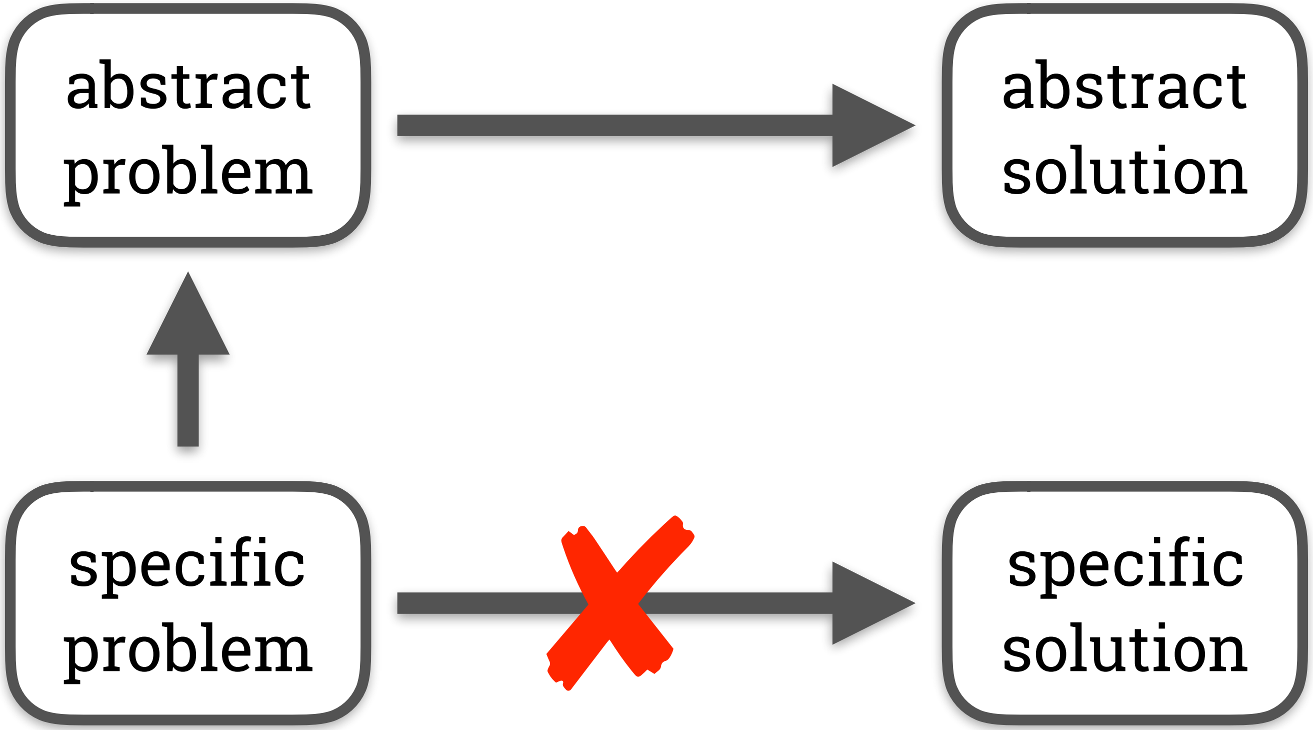
specific
problem

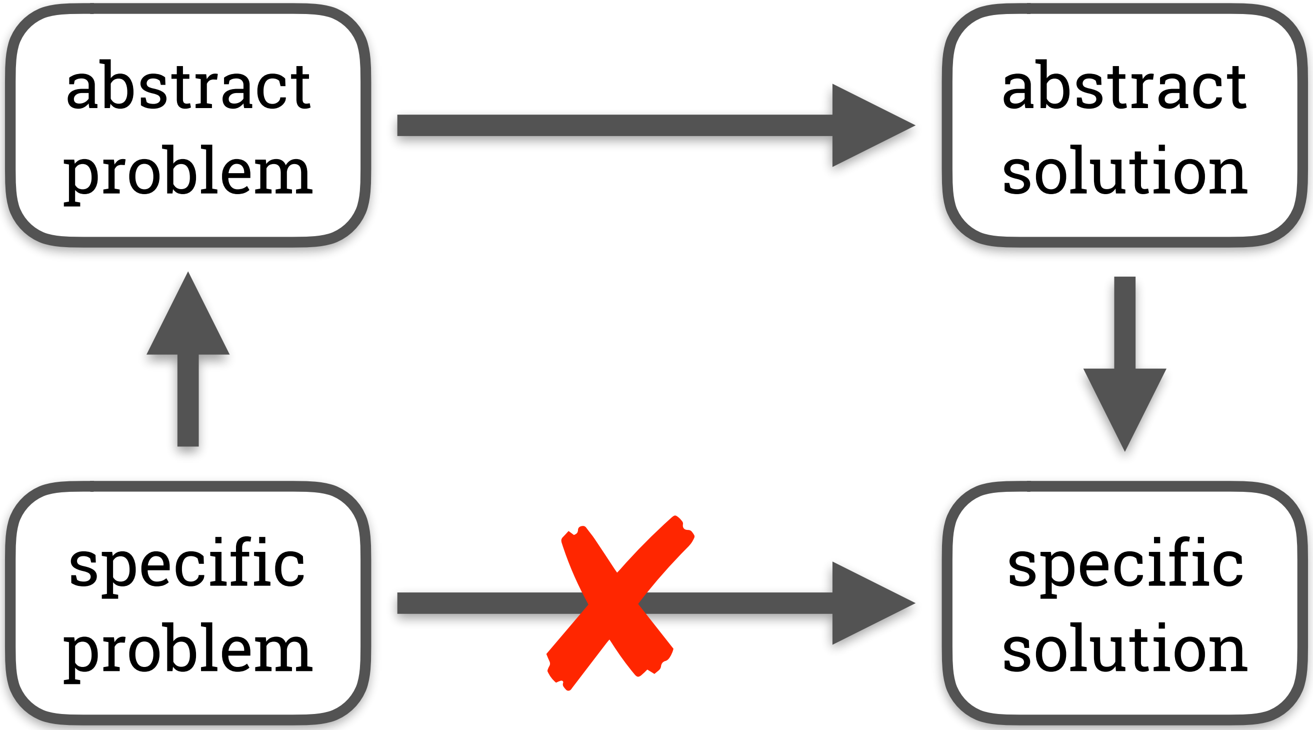
specific problem

specific solution


specific
problem
specific
solution


abstract problem
specific problem
specific solution


abstract problem
abstract solution
specific problem
specific solution


abstract problem
abstract solution
specific problem
specific solution

Technical background diversity

Develop diverse interests

Thank you!

fastly