Data-driven Stroke Rehabilitation Using Machine Learning

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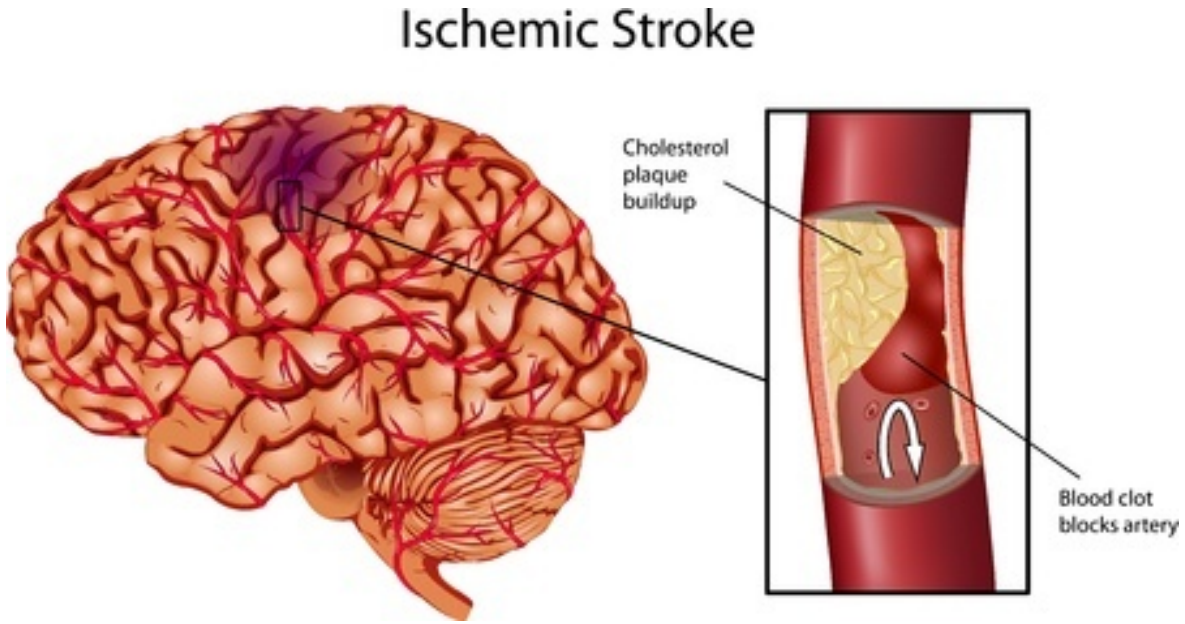
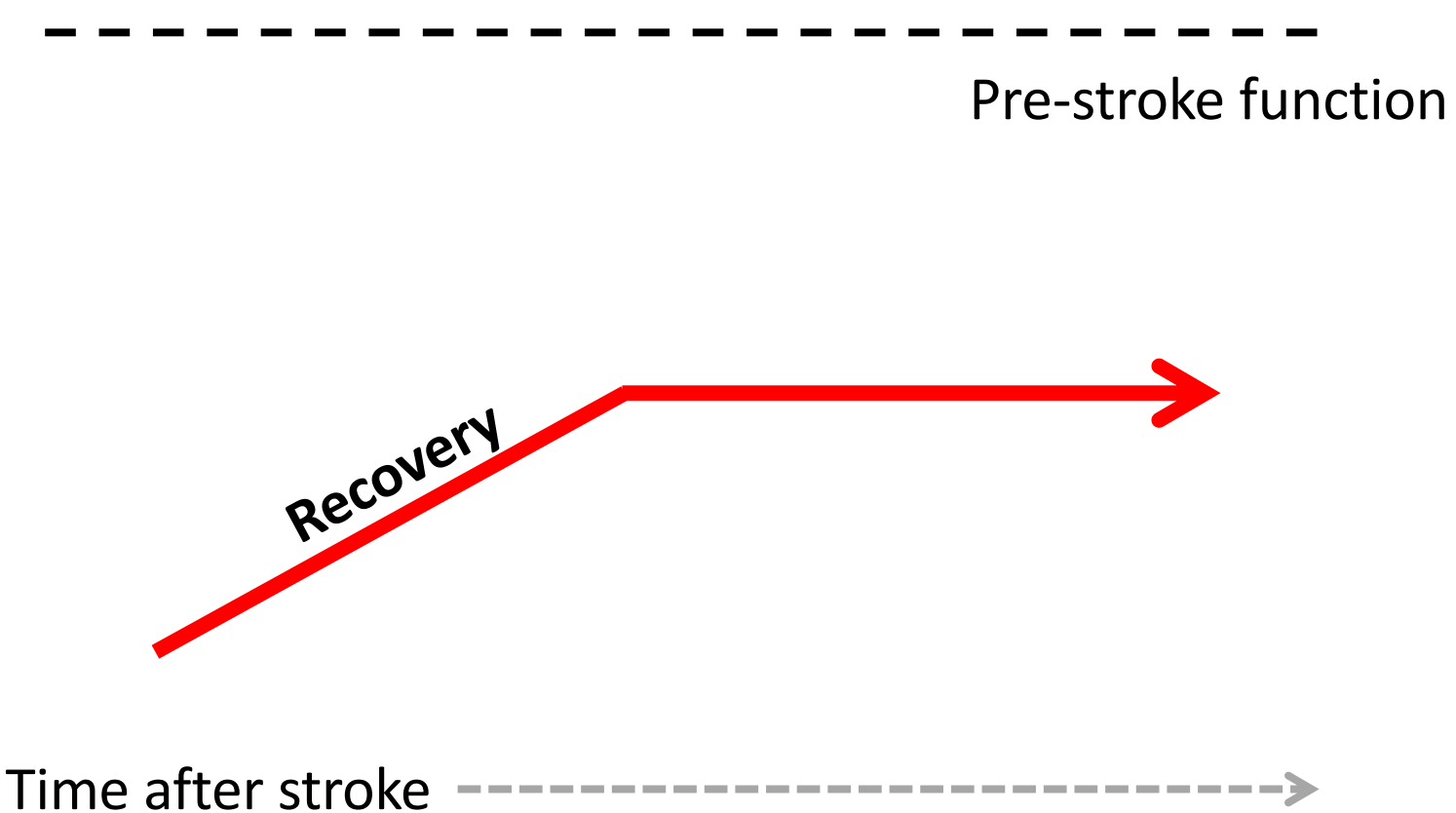
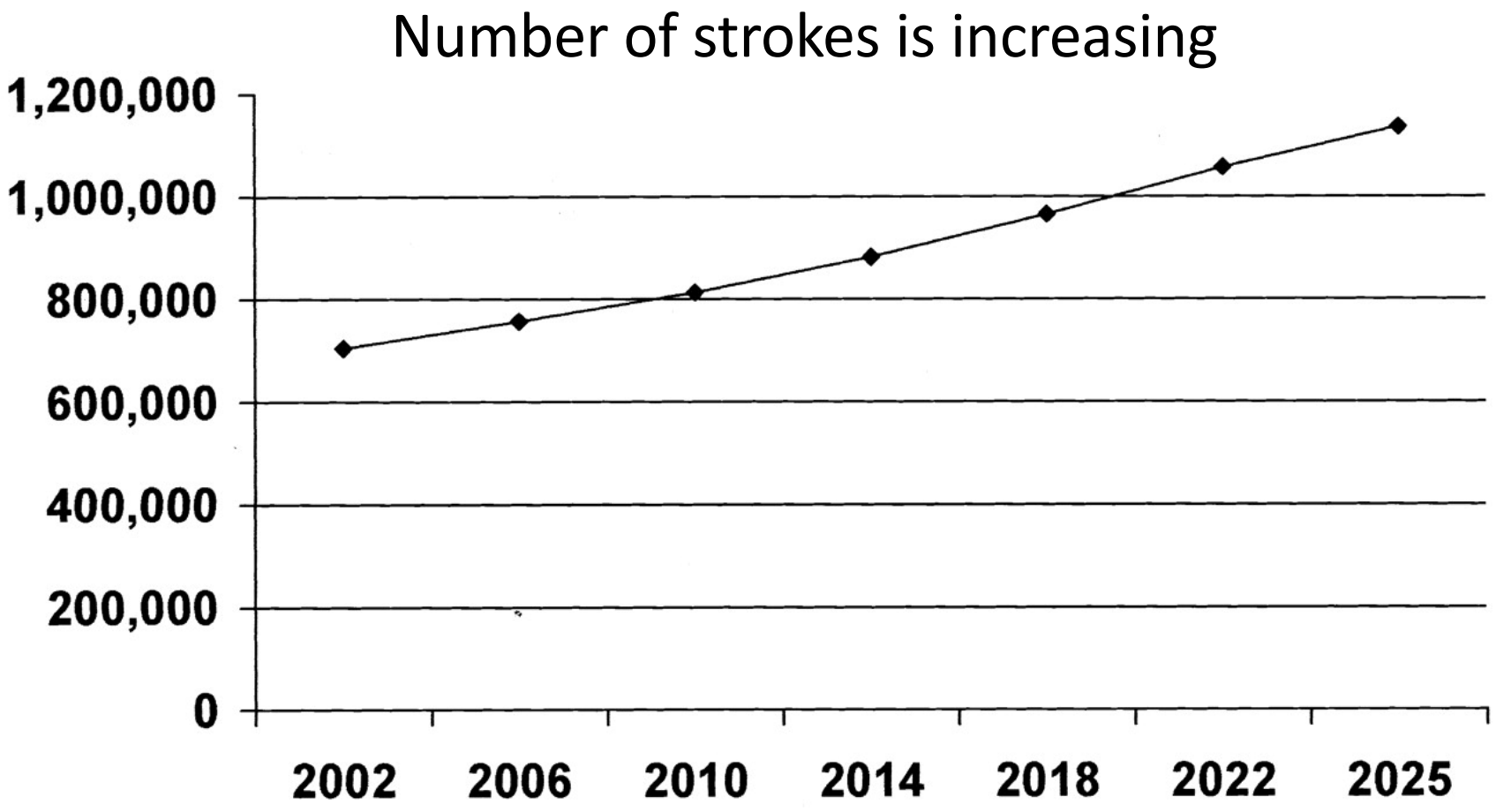
Stroke and the brain



Post-stroke recovery



Stroke is the LEADING CAUSE of disability in the US

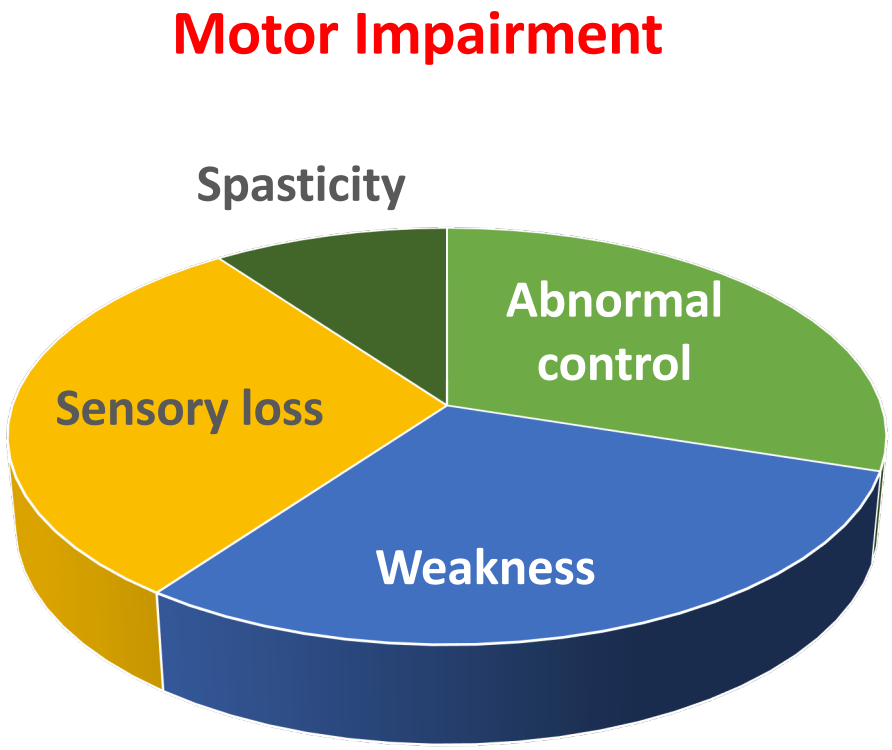


Broderick 2004 Stroke

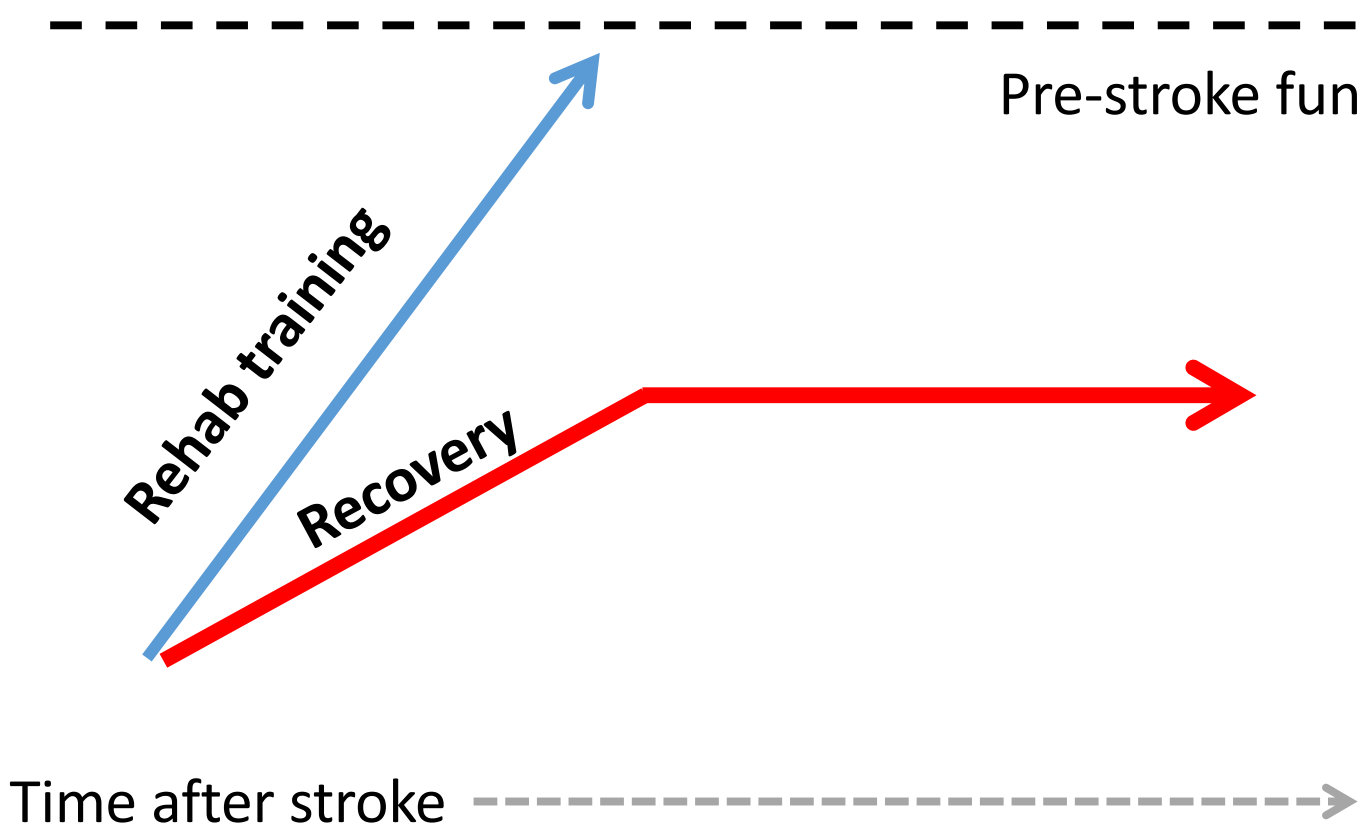
Stroke and the arm

Stroke affects the arm in 77% of patients

At 6 months, motor impairment still limits activities in 80% of patients



Approaches to improving recovery

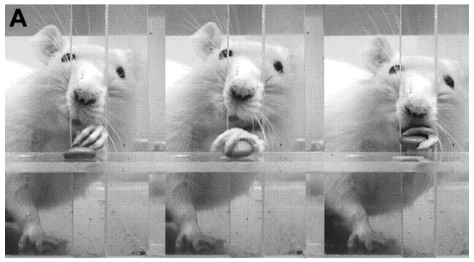


Primary role of upper extremities in humans: act on objects

Functional UE movements have 4 components:

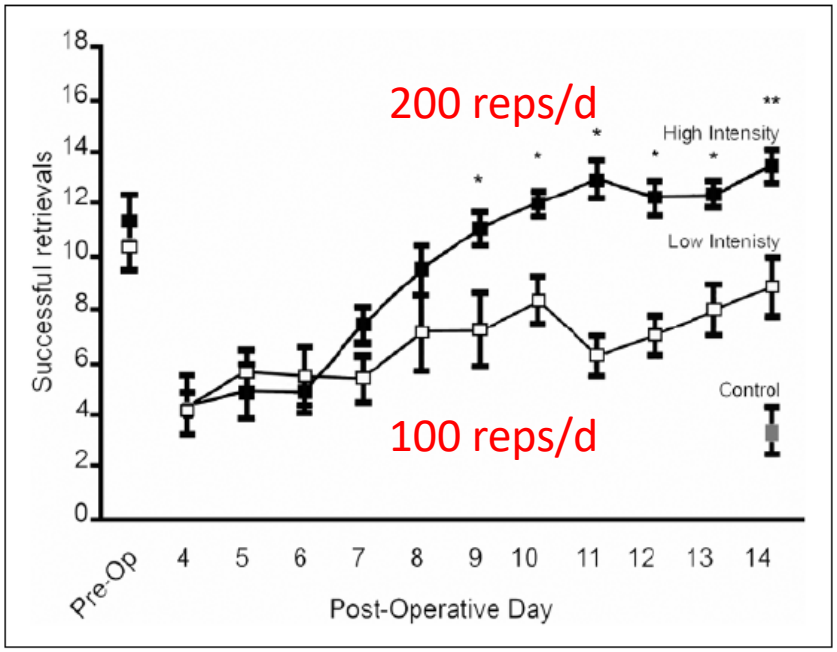
1. Reach
2. Contact (grasp/touch)
3. Object-specific action
4. Release

Birkenmeier 2010 NNR

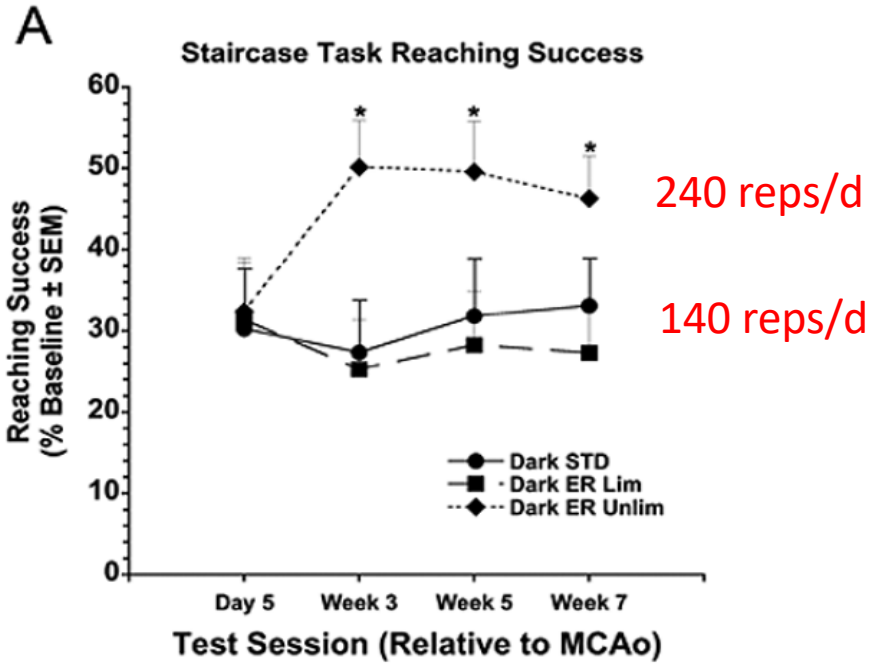


How much should we be dosing our patients?

Animals require 200-1000 reps/day to recover

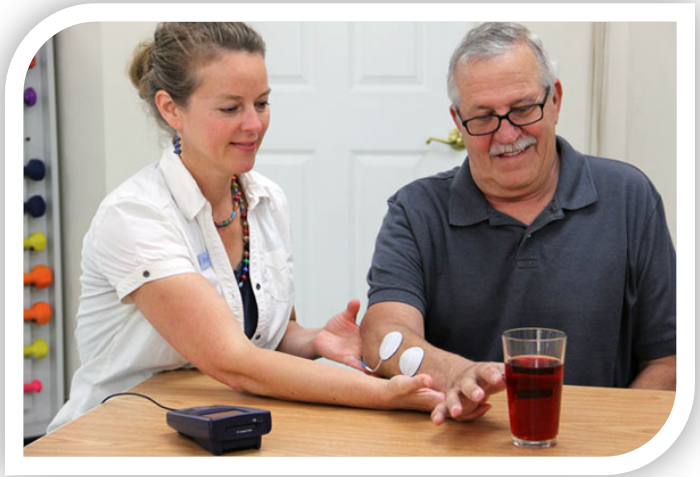


Bell 2015 NNR



MacLellan 2011 NNR

What actually happens in stroke rehab?



Functional arm movements

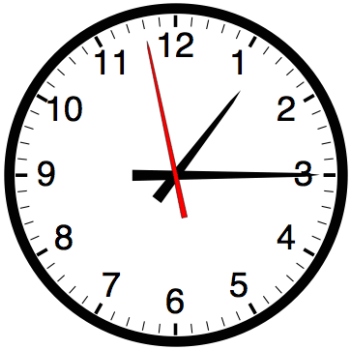
- In only 51% of therapy sessions
- In these, 32 reps/session (range 1-420)

We are likely under-dosing our patients by 10x

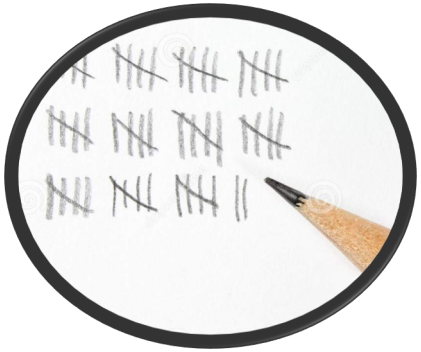
Lang 2009 APMR

Measuring training dose is tough

Time



Hand tally



Motion capture systems

Activity monitors

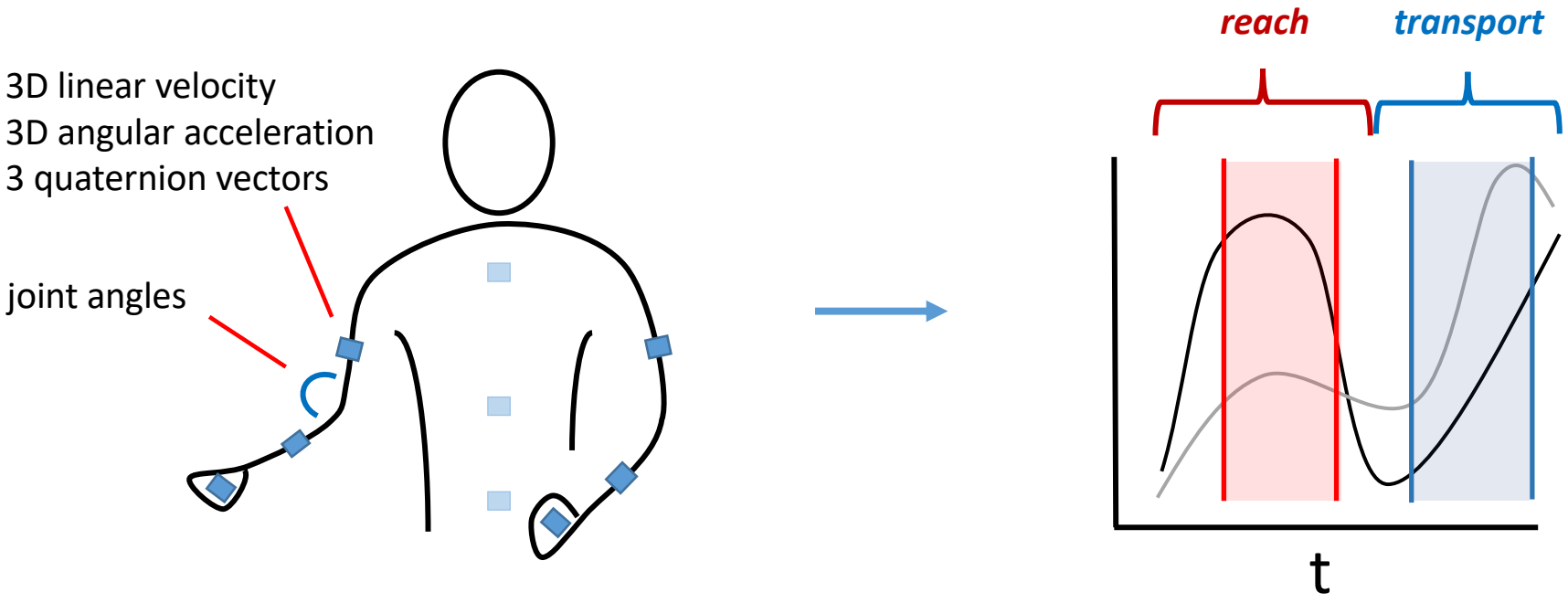
Automatic identification

3D motion capture with wearable sensors

+

Machine learning

Automatic identification

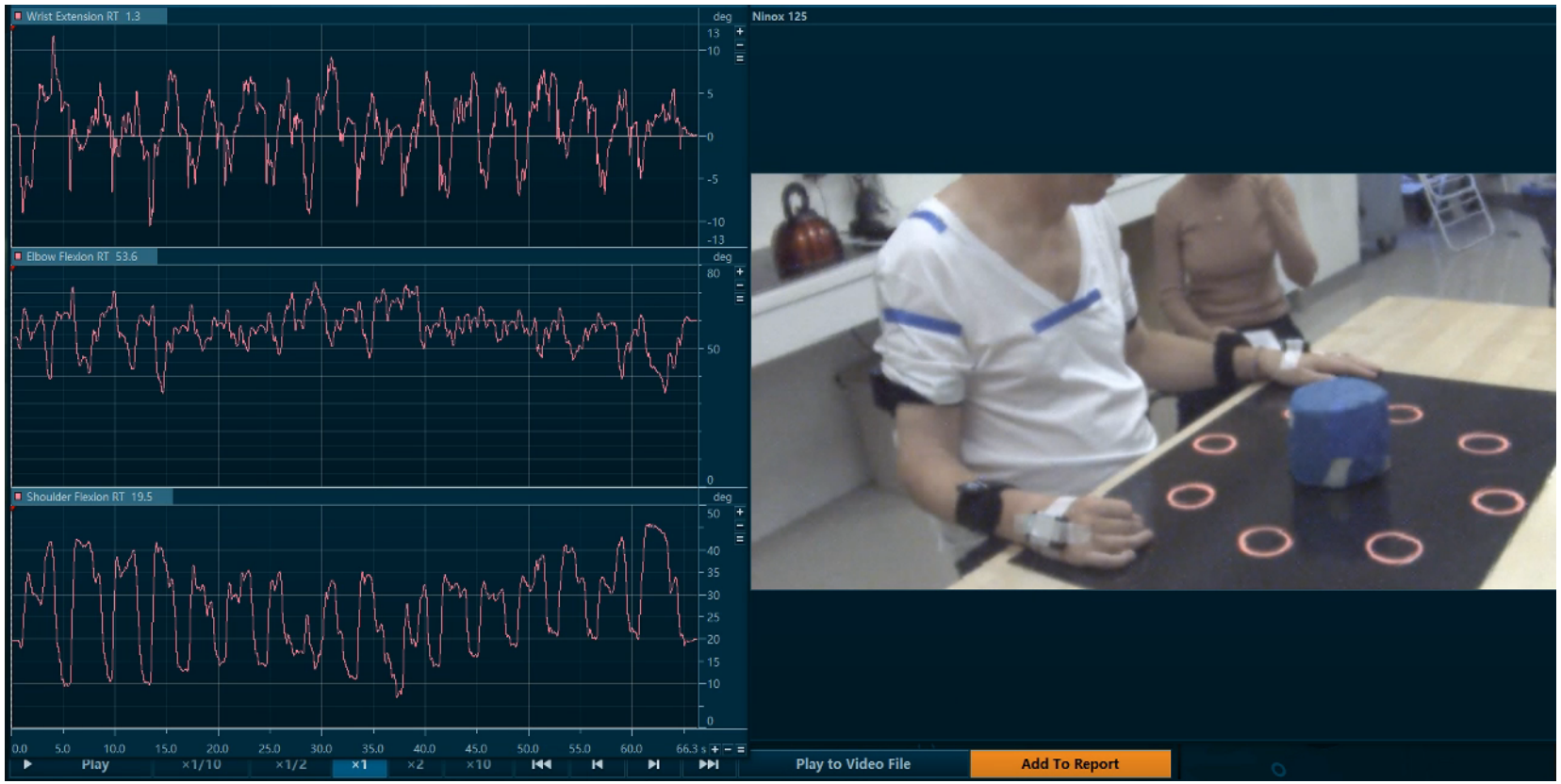


Motion capture: inertial measurement units (IMUs)

3D linear and angular motion
High precision
East to wear
No occlusion

- 100 Hz capture
- Record up to 10 h
- Transmit up to 150 m

Motion capture in reality



Machine learning

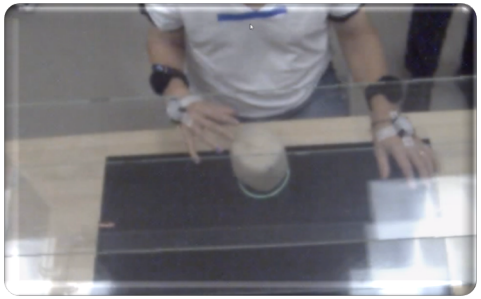
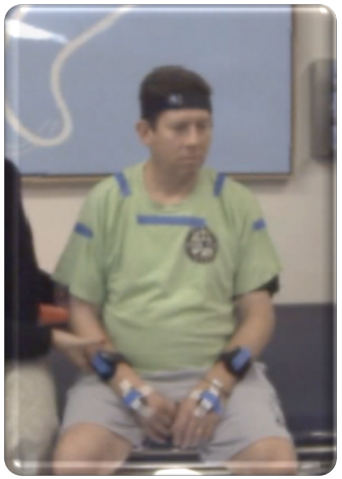
1. Gather data
2. Label the data
3. Build a model mapping data to labels
4. Apply the model on new data

Gather data

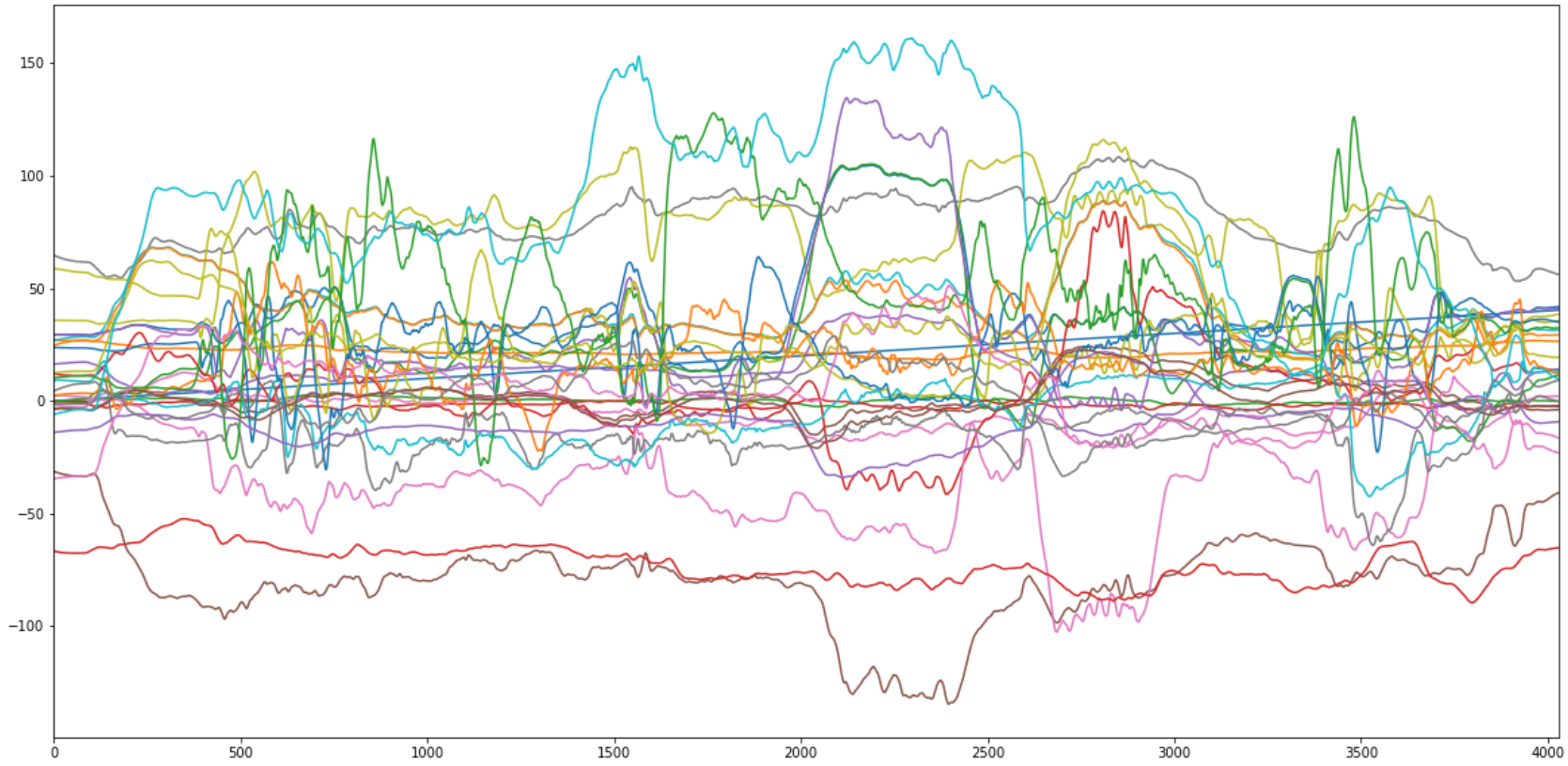






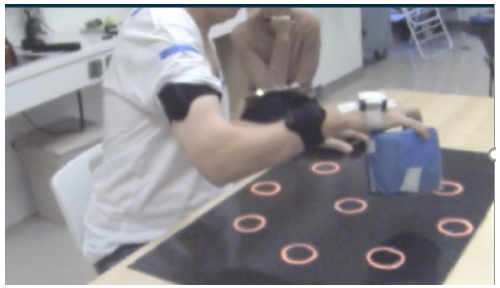
Data



Label data

“rest”

“reach”



“transport”

1 min video = 1 hour labeling

Build a model

A model is a function that maps data to labels

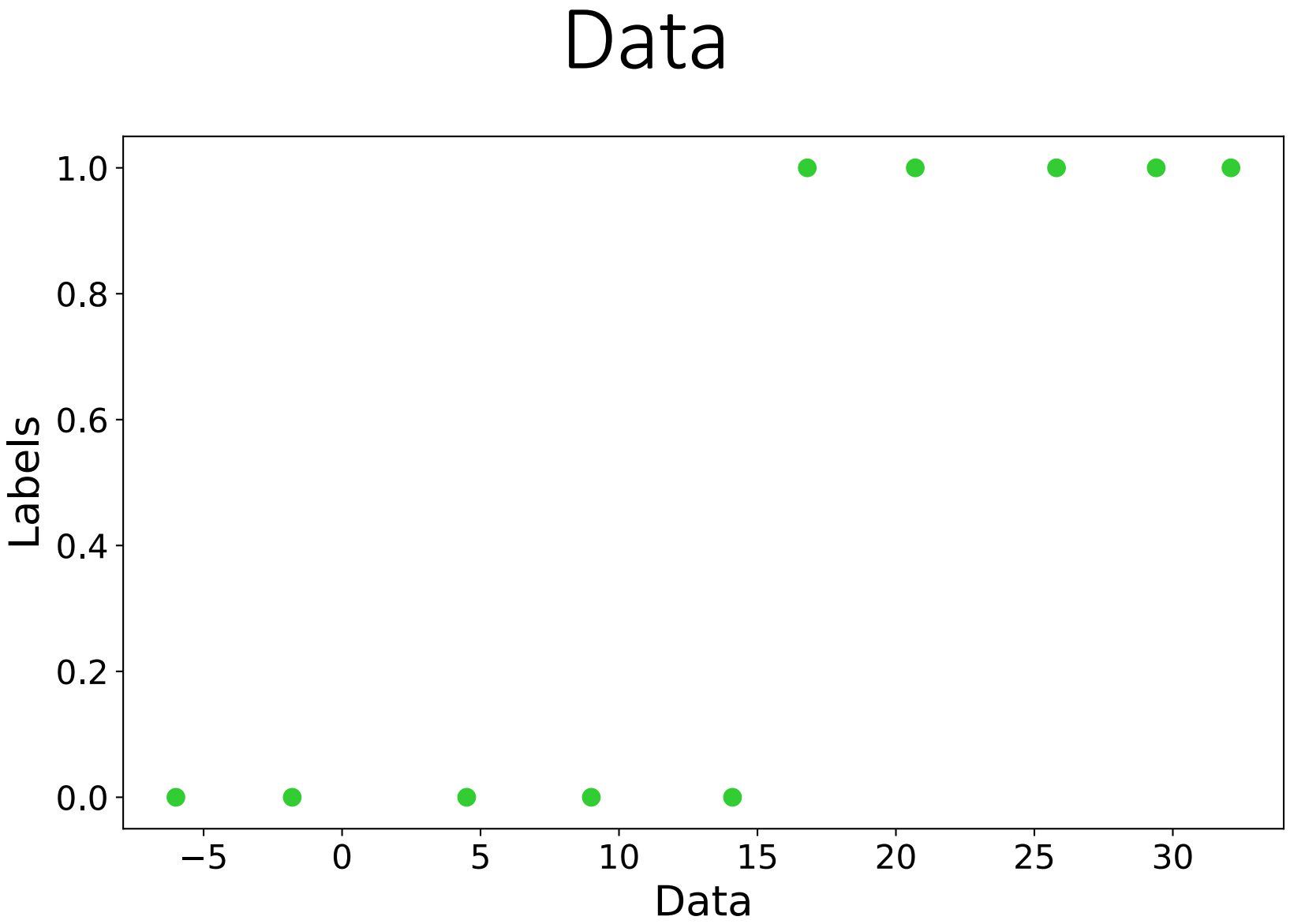
How do we build the function?

Change it until the error is small

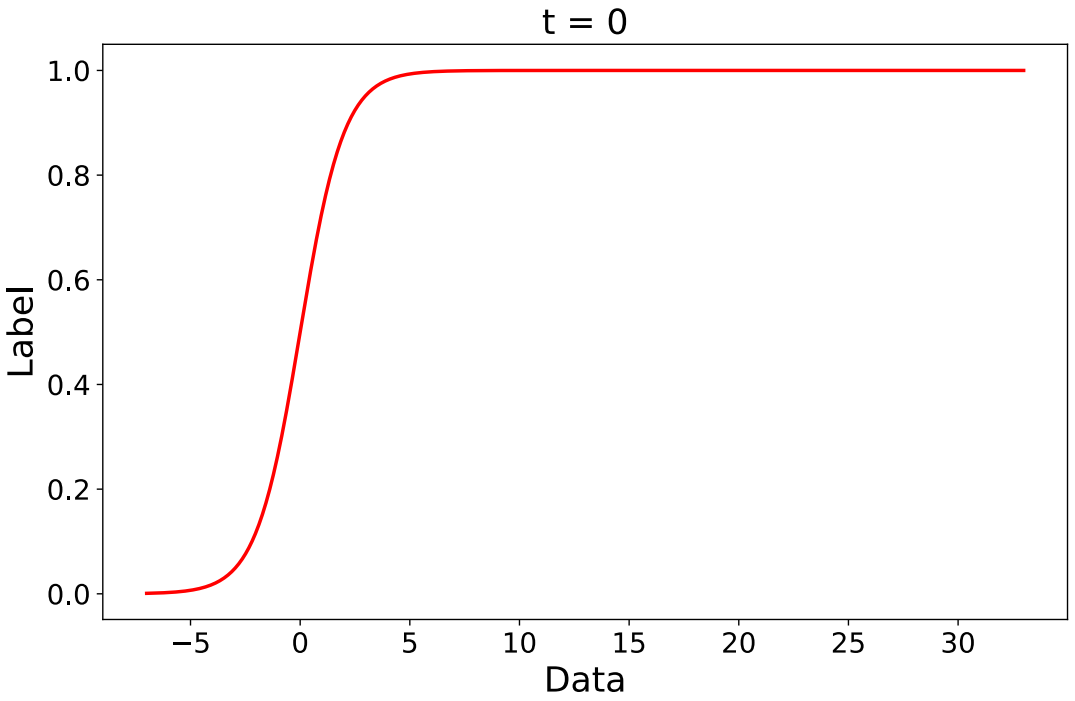
Toy example

Data: Real numbers

Labels: 0 or 1

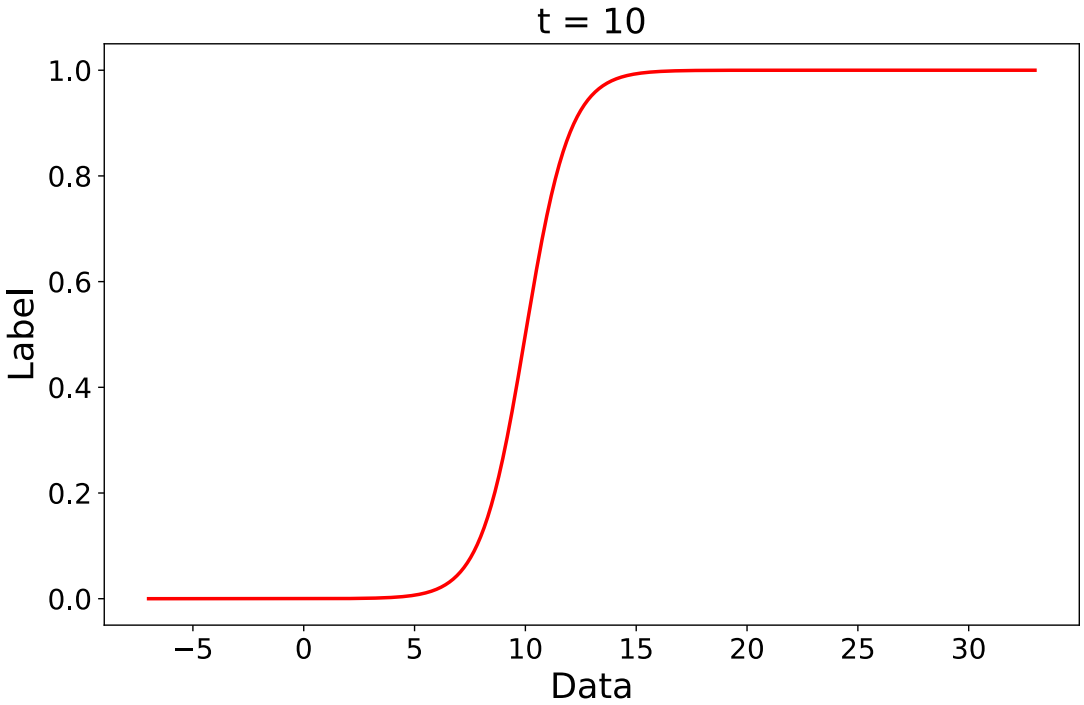

Data
Labels
1.0
0.8
0.6
0.4
0.2
0.0
−5
0
5
10
15
20
25
30
Data

Model



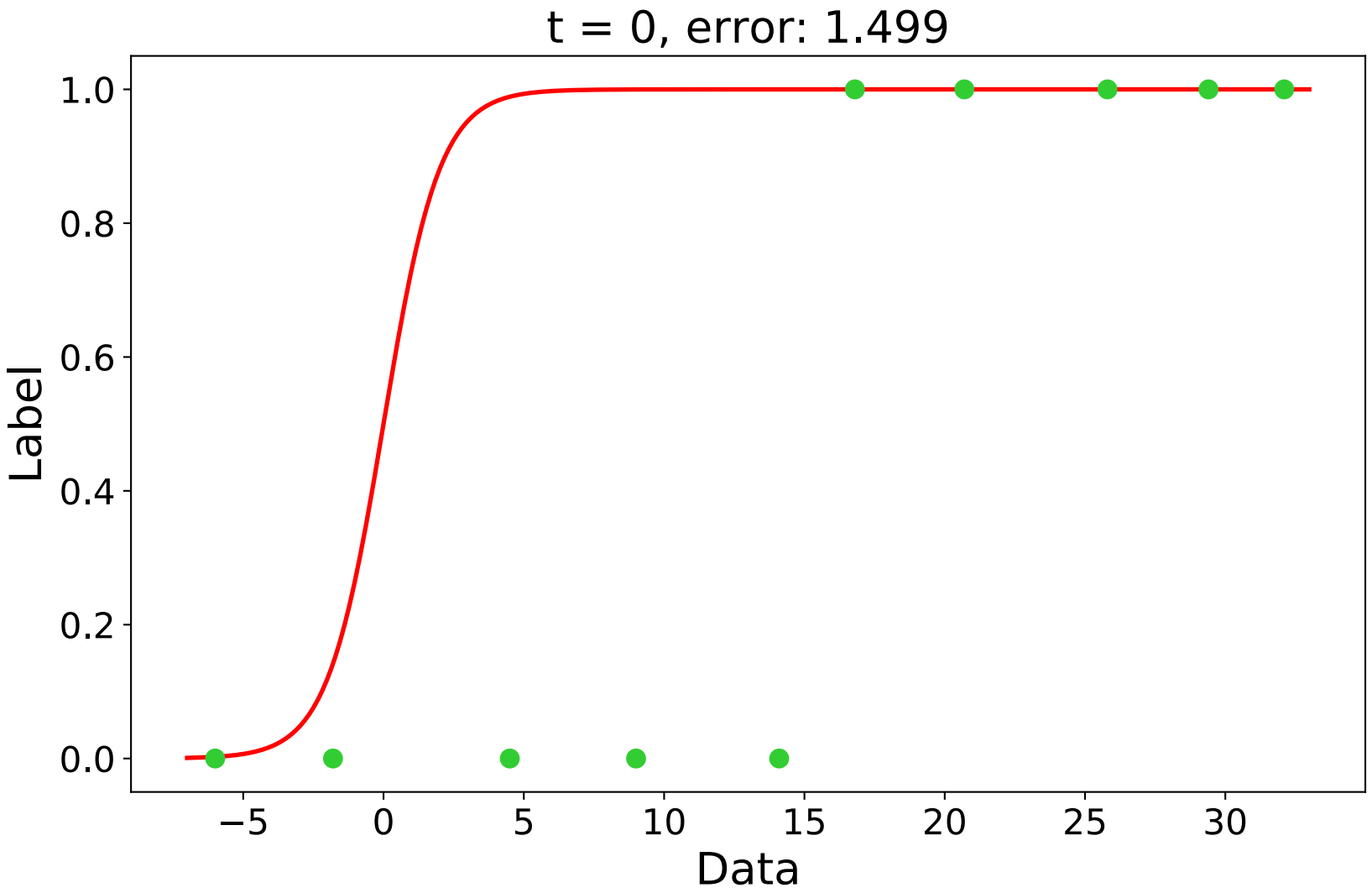
Logistic function shifted by t

Model

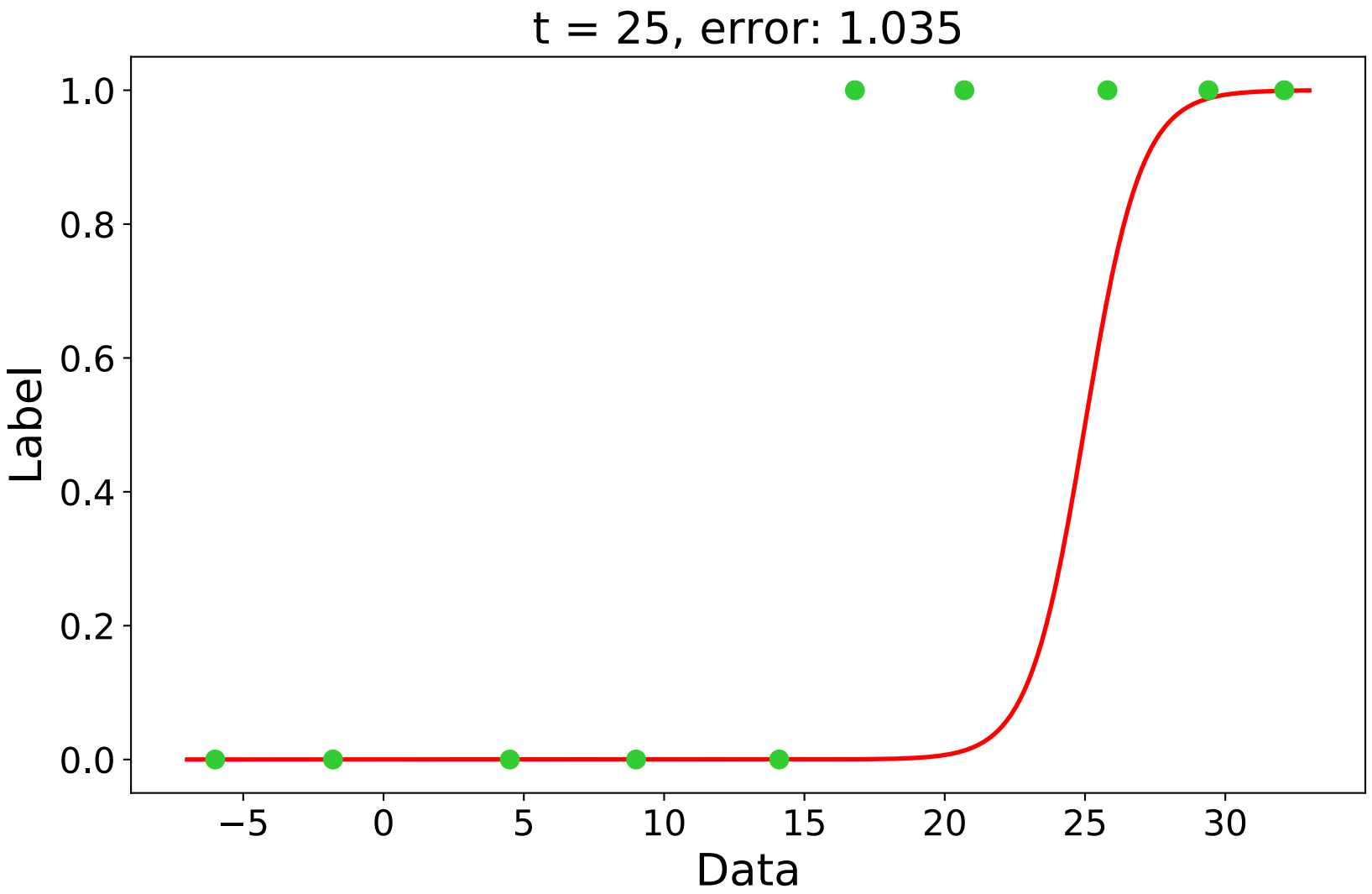


Logistic function shifted by t

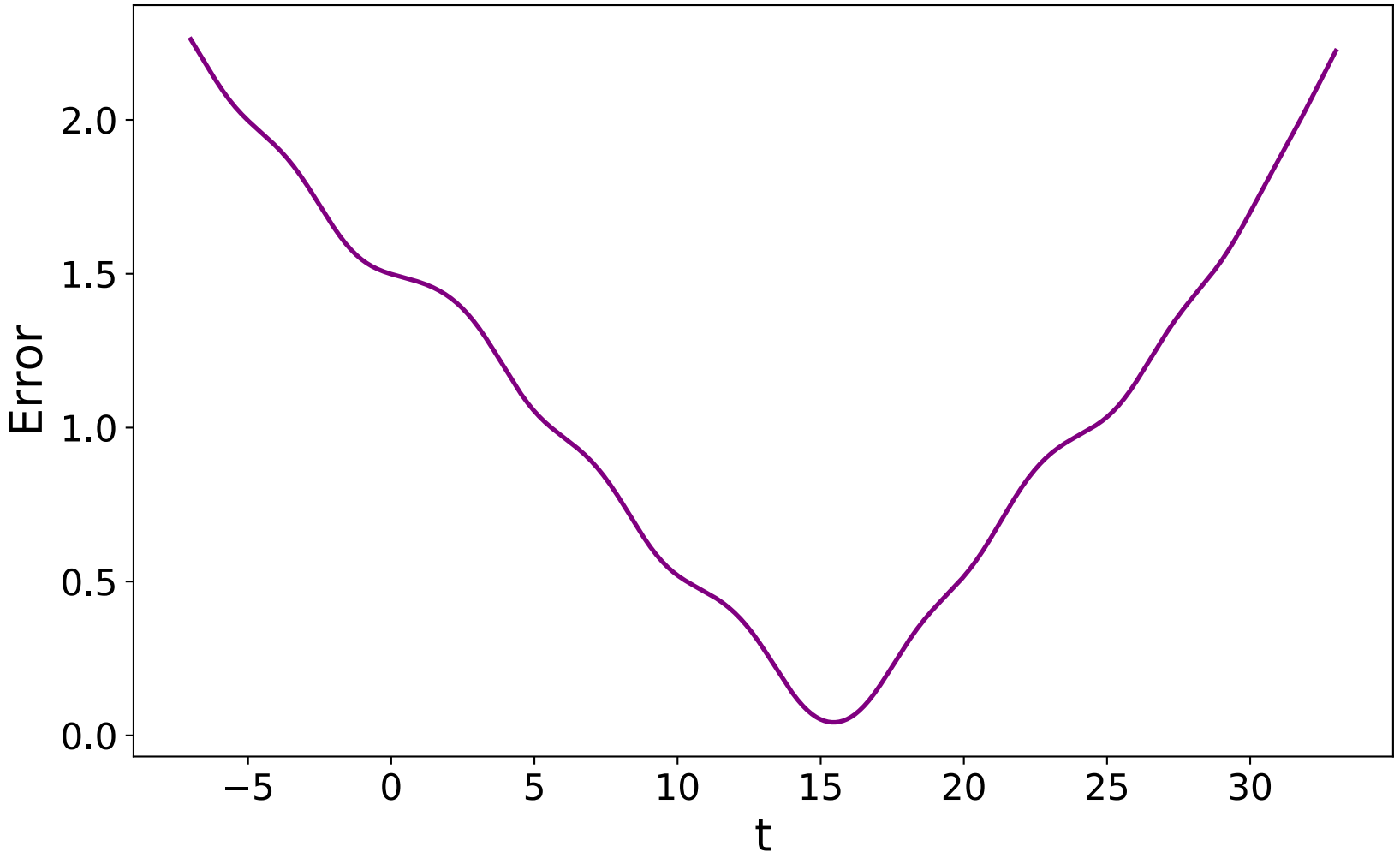
Problem: How to choose t?



Problem: How to choose t?



Error as a function of t



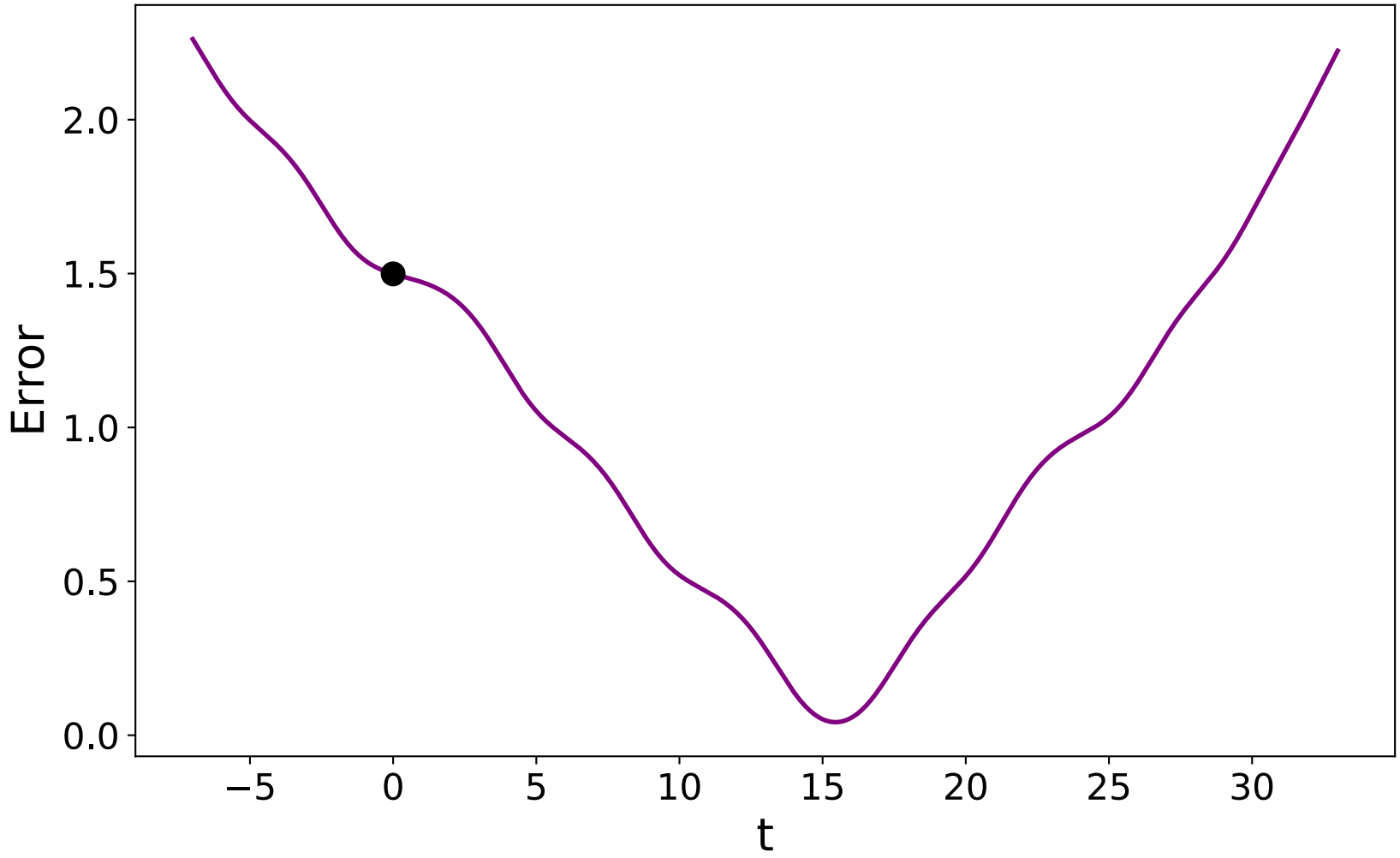
How to get to minimum

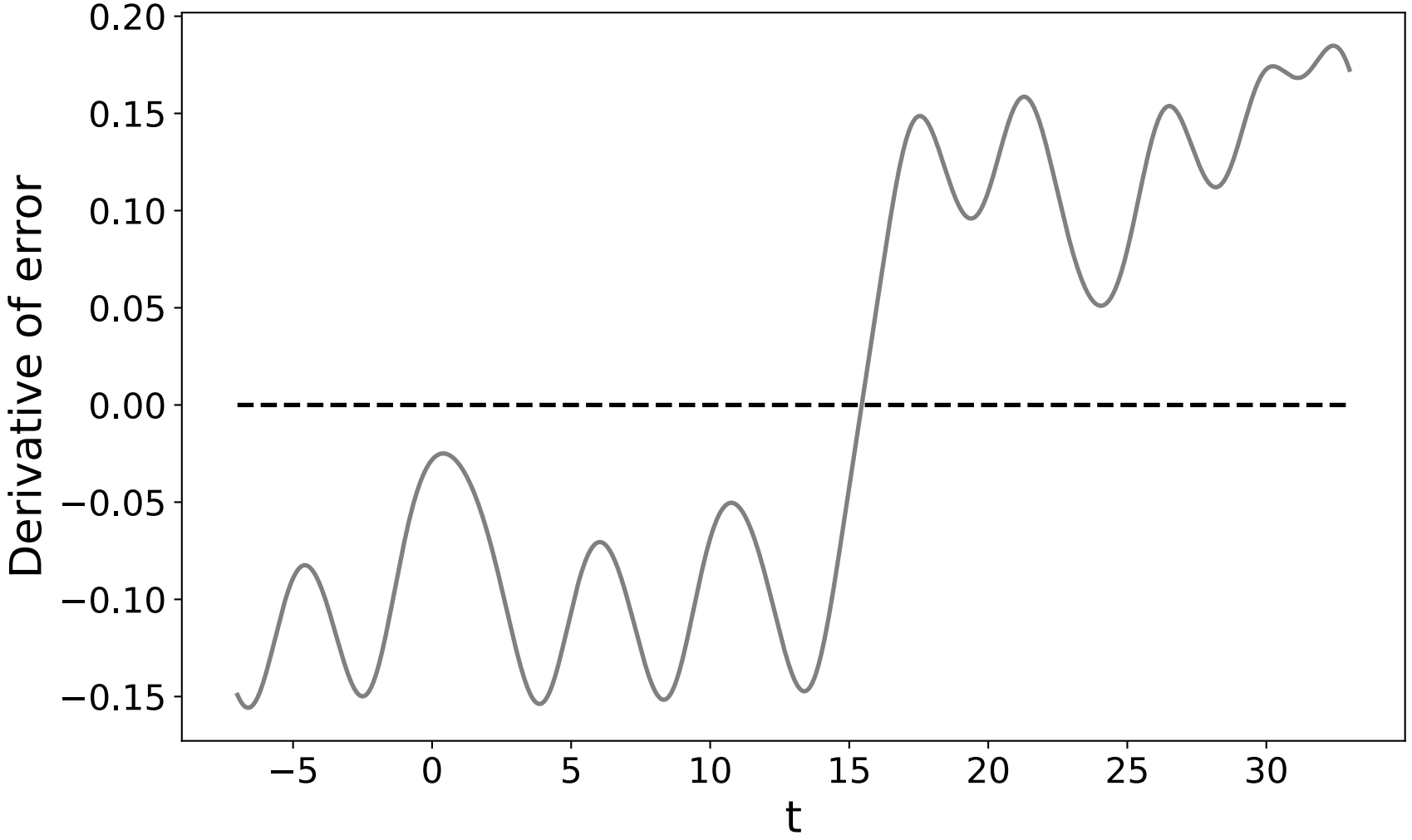
In real problems, we need to fit many parameters (not just one)

Data are multidimensional (not 1D)

Computing error for all possible values of the data is impossible!

How can we make progress?



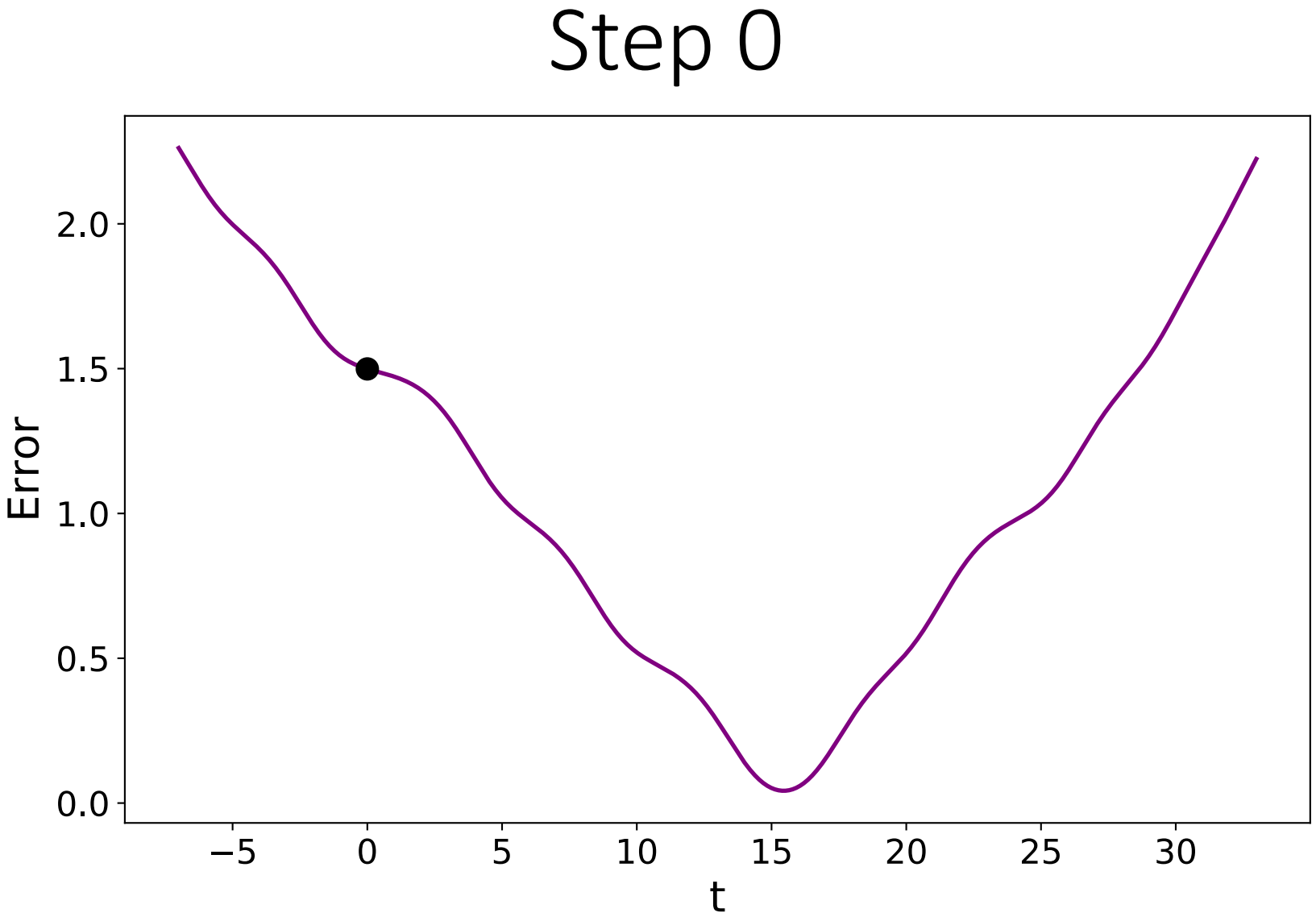

0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
Derivative of error
−5
0
5
10
15
20
25
30
t

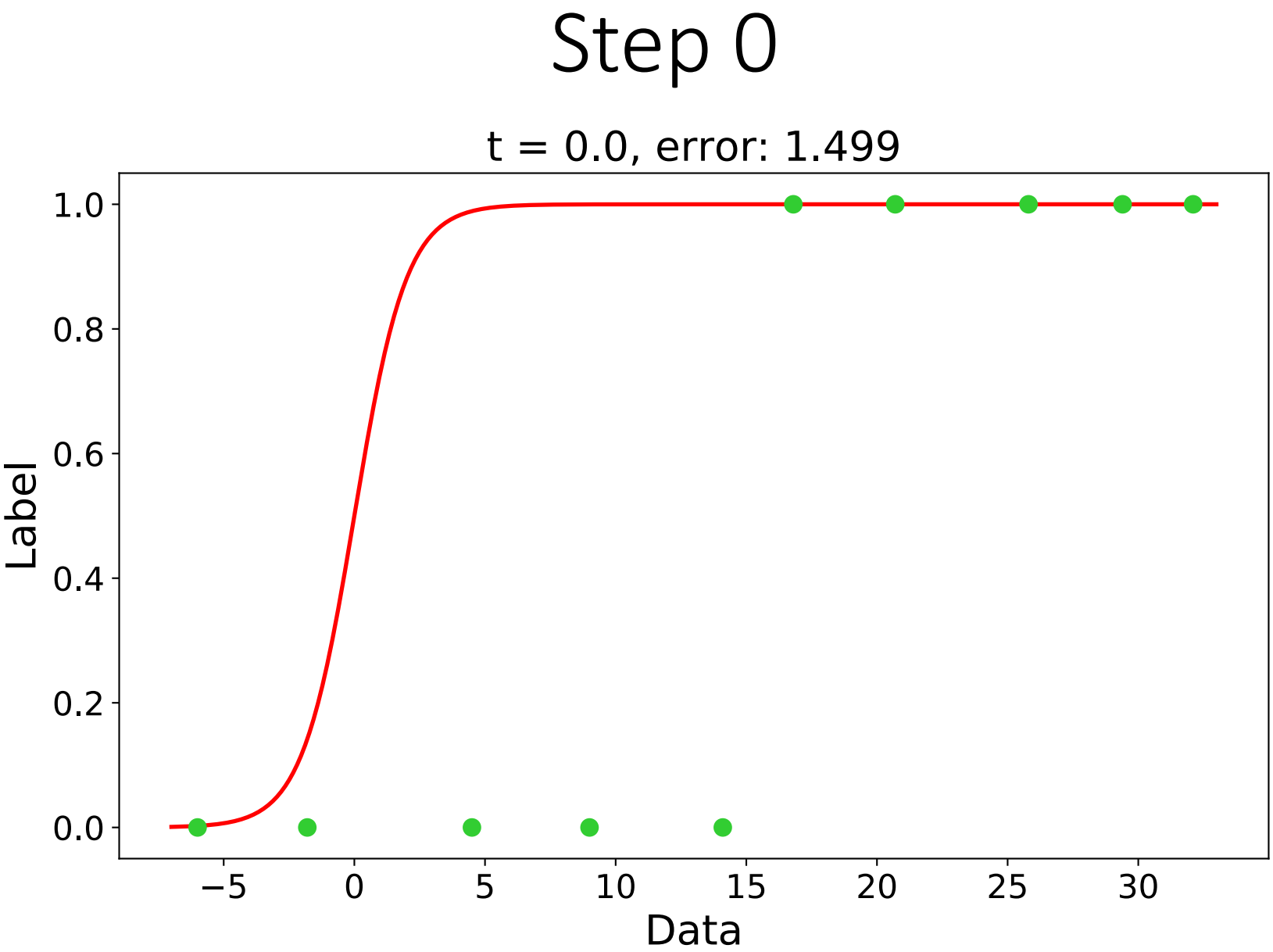
Descent method

Move in the direction opposite to the derivative until it's zero

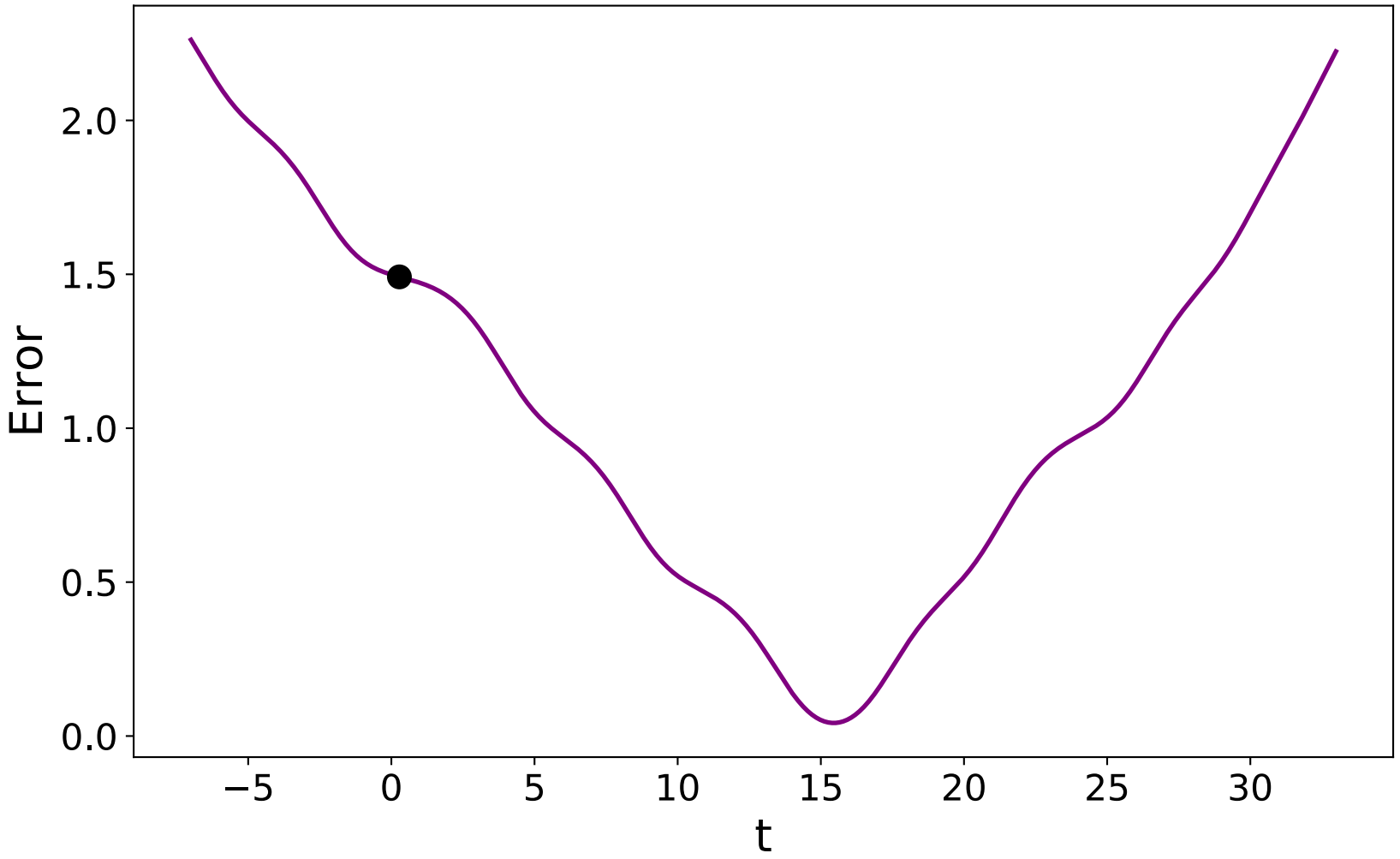
New t = old t – constant * derivative at t

Constant controls how fast we move

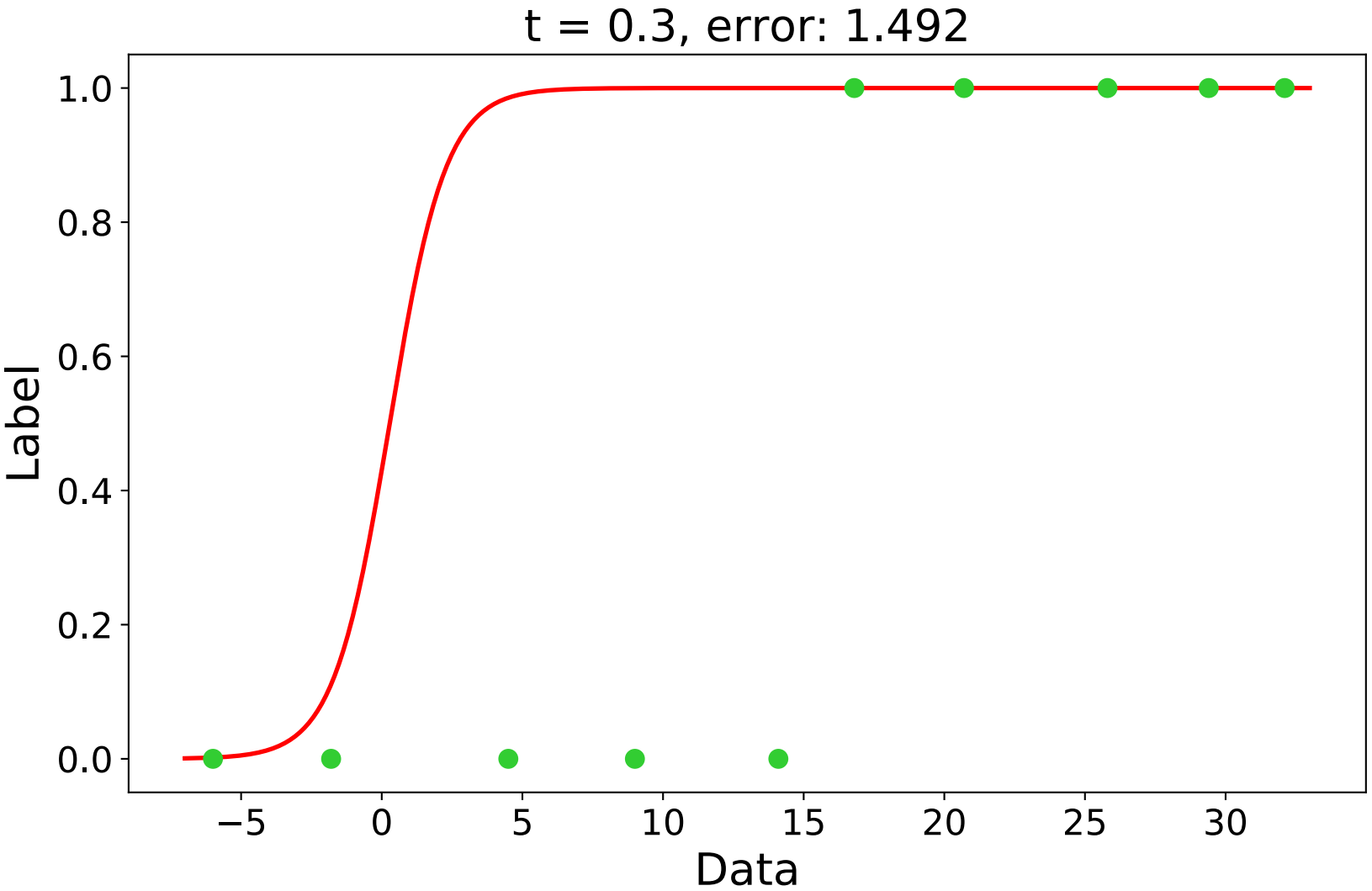

Step 0
Error
2.0
1.5
1.0
0.5
0.0
−5
0
5
10
15
20
25
30
t


Step 0
t = 0.0, error: 1.499
1.0
0.8
0.6
0.4
0.2
0.0
Label
−5
0
5
10
15
20
25
30
Data

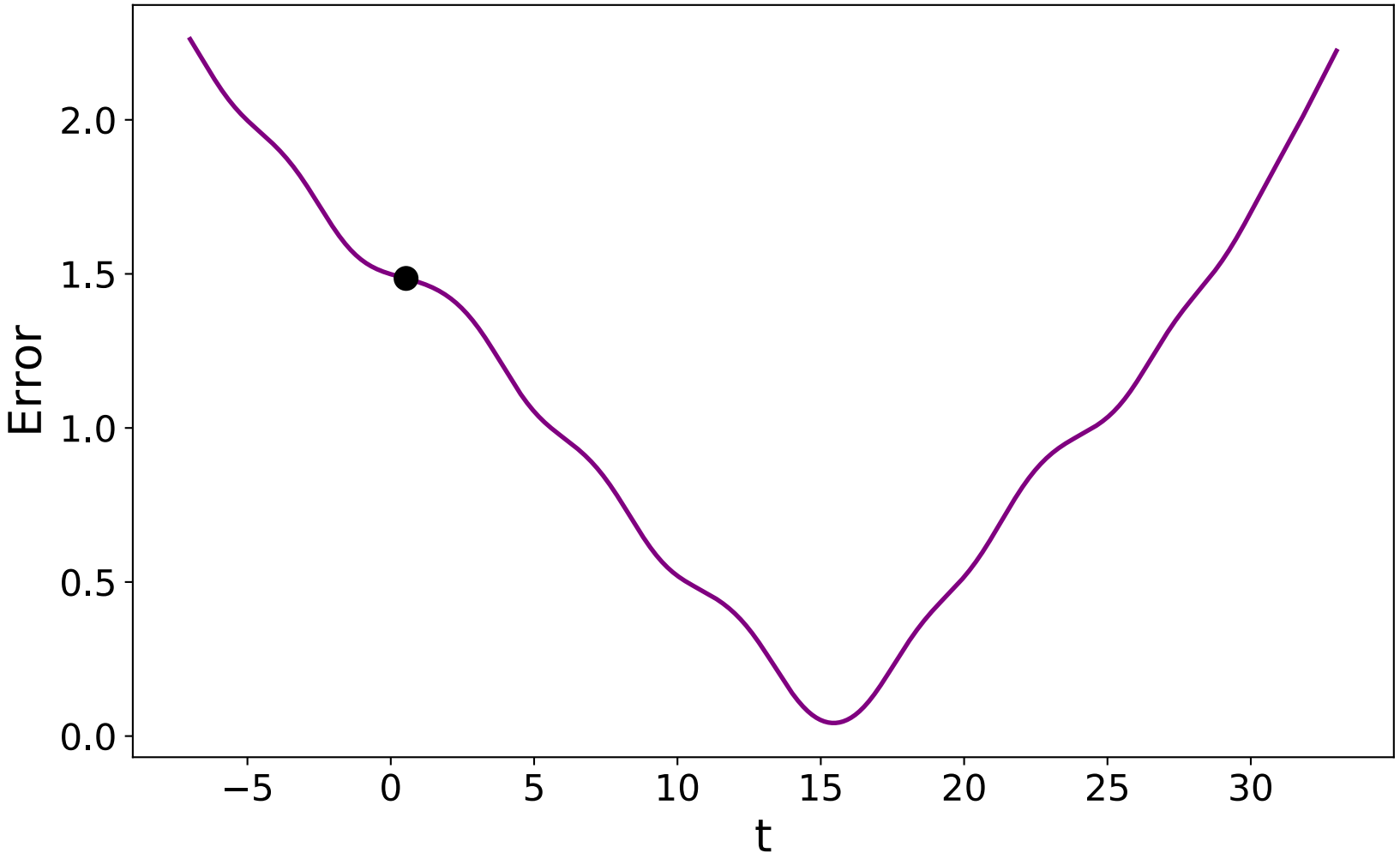
Step 1

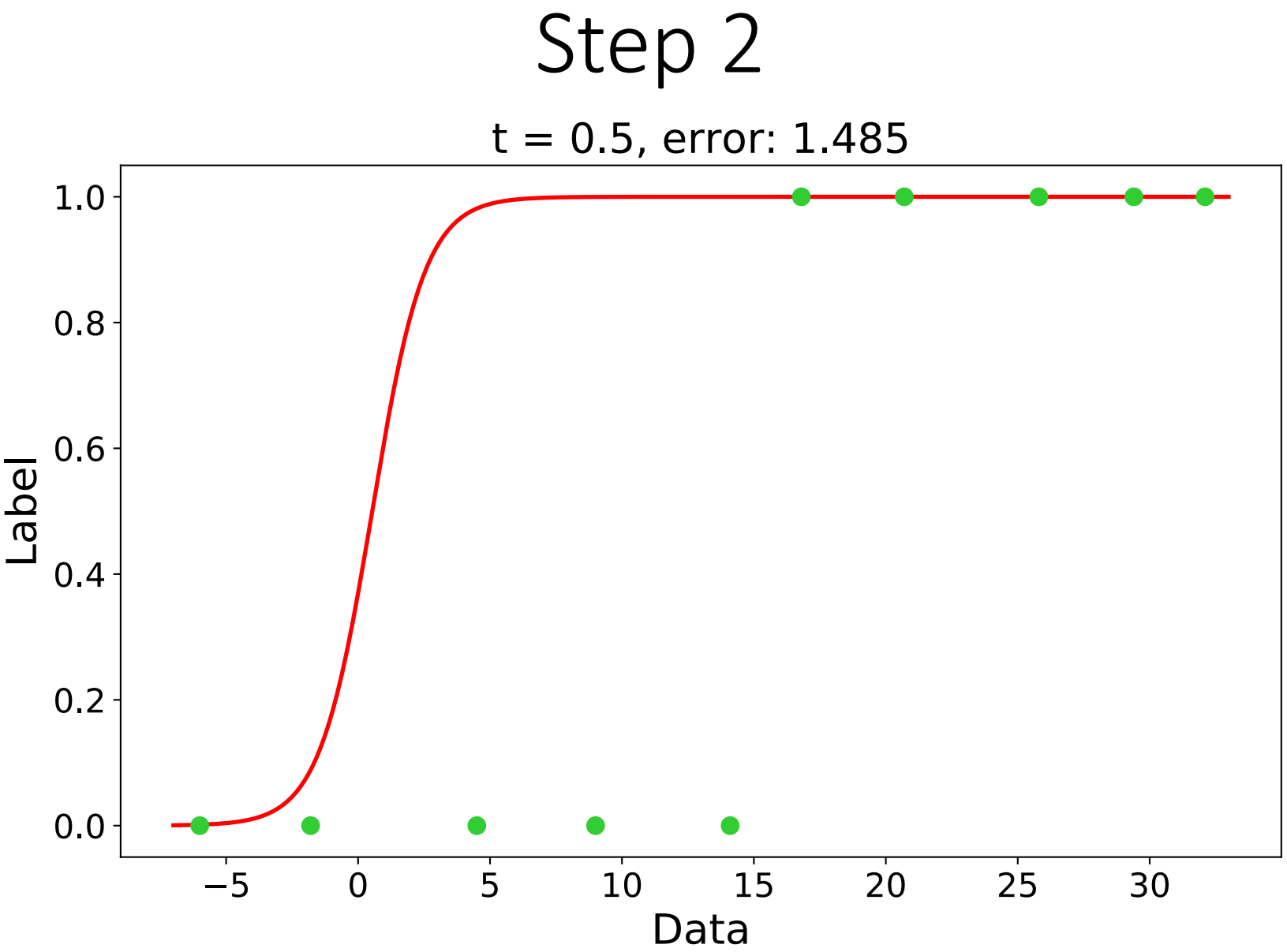


Step 1

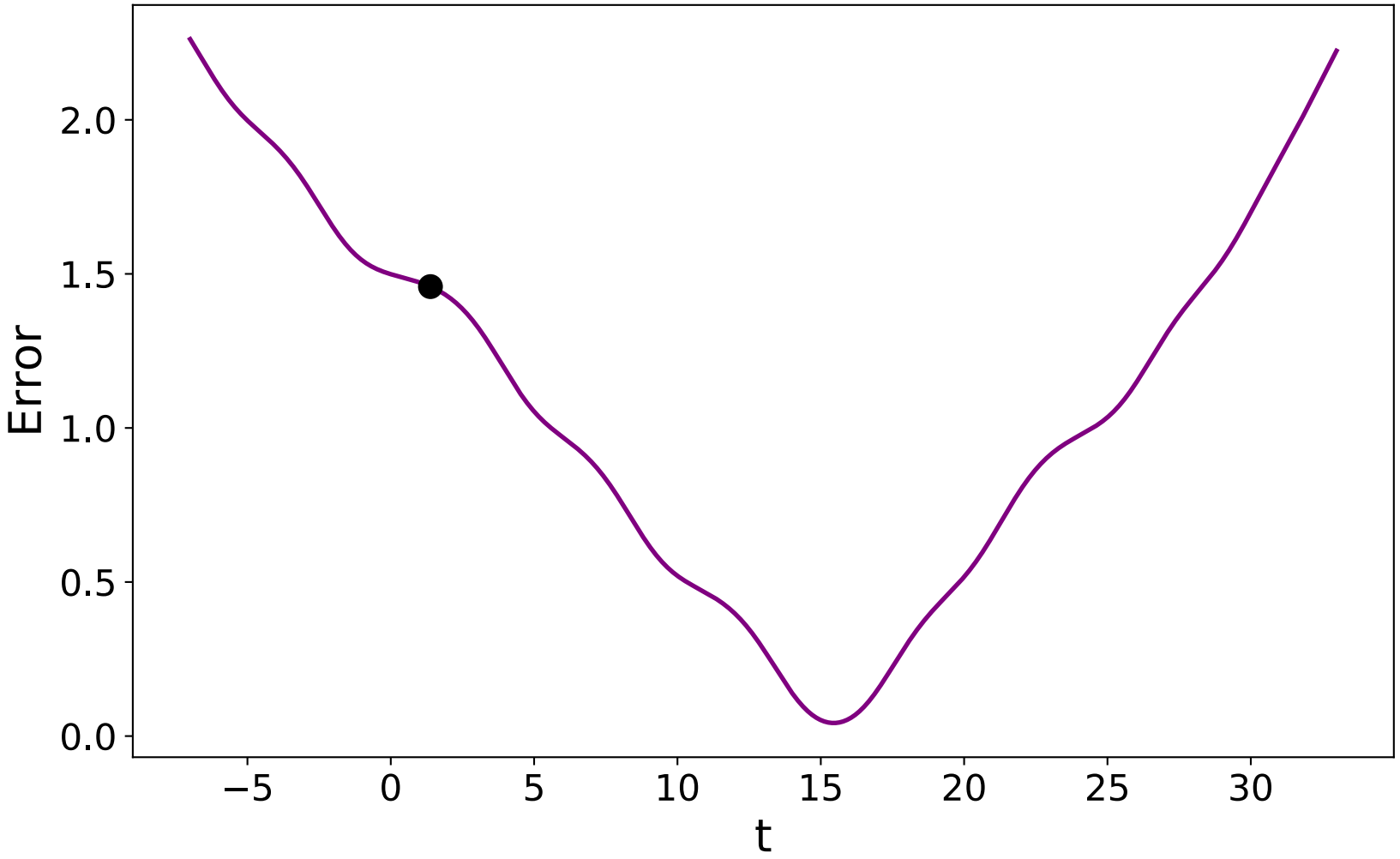


Step 2

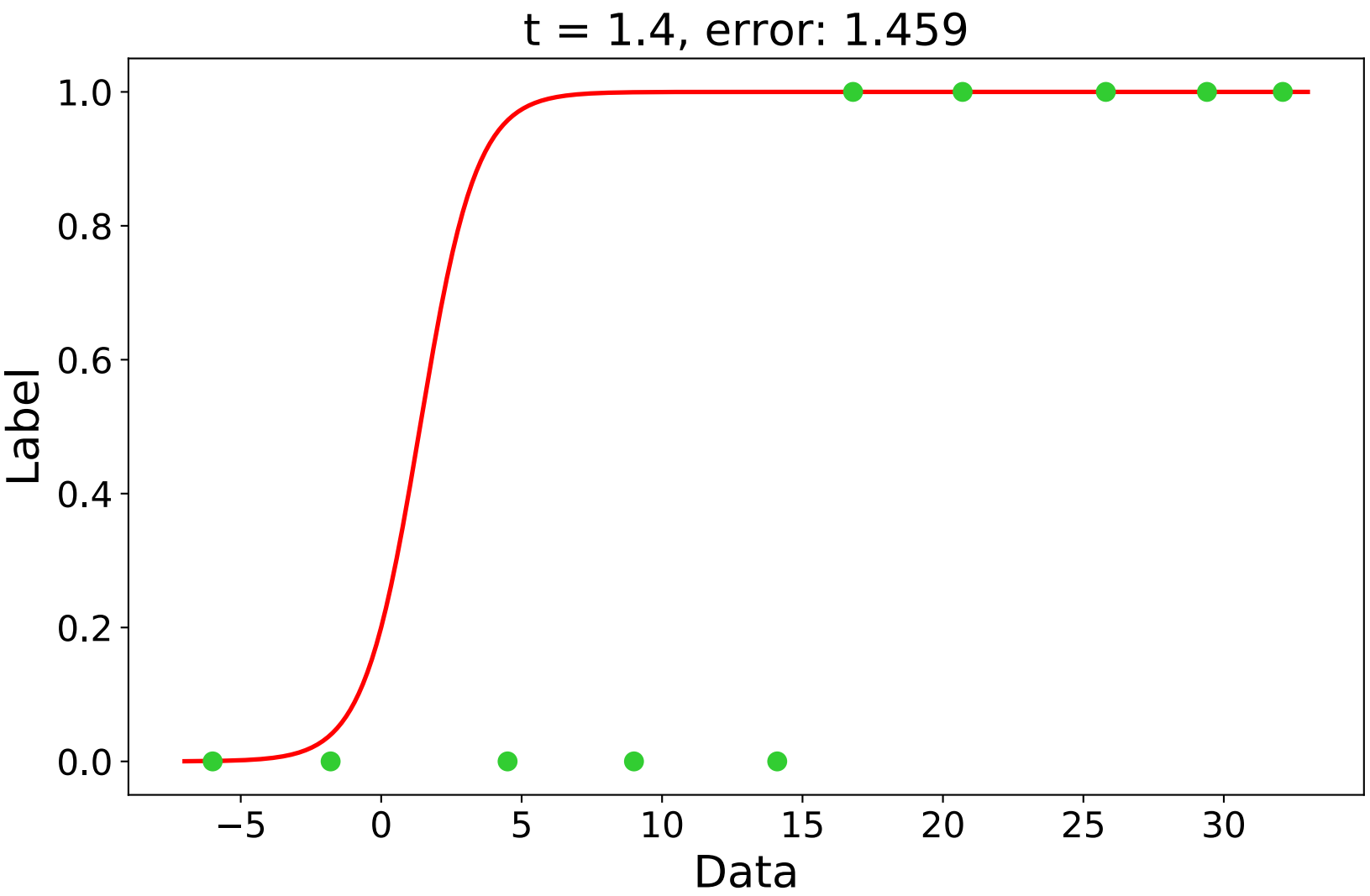



Step 2
t = 0.5, error: 1.485
Label
Data
1.0
0.8
0.6
0.4
0.2
0.0
−5
0
5
10
15
20
25
30

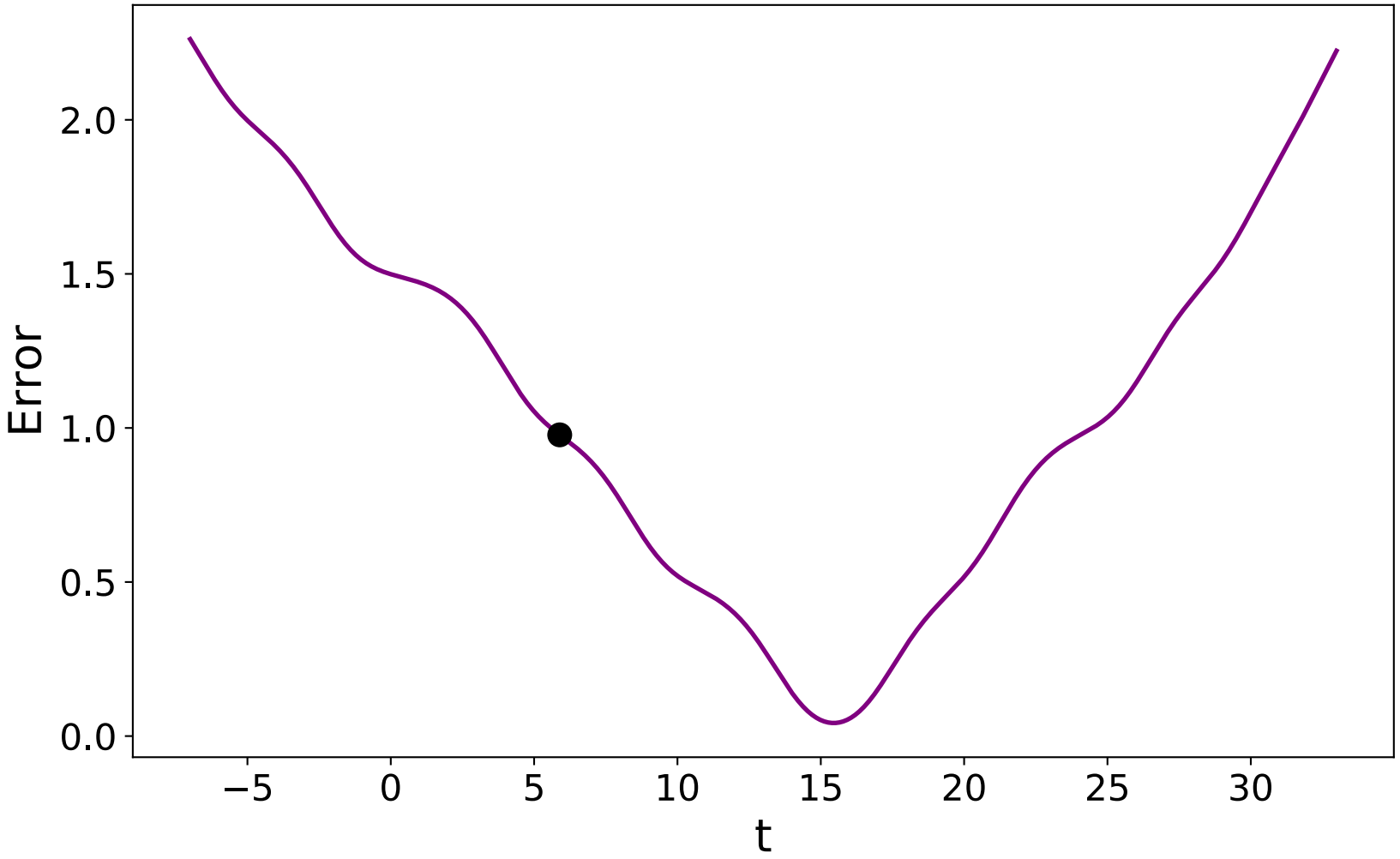
Step 5



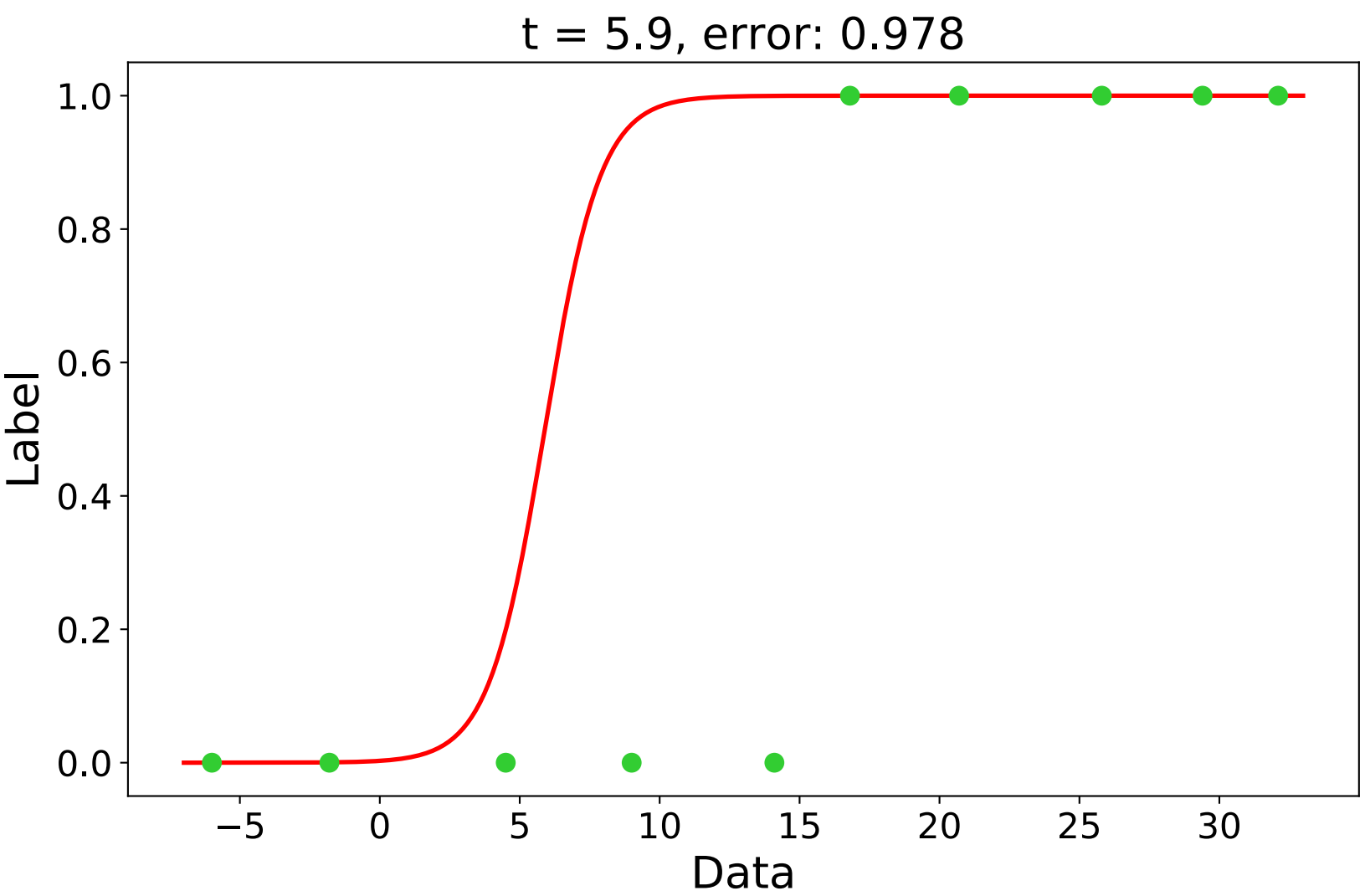
Step 5



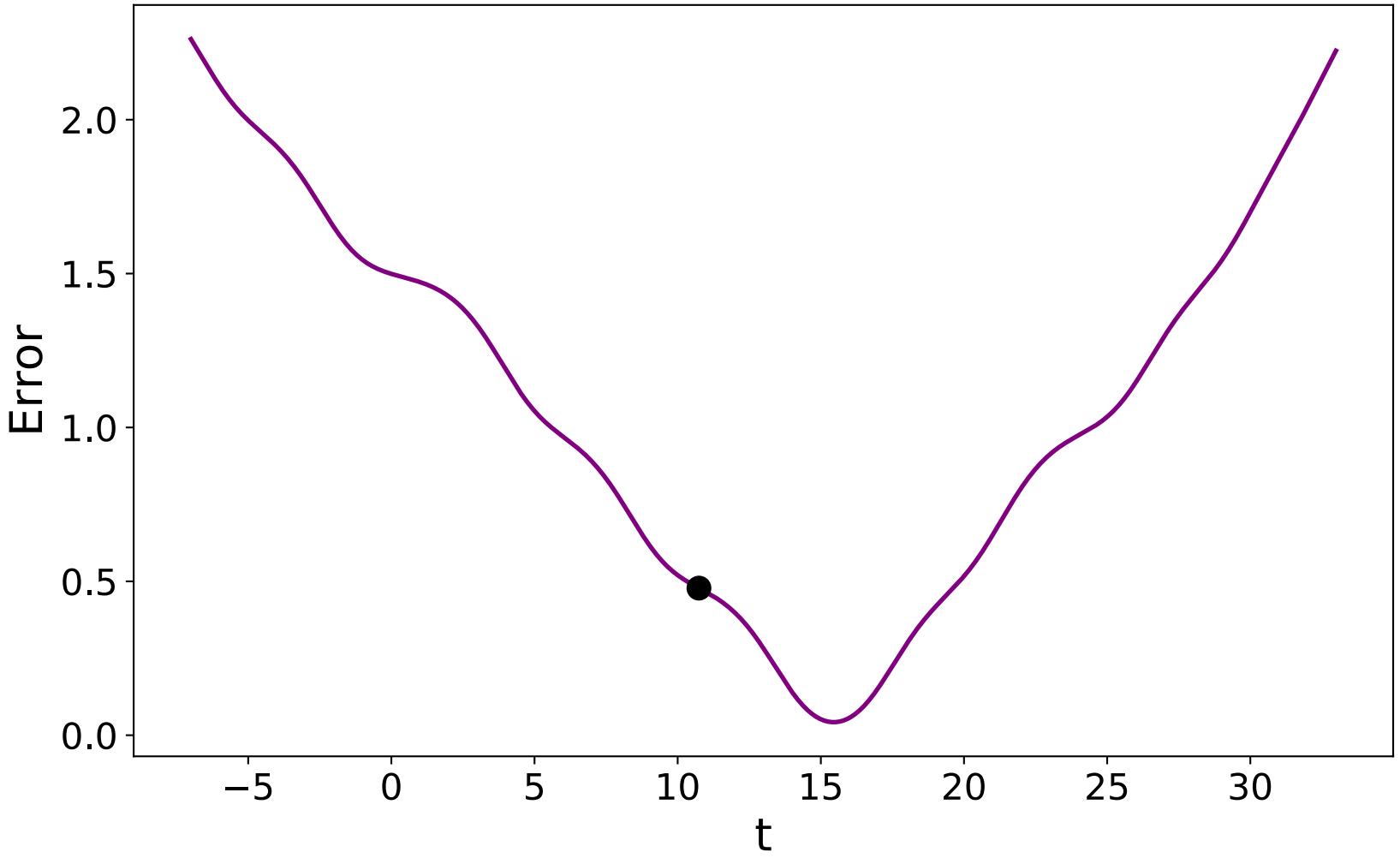
Step 10



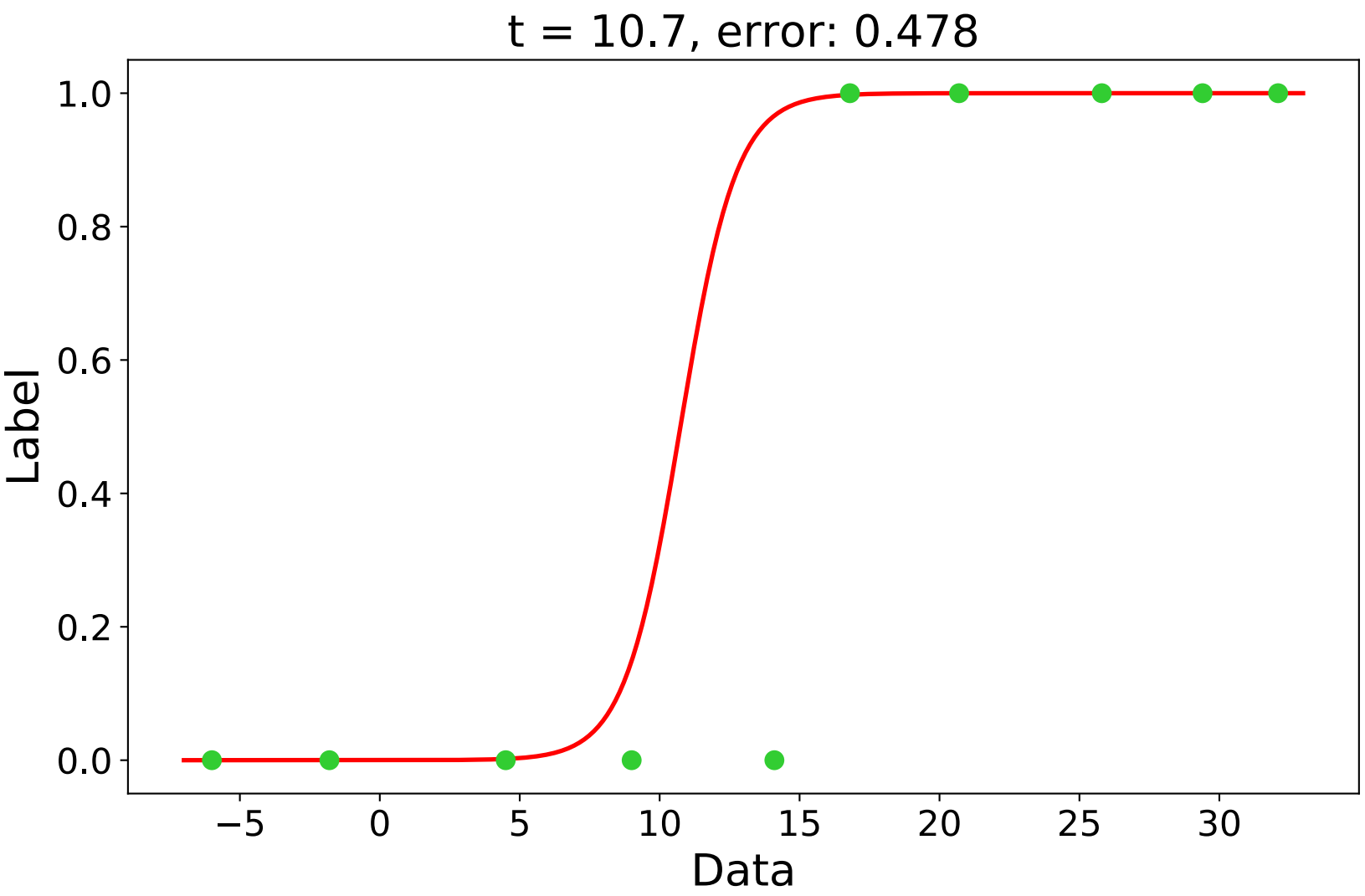
Step 10



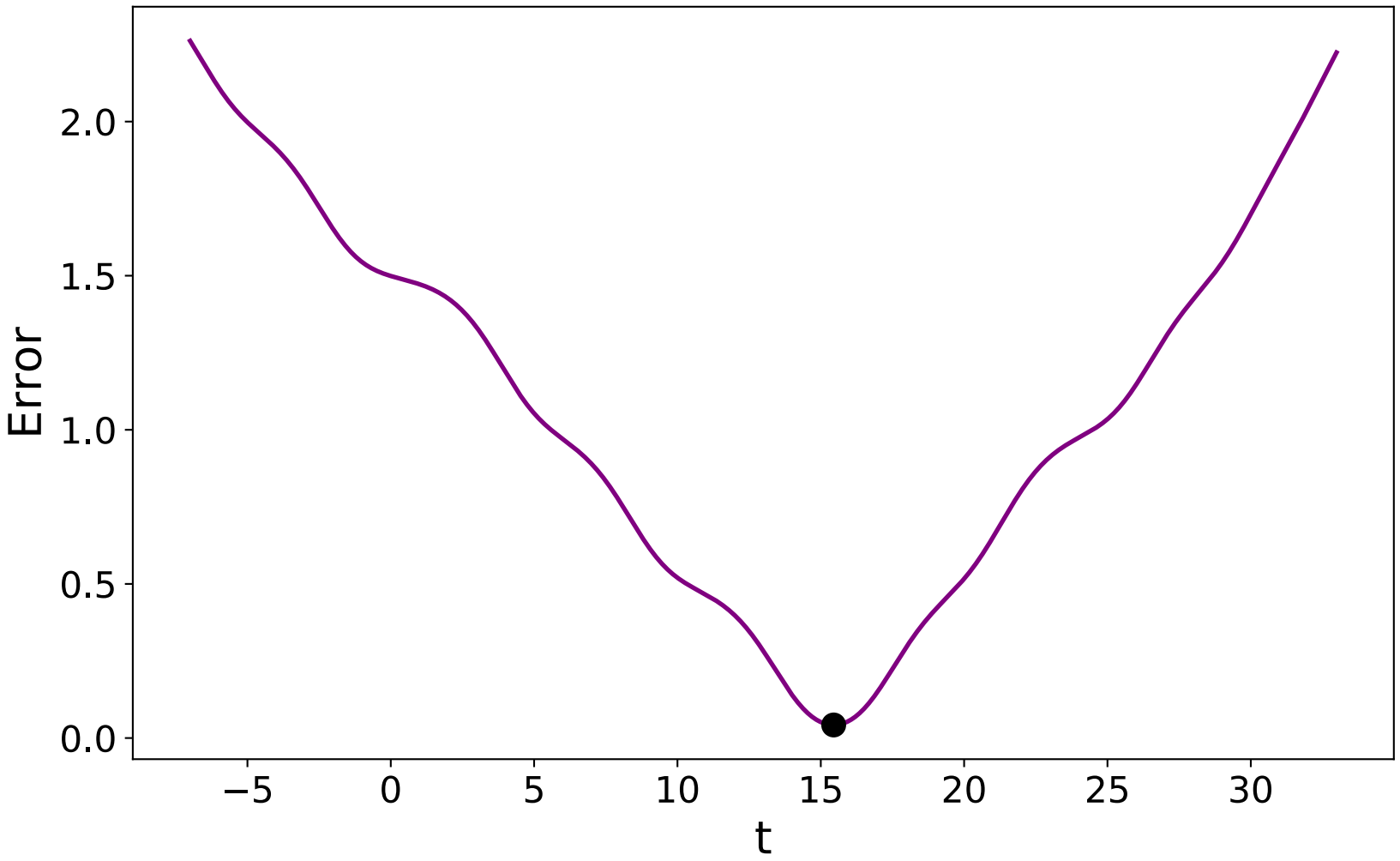
Step 15

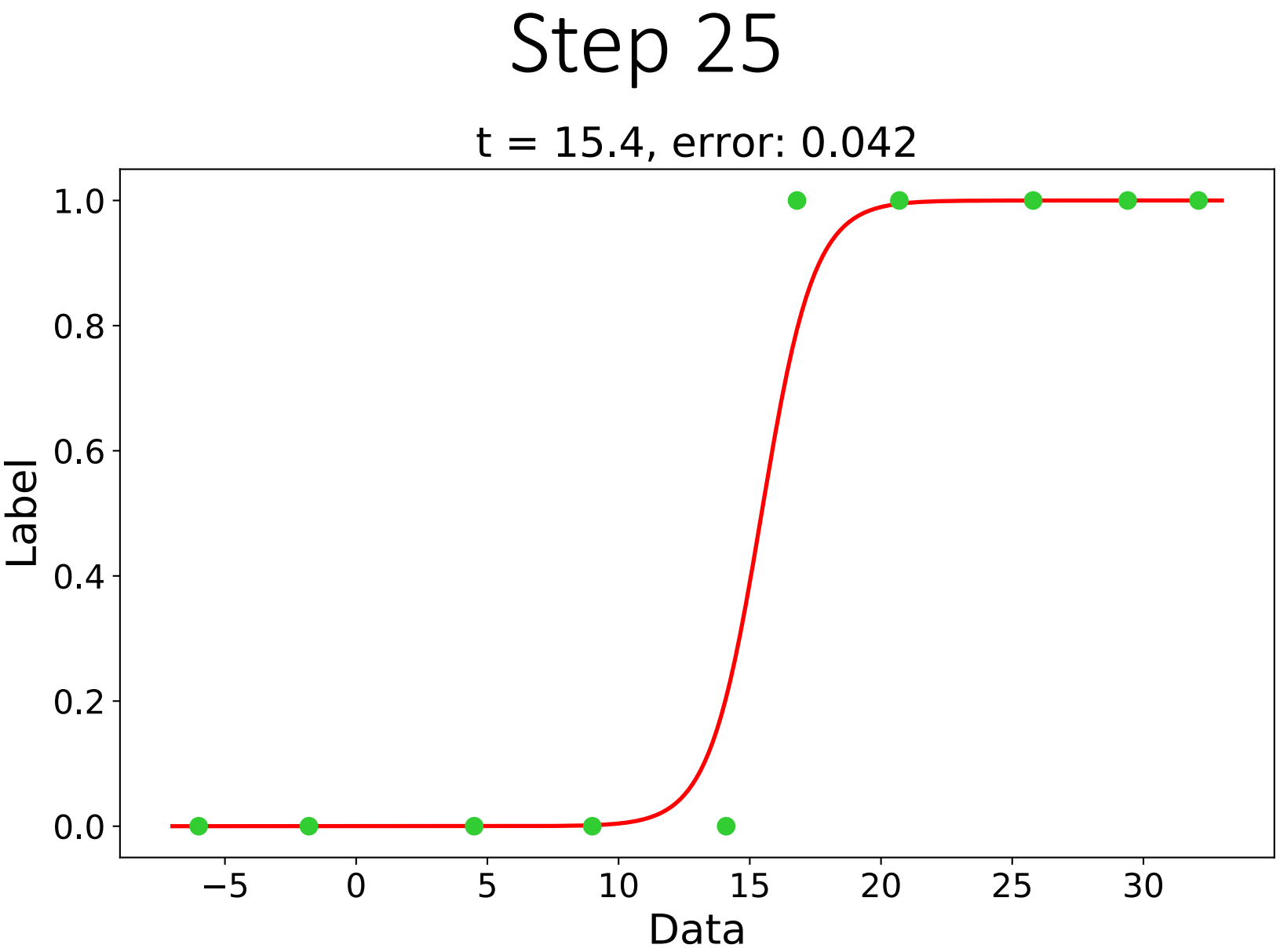


Step 15



Step 25




Step 25
t = 15.4, error: 0.042
Label
Data
1.0
0.8
0.6
0.4
0.2
0.0
−5
0
5
10
15
20
25
30