

Parameter Server on Flink

an approach for model-parallel machine learning

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About us

- Institute for Computer Science and Control, Hungarian Academy of Sciences (MTA SZTAKI)
- Informatics Laboratory
 - „Big Data – Momentum” research group
 - „Data Mining and Search” research group
- Research group with strong industry ties
 - Ericsson, Rovio, Portugal Telekom, etc.

DISCLAIMER

- Gábor Hermann works at
Bol.com
- Largest e-commerce platform in the Netherlands and Belgium



Agenda

1. Model-parallel training
2. Parameter Server on Flink Streaming
3. Batch on streaming?

Model-parallel training

Spam filtering

Free money for you...

Hey, how are you...

:

One click, free sex...

Spam filtering

Free money for you... ✗

Hey, how are you... ✓

⋮

One click, free sex... ✗

Spam filtering

Free money for you... ✗

Hey, how are you... ✓

⋮

One click, free sex... ✗

Hi, how was FF2017... ?

Spam filtering

Free money for you...

✗



Hey, how are you...

✓



:

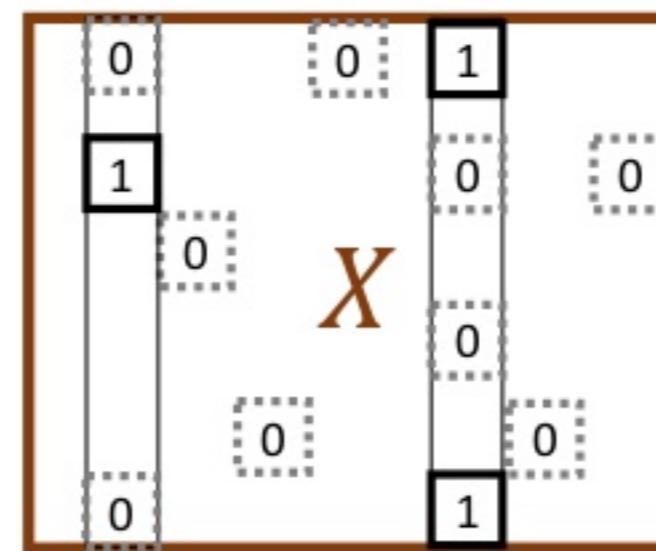
One click, free sex...

✗



Hi, how was FF2017...

?



Spam filtering

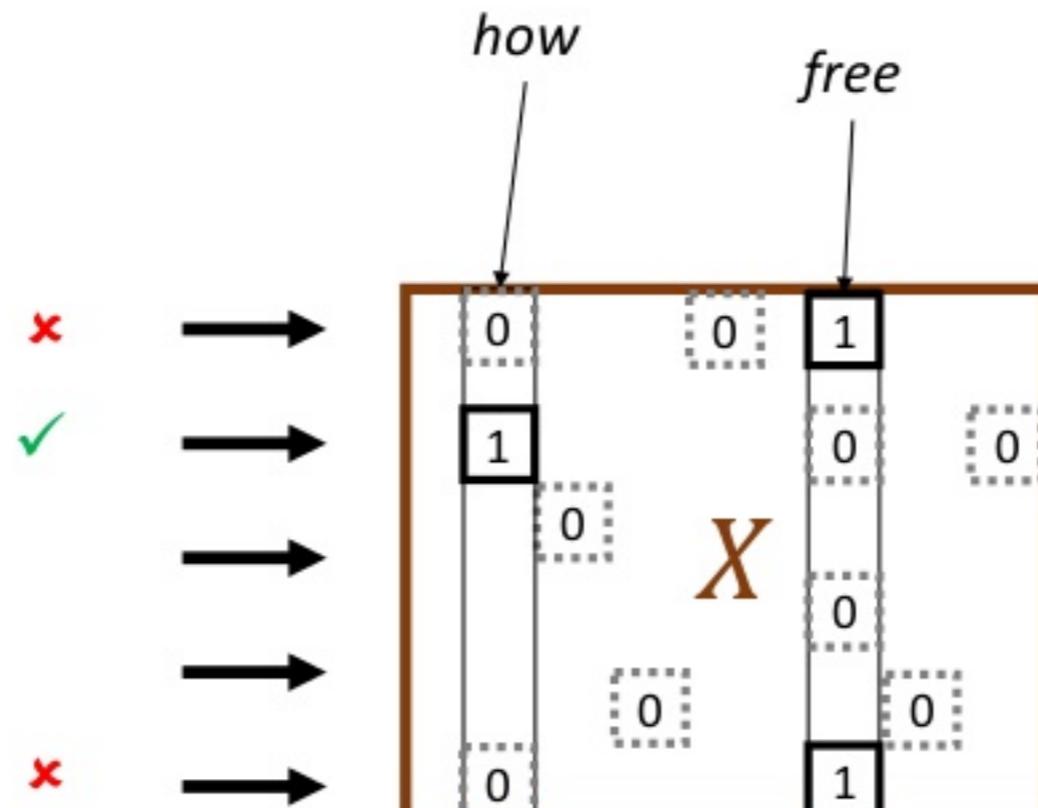
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Spam filtering

Free money for you...

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Hey, how are you...

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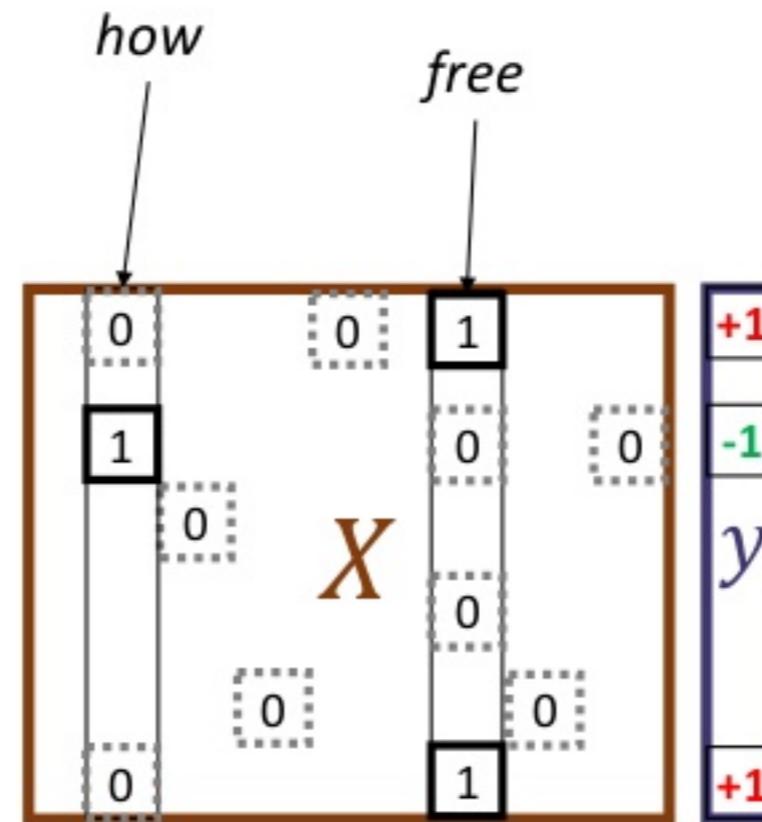
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Hi, how was FF2017...

?



Spam filtering

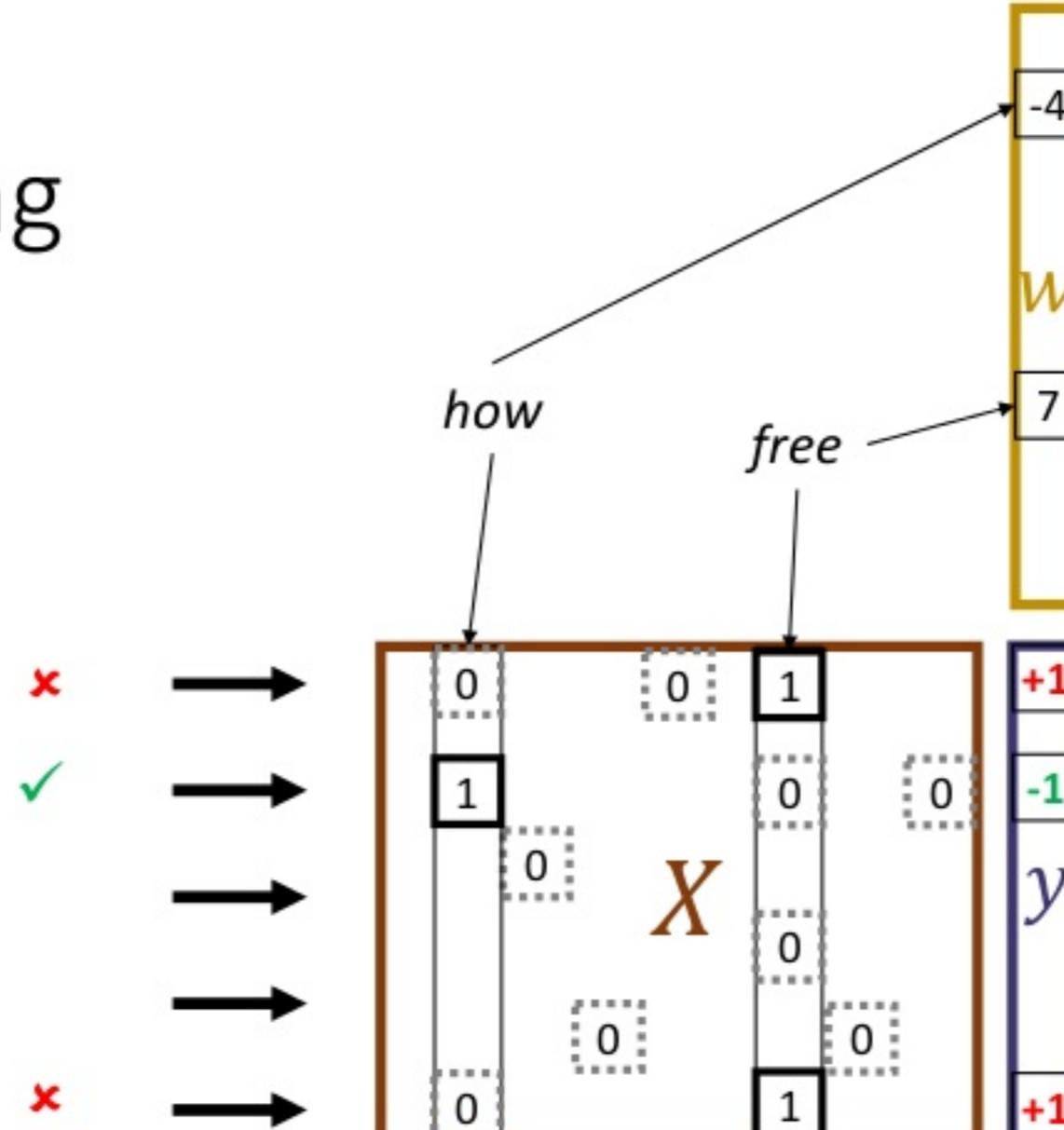
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$$X \cdot w \approx y$$

Spam filtering

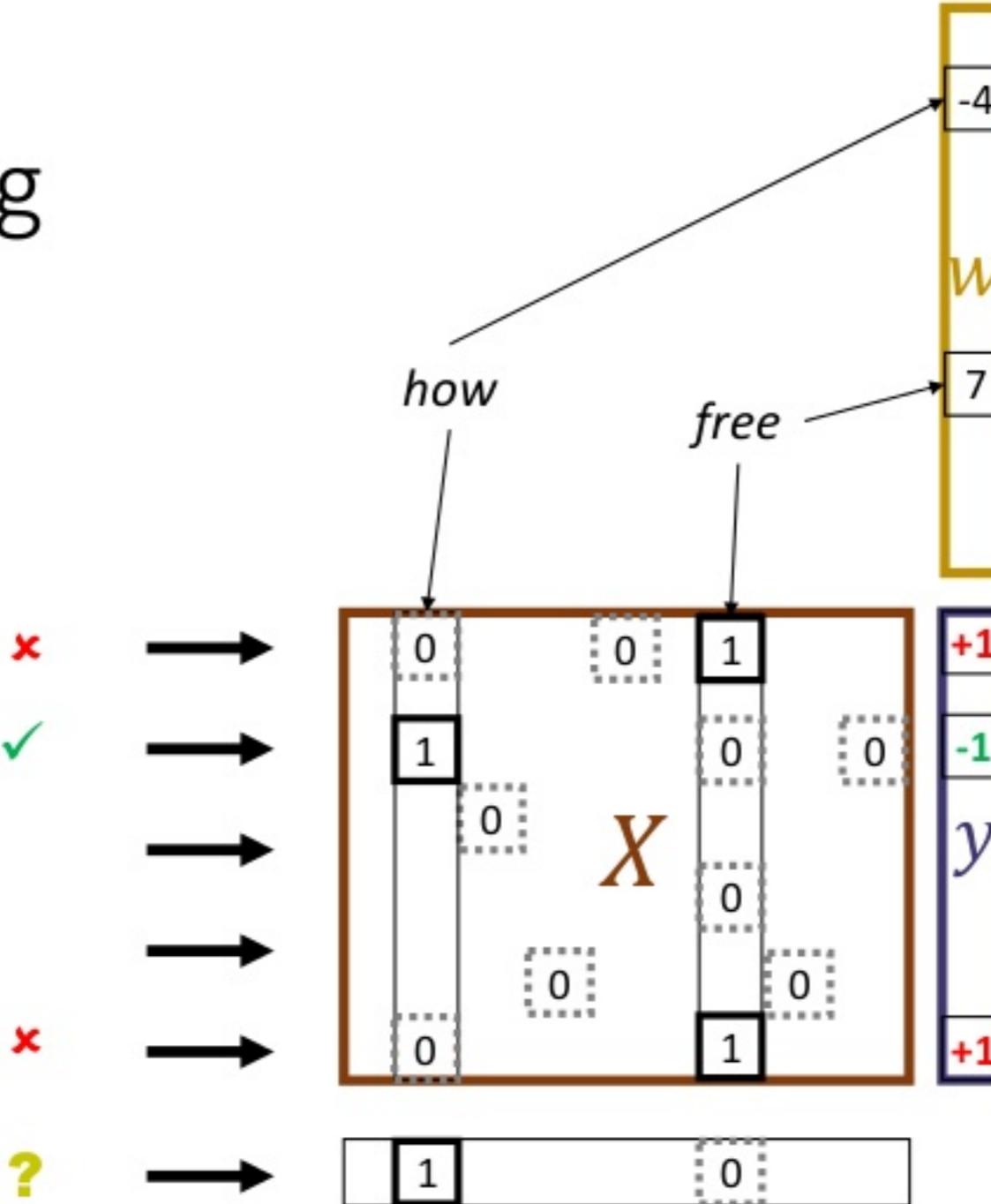
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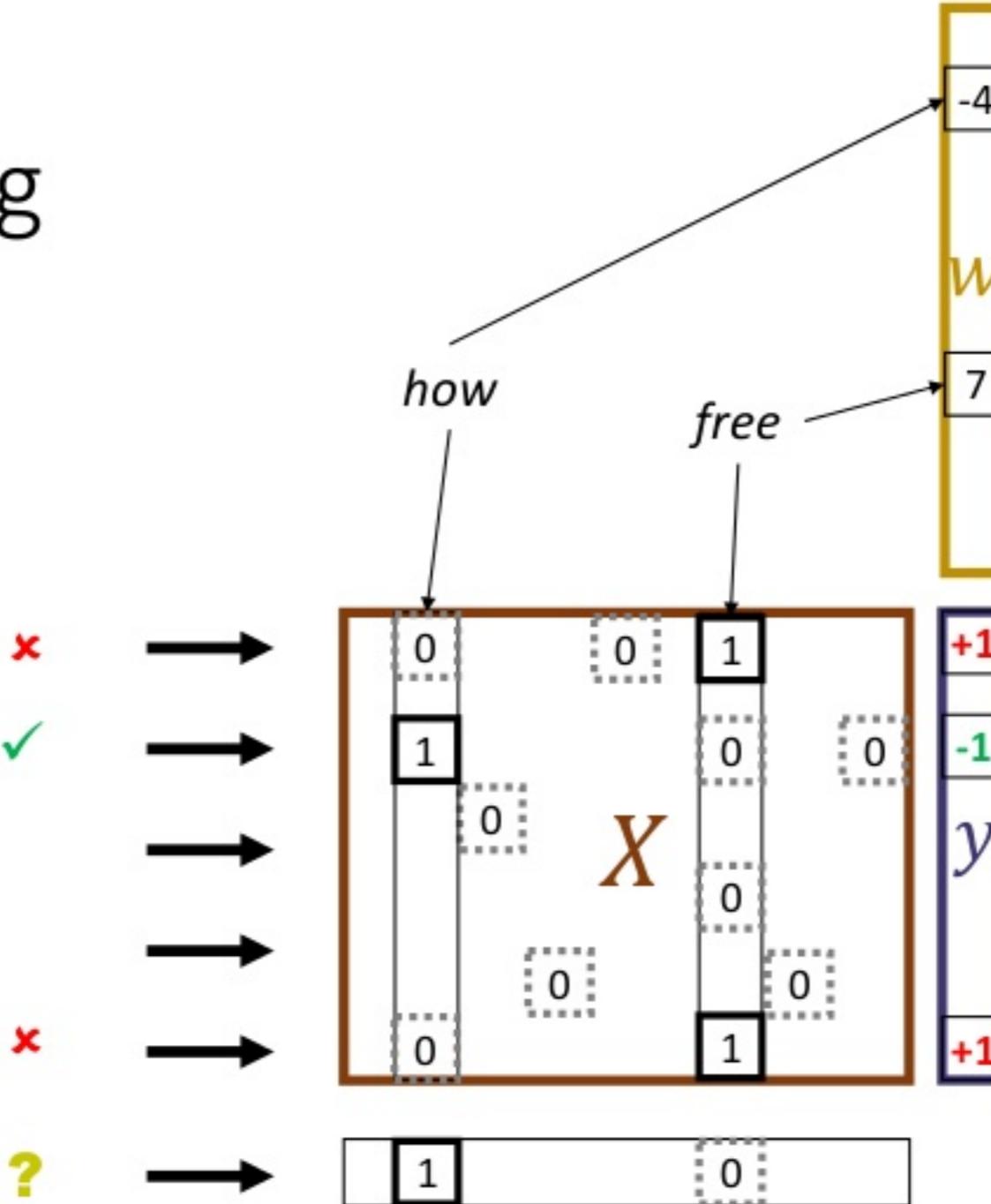
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Spam filtering

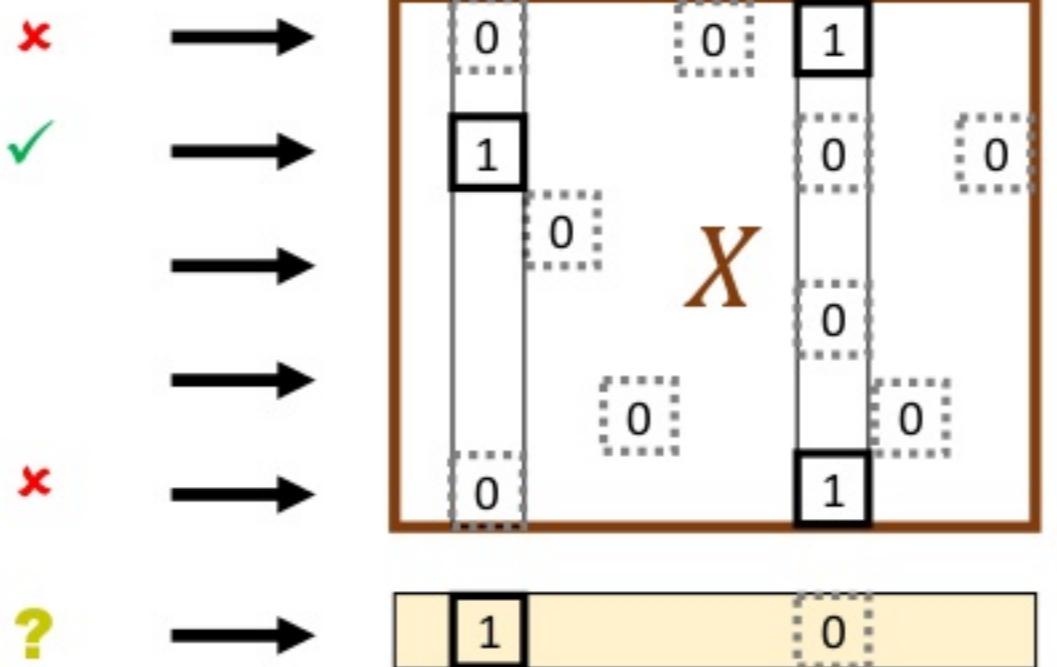
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$$X \cdot w \approx y$$

Spam filtering

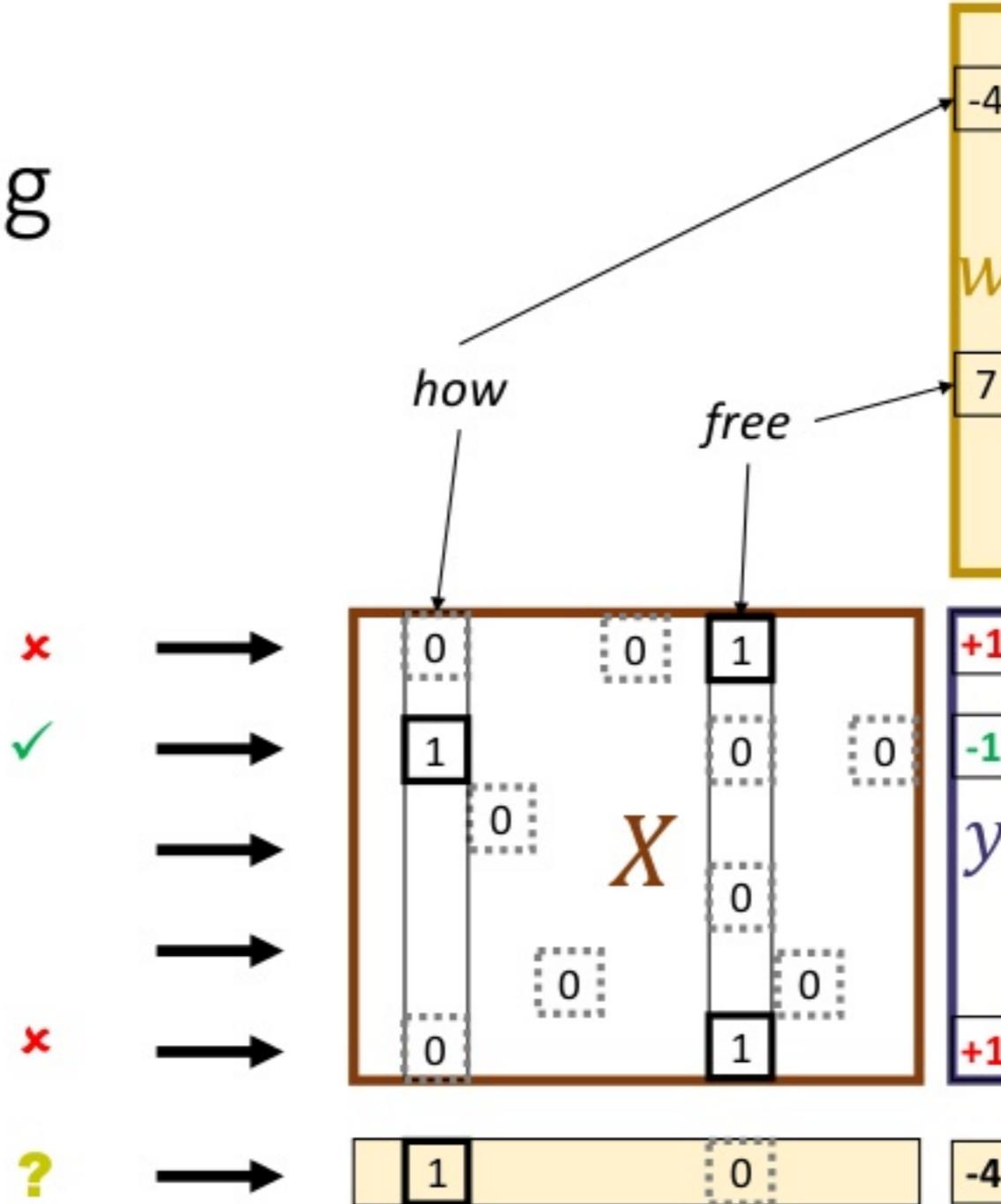
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Spam filtering

Free money for you...

x



Hey, how are you...

✓



:

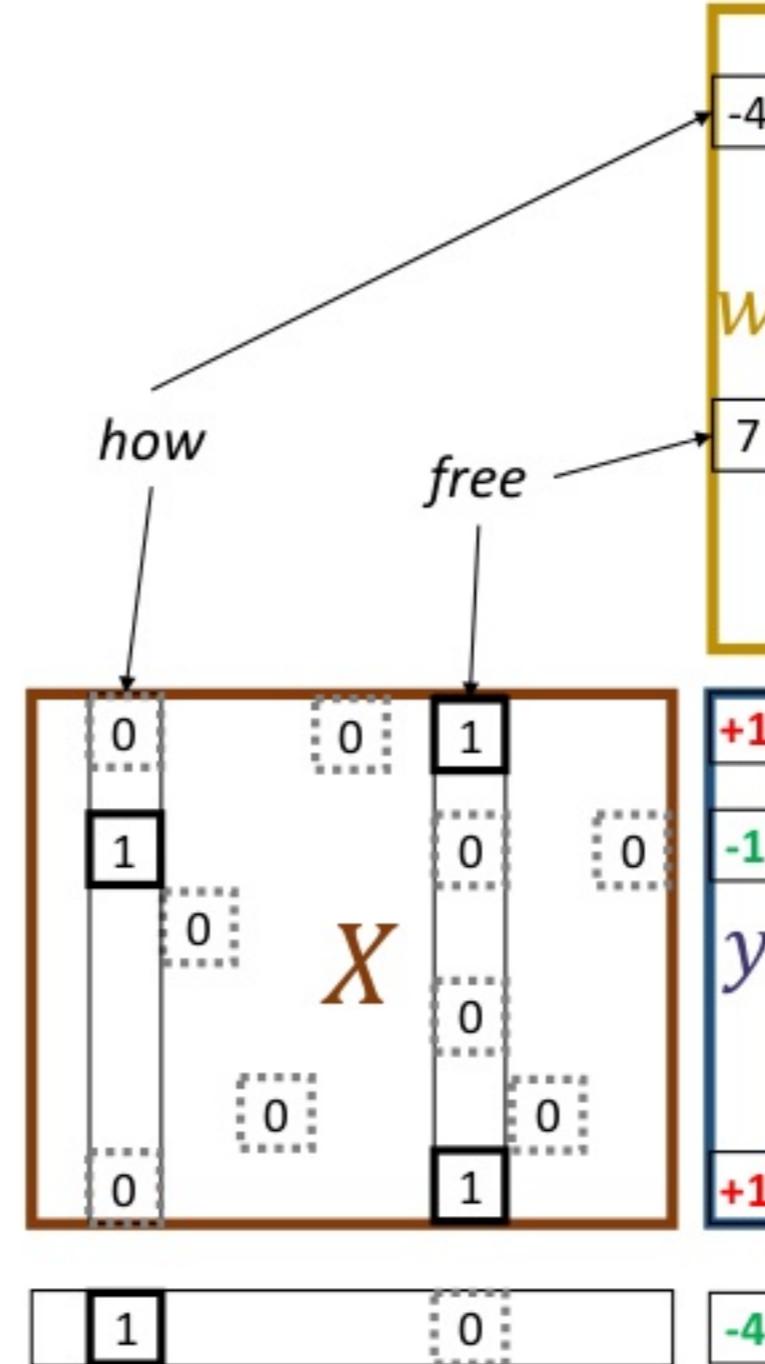
One click, free sex...

x



Hi, how was FF2017...

✓



$$X \cdot w \approx y$$

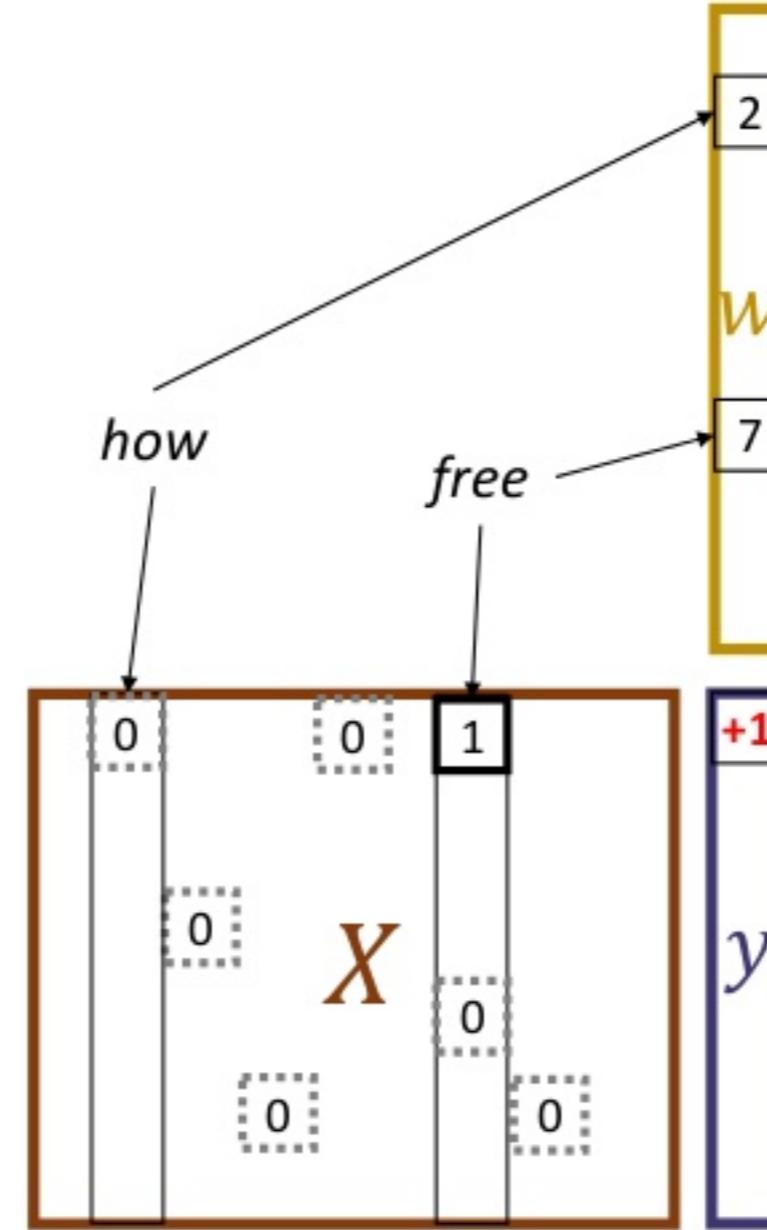
Spam filtering with Passive-Aggressive algorithm



Spam filtering with Passive-Aggressive algorithm

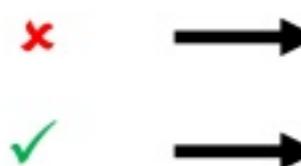
Free money for you...

✗

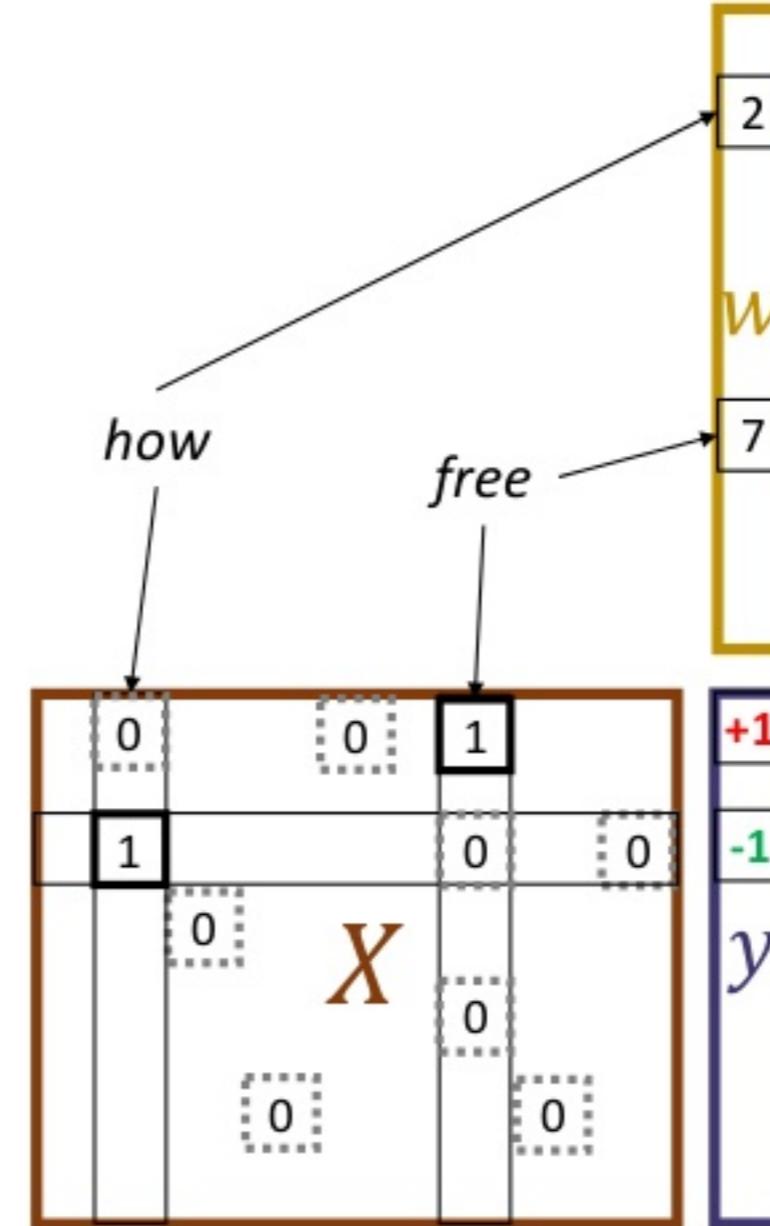


Spam filtering with Passive-Aggressive algorithm

Free money for you... ✗



Hey, how are you... ✓

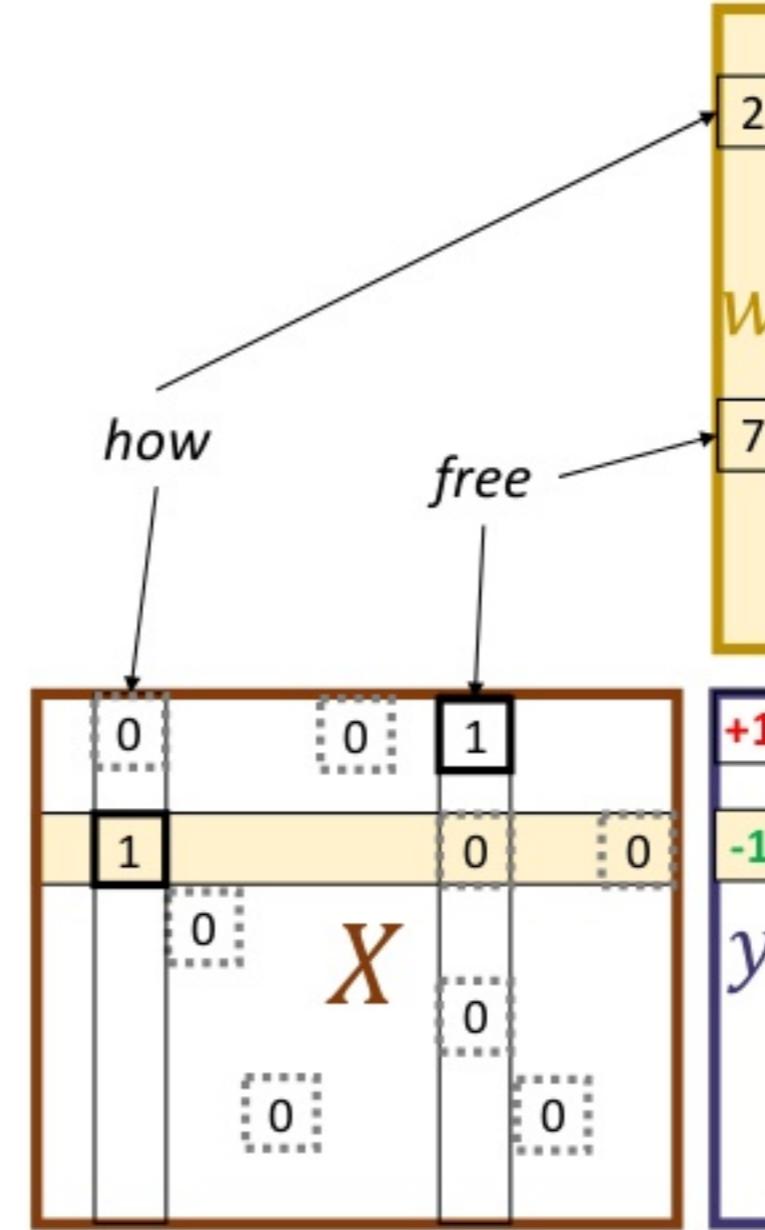


Spam filtering with Passive-Aggressive algorithm

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Hey, how are you... ✓

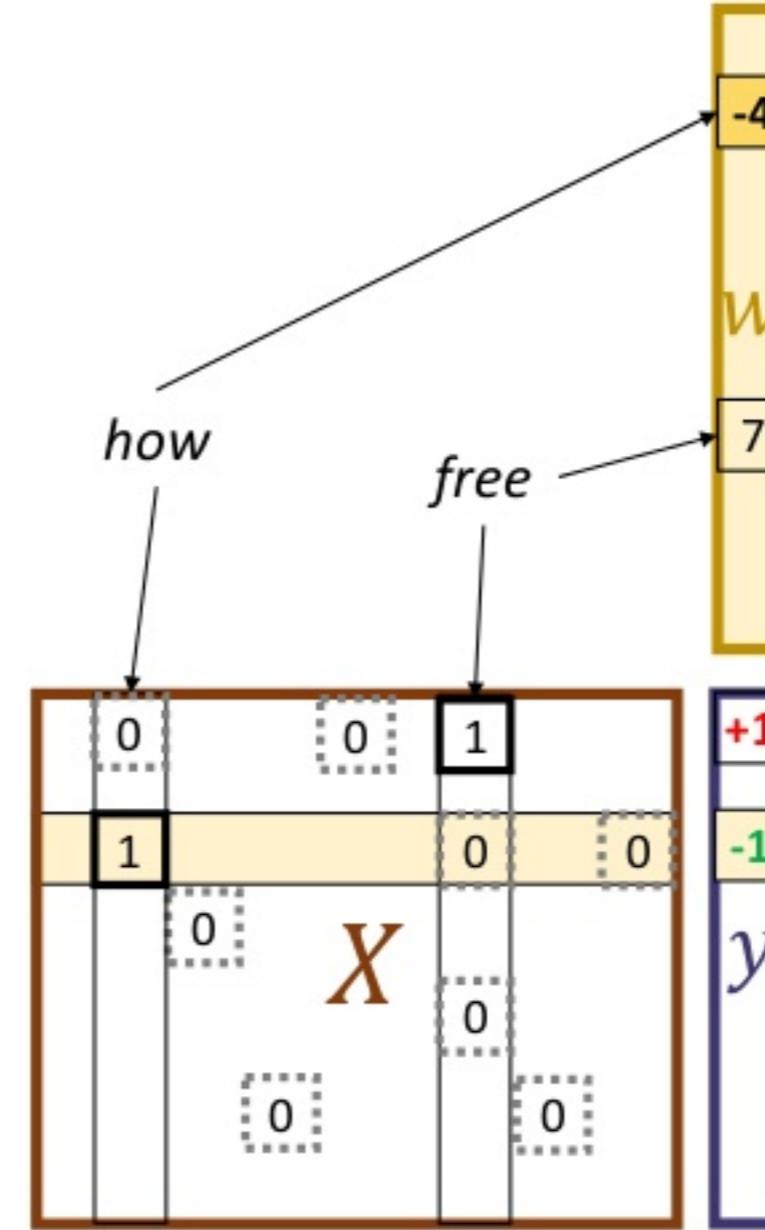


Spam filtering with Passive-Aggressive algorithm

Free money for you... ✗



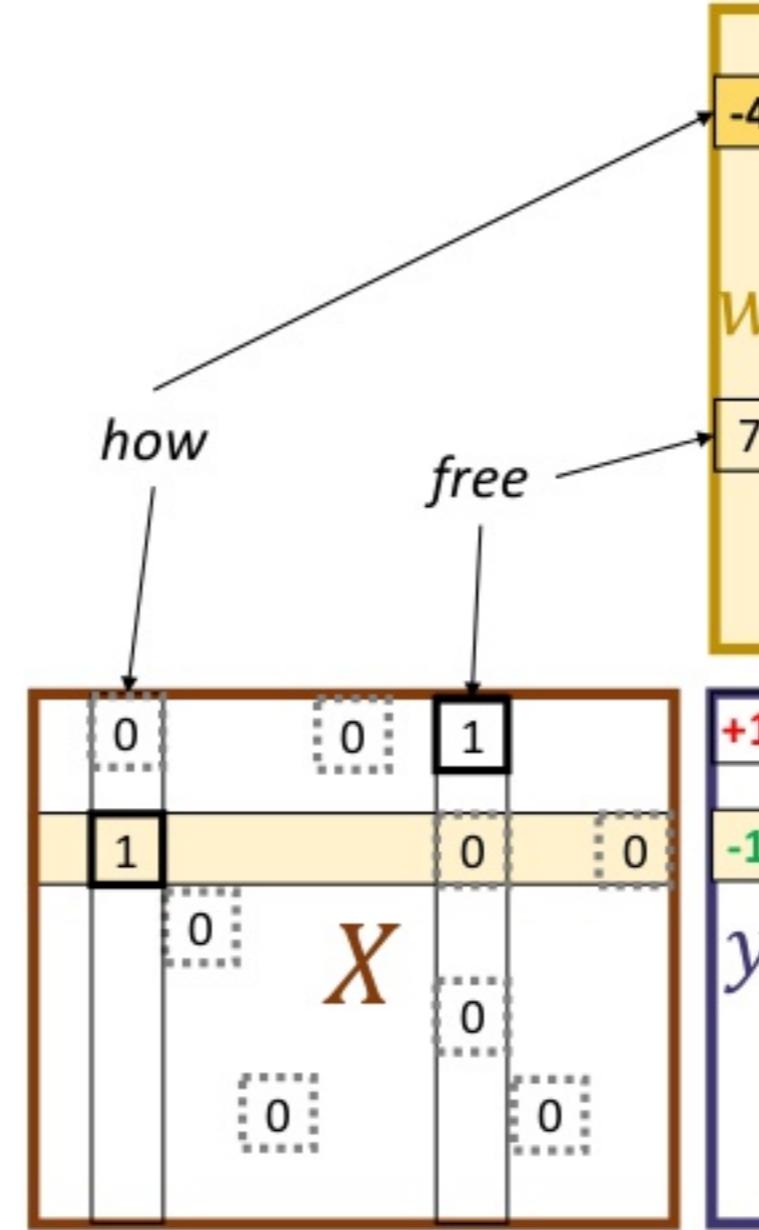
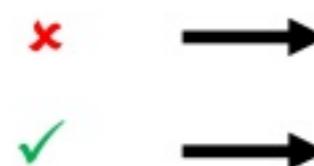
Hey, how are you... ✓



Spam filtering with Passive-Aggressive algorithm

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Crammer et al.: *Online
Passive-Aggressive
Algorithms* (2006)

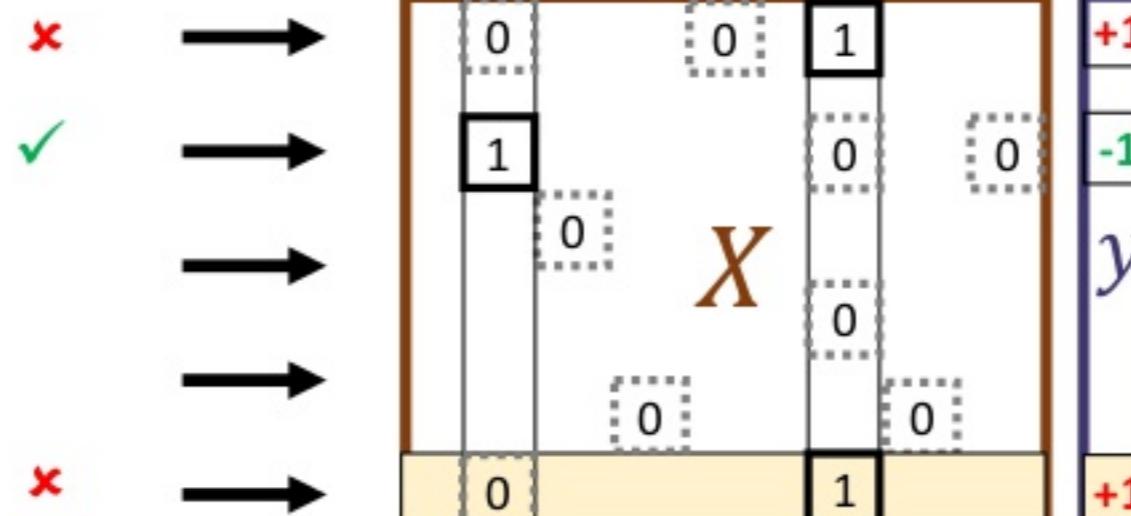
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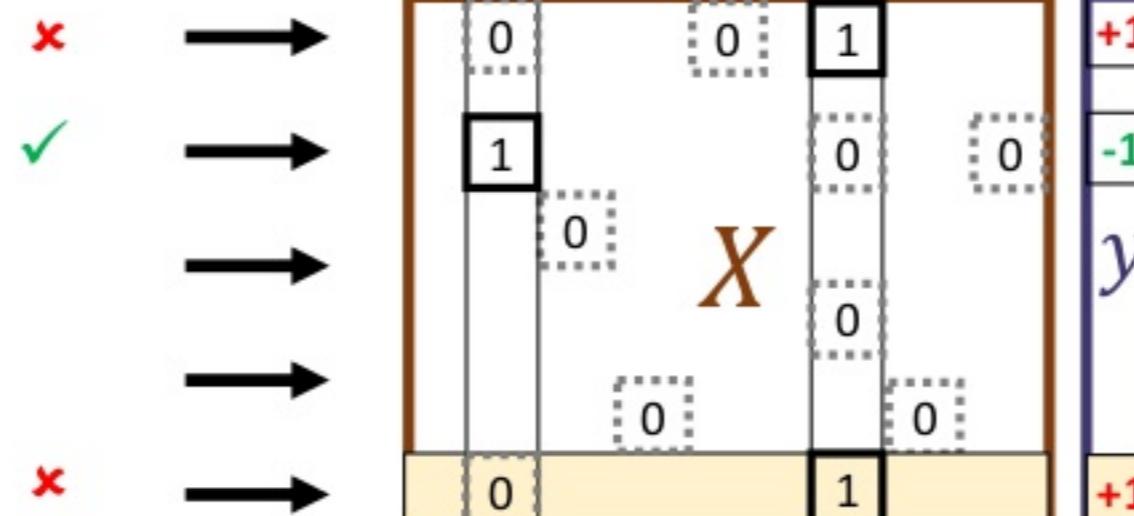
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Spam filtering with Passive-Aggressive algorithm

Free money for you...

x

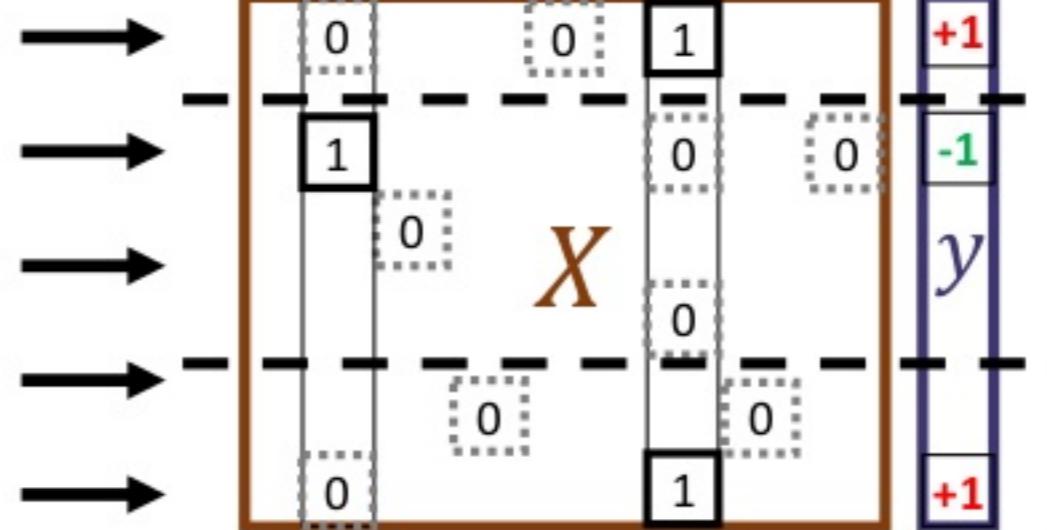
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Spam filtering with Passive-Aggressive algorithm

Free money for you...

✗



Hey, how are you...

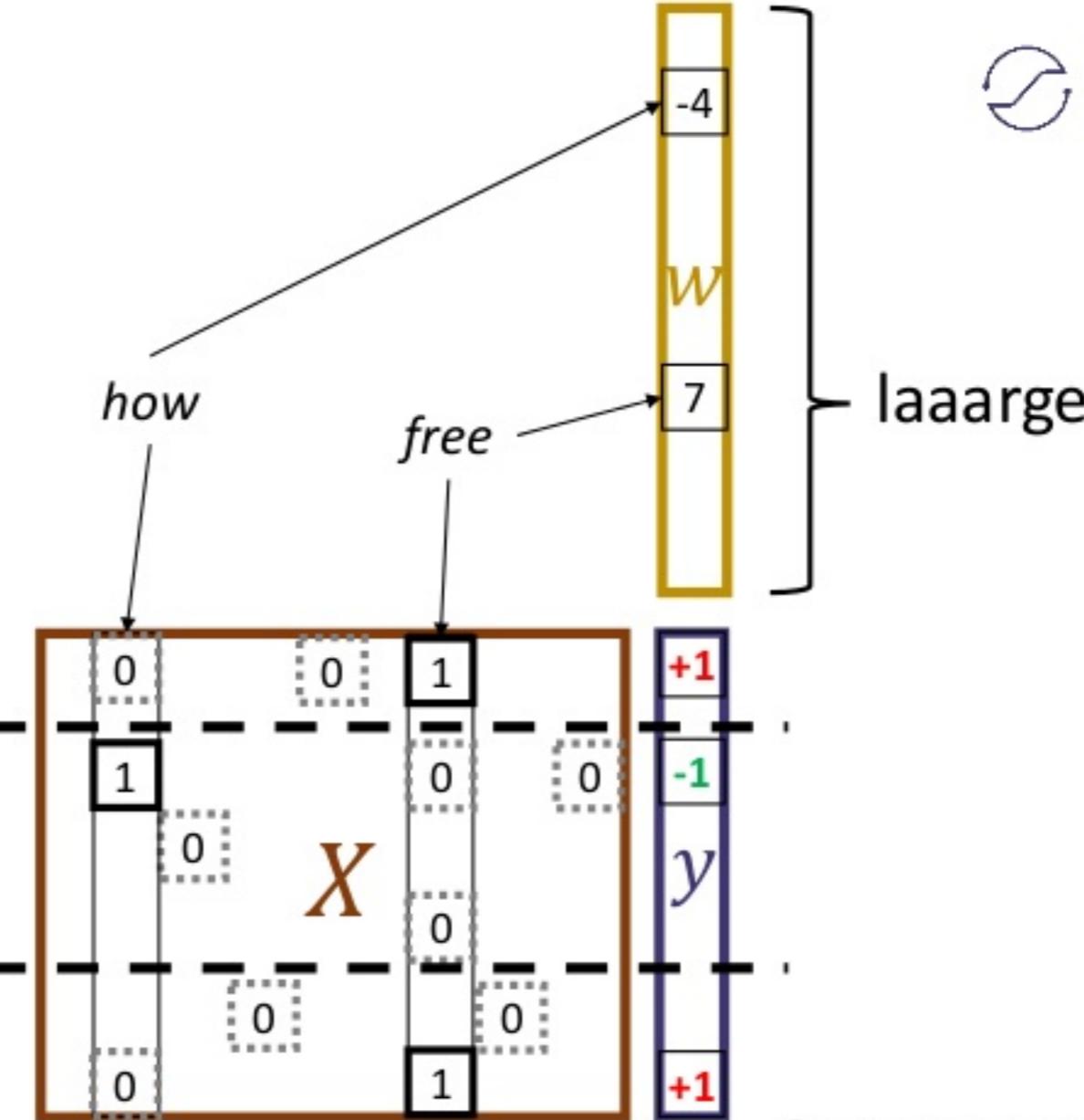
✓



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One click, free sex...

✗



Crammer et al.: *Online
Passive-Aggressive
Algorithms* (2006)

Spam filtering with Passive-Aggressive algorithm

Free money for you...

✗



Hey, how are you...

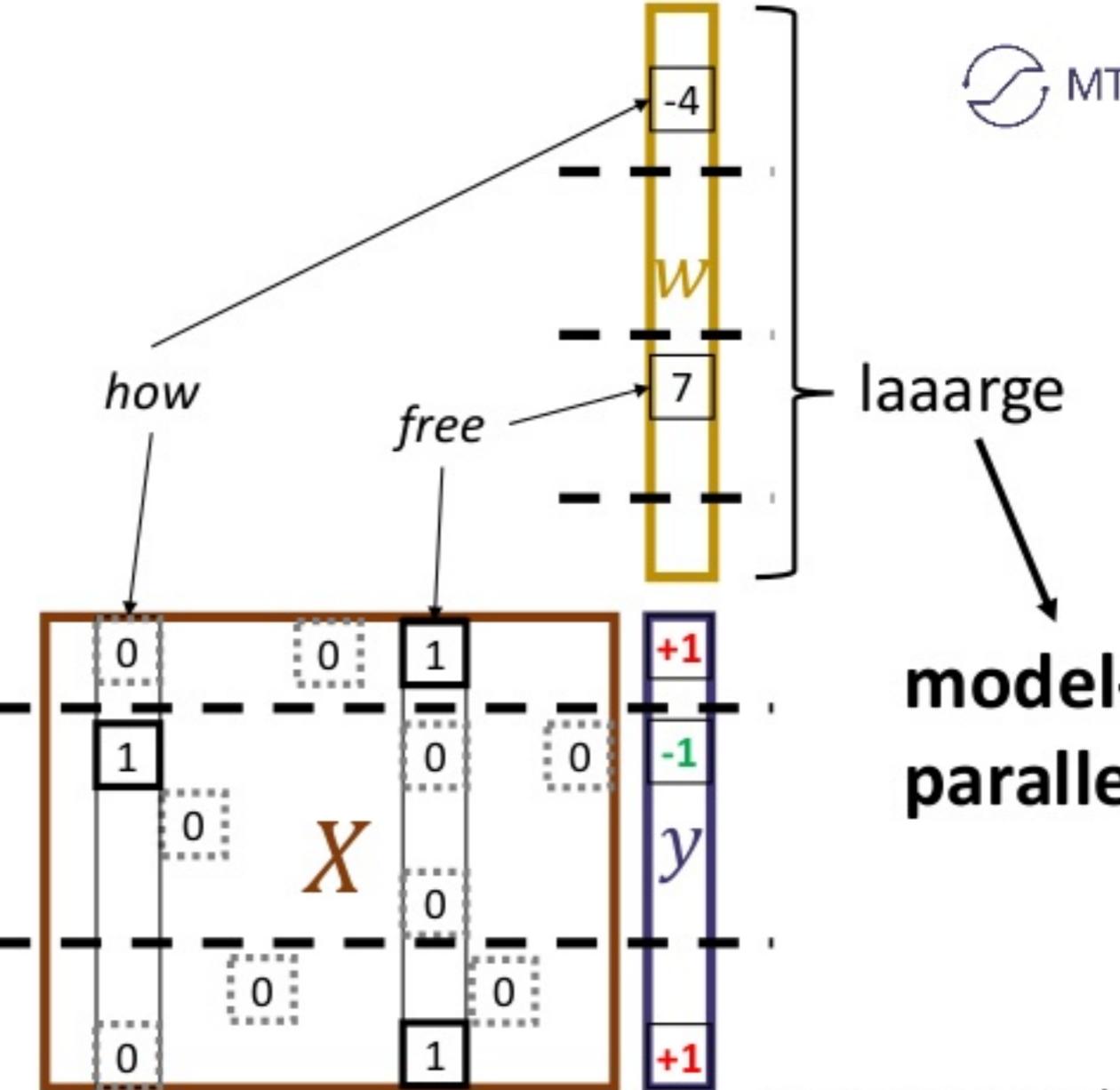
✓



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One click, free sex...

✗



Crammer et al.: *Online
Passive-Aggressive
Algorithms* (2006)

Spam filtering with Passive-Aggressive algorithm

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Hey, how are you...

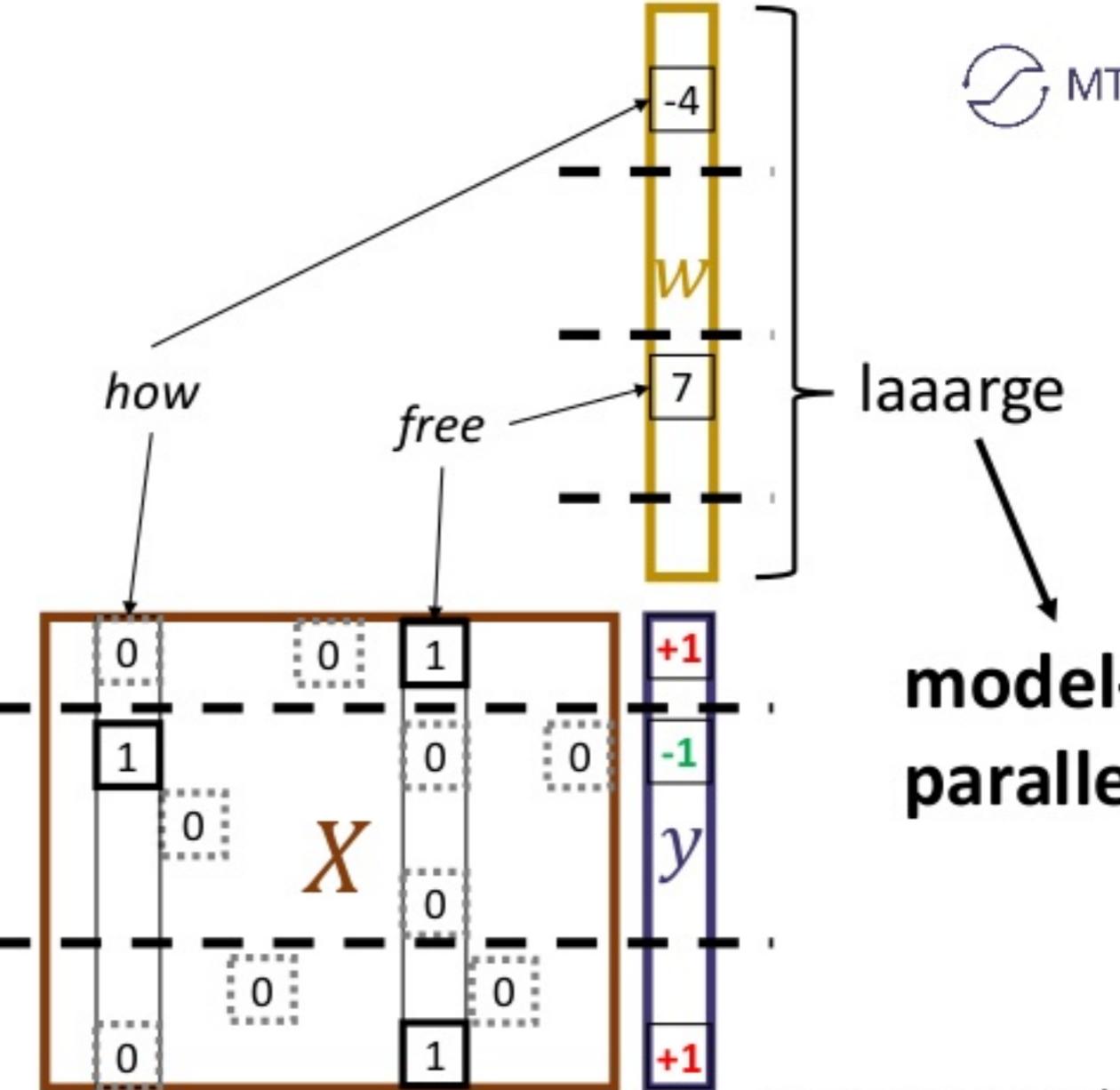
✓



:

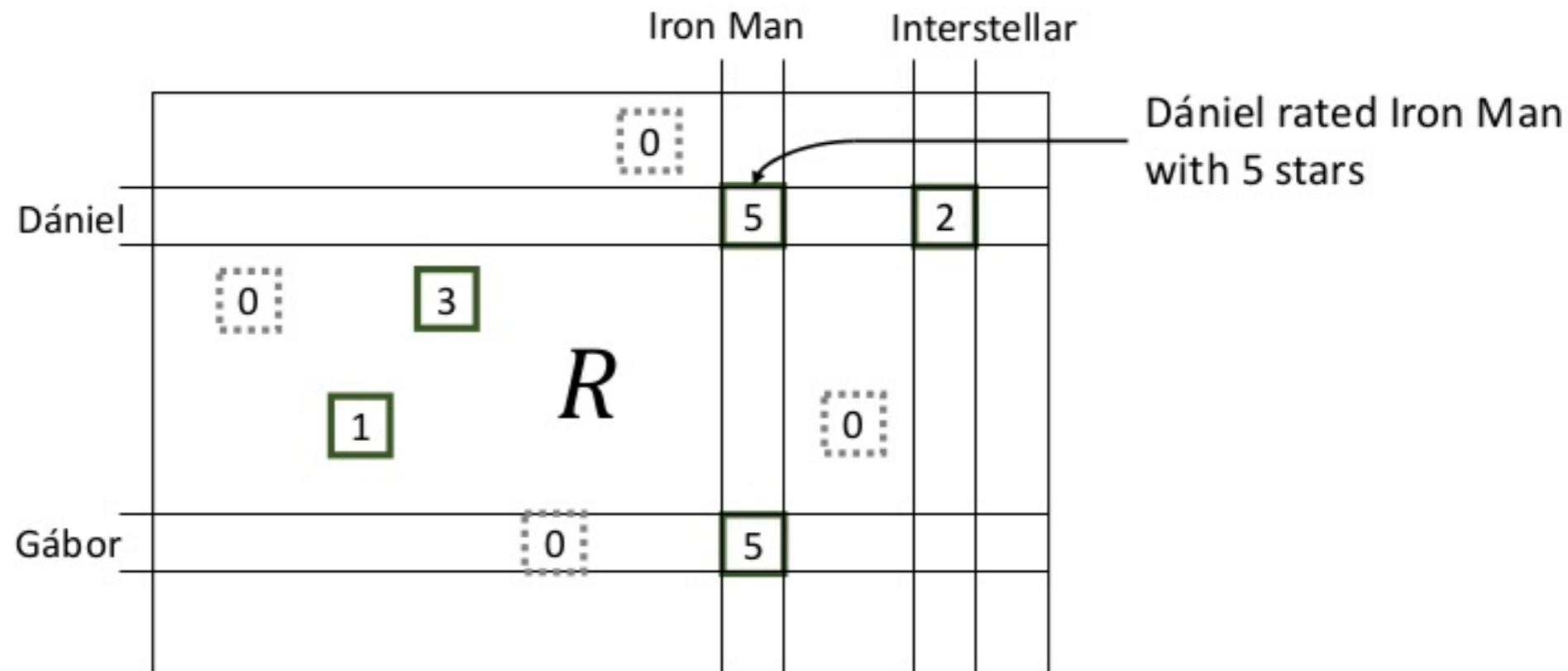
One click, free sex...

✗

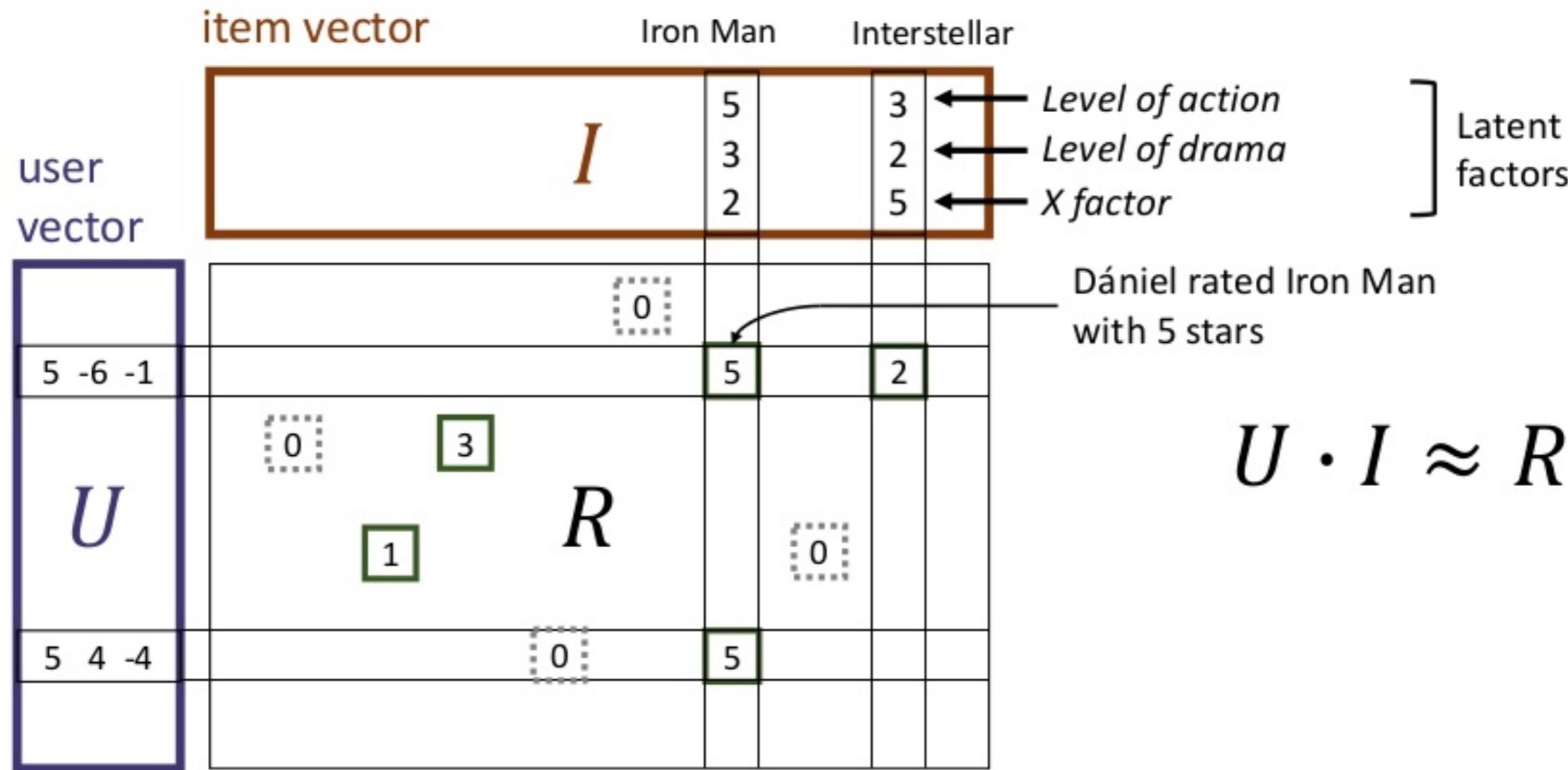


Crammer et al.: *Online
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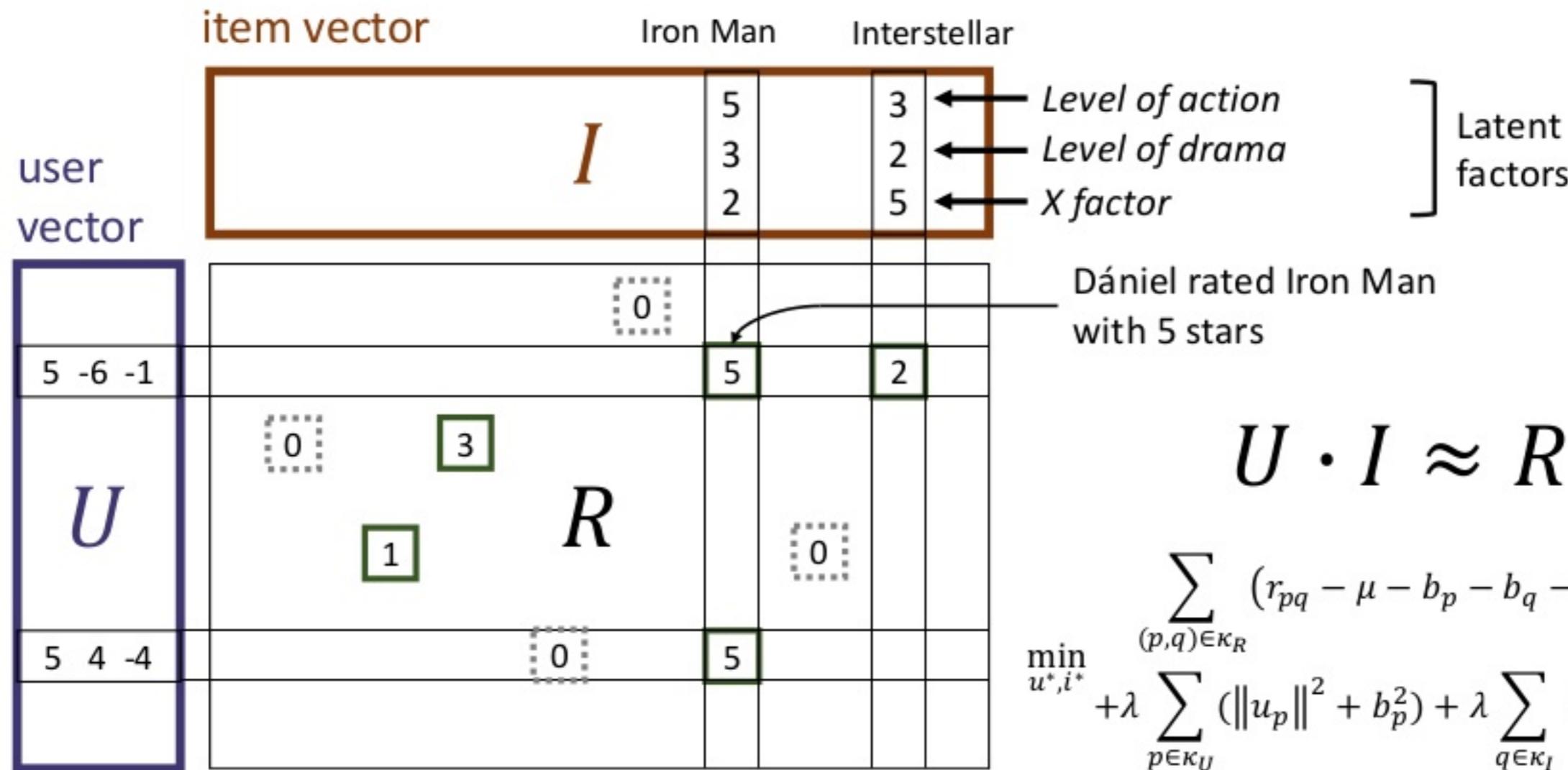
Recommendation with matrix factorization



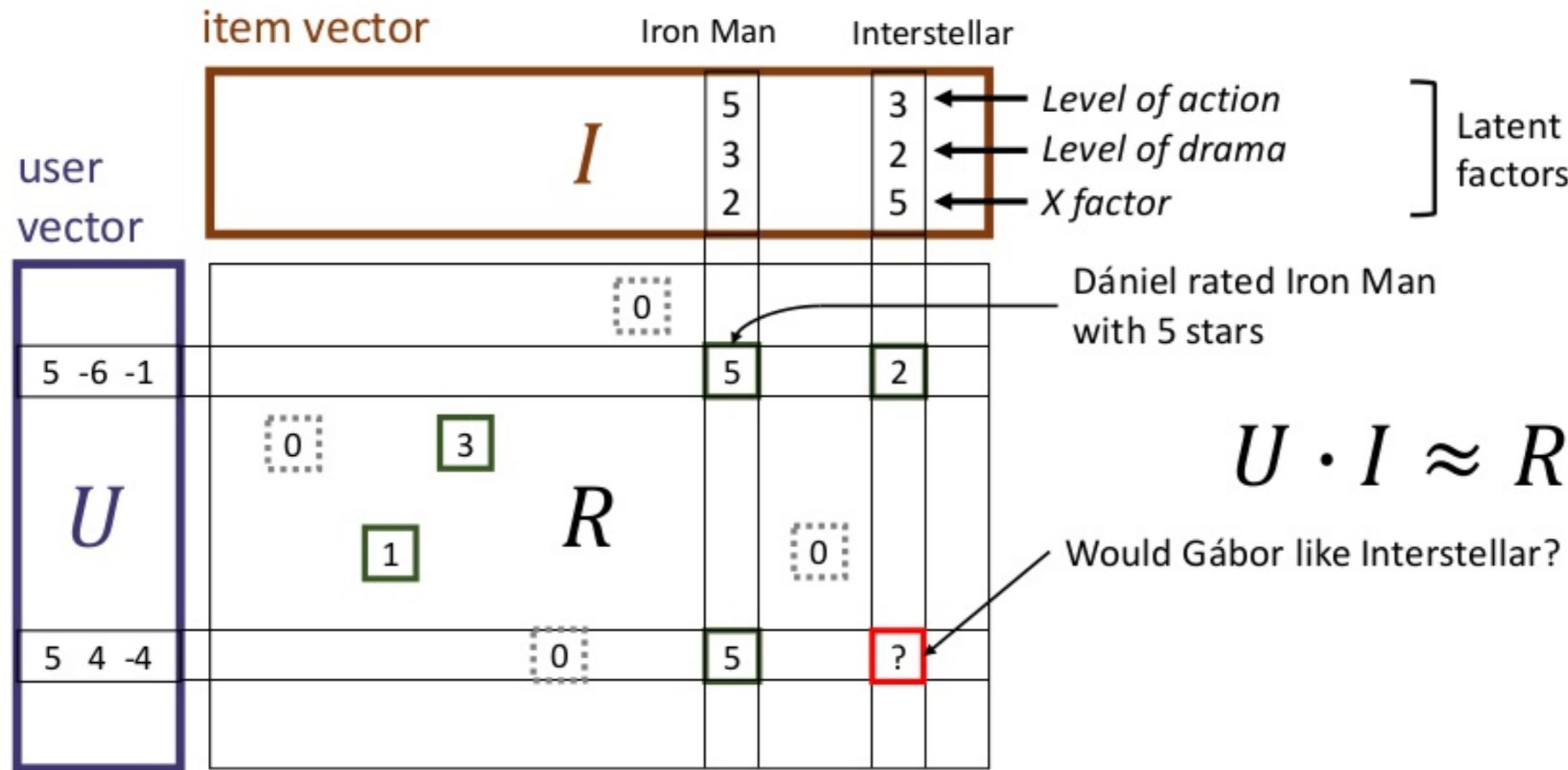
Recommendation with matrix factorization



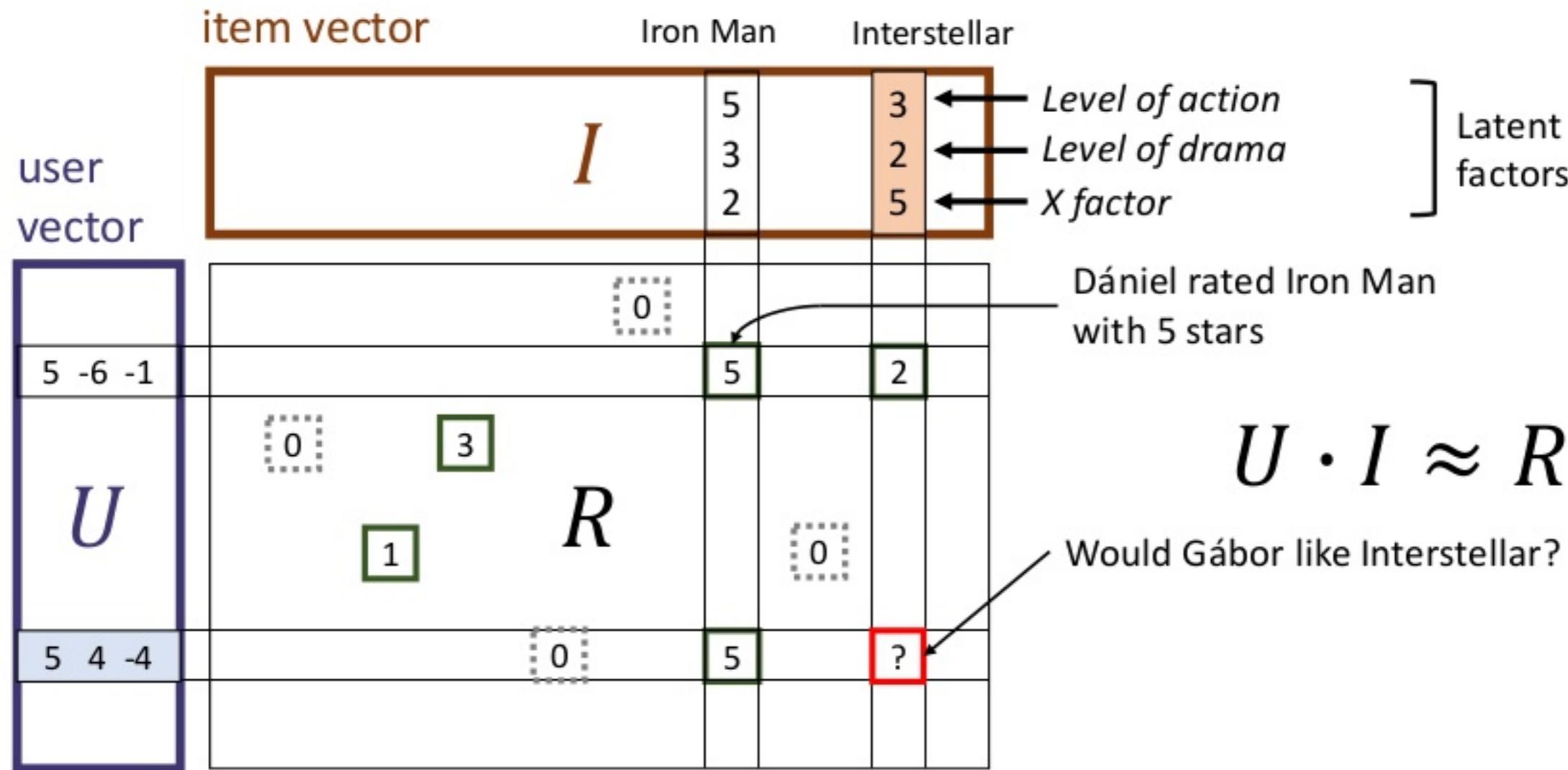
Recommendation with matrix factorization



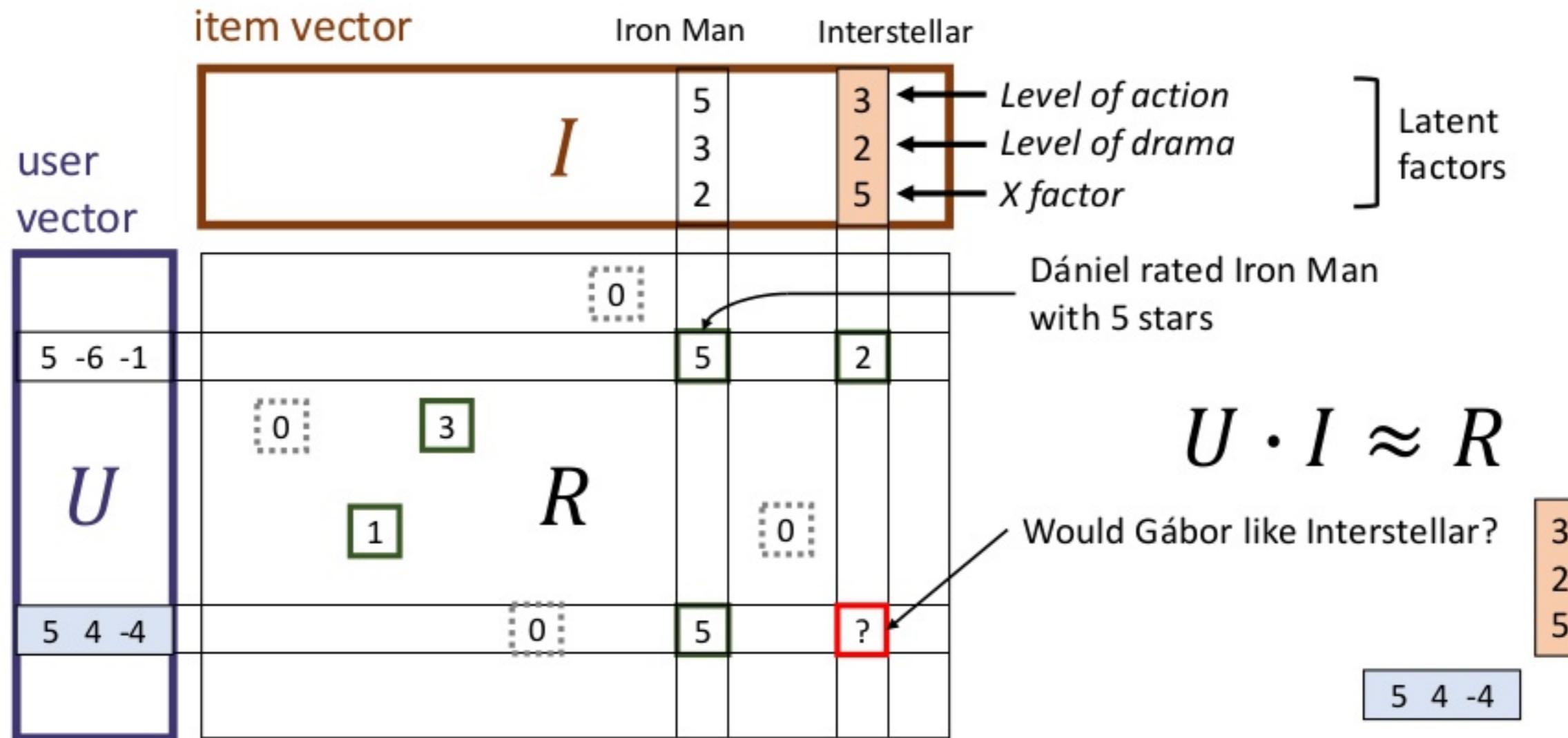
Recommendation with matrix factorization



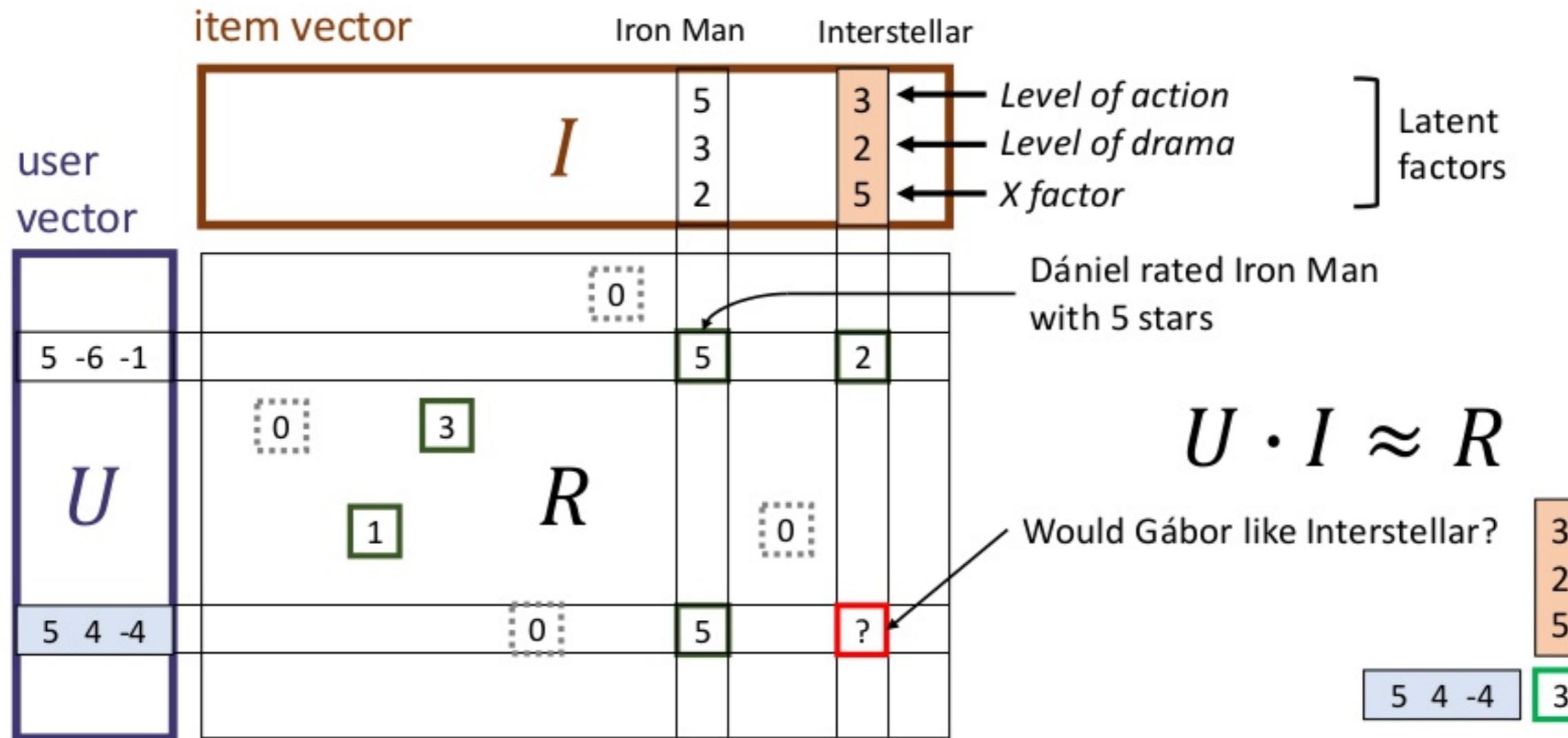
Recommendation with matrix factorization



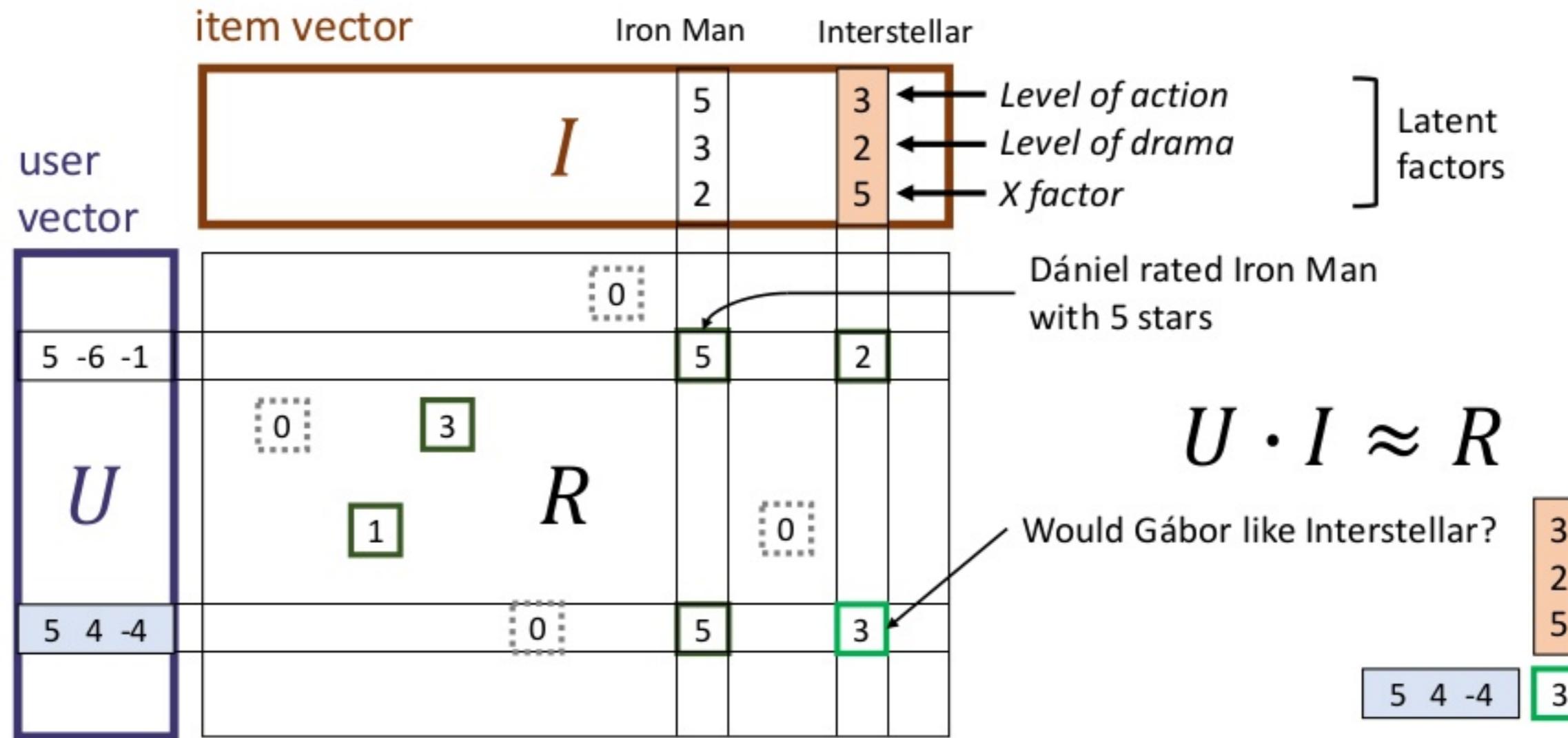
Recommendation with matrix factorization



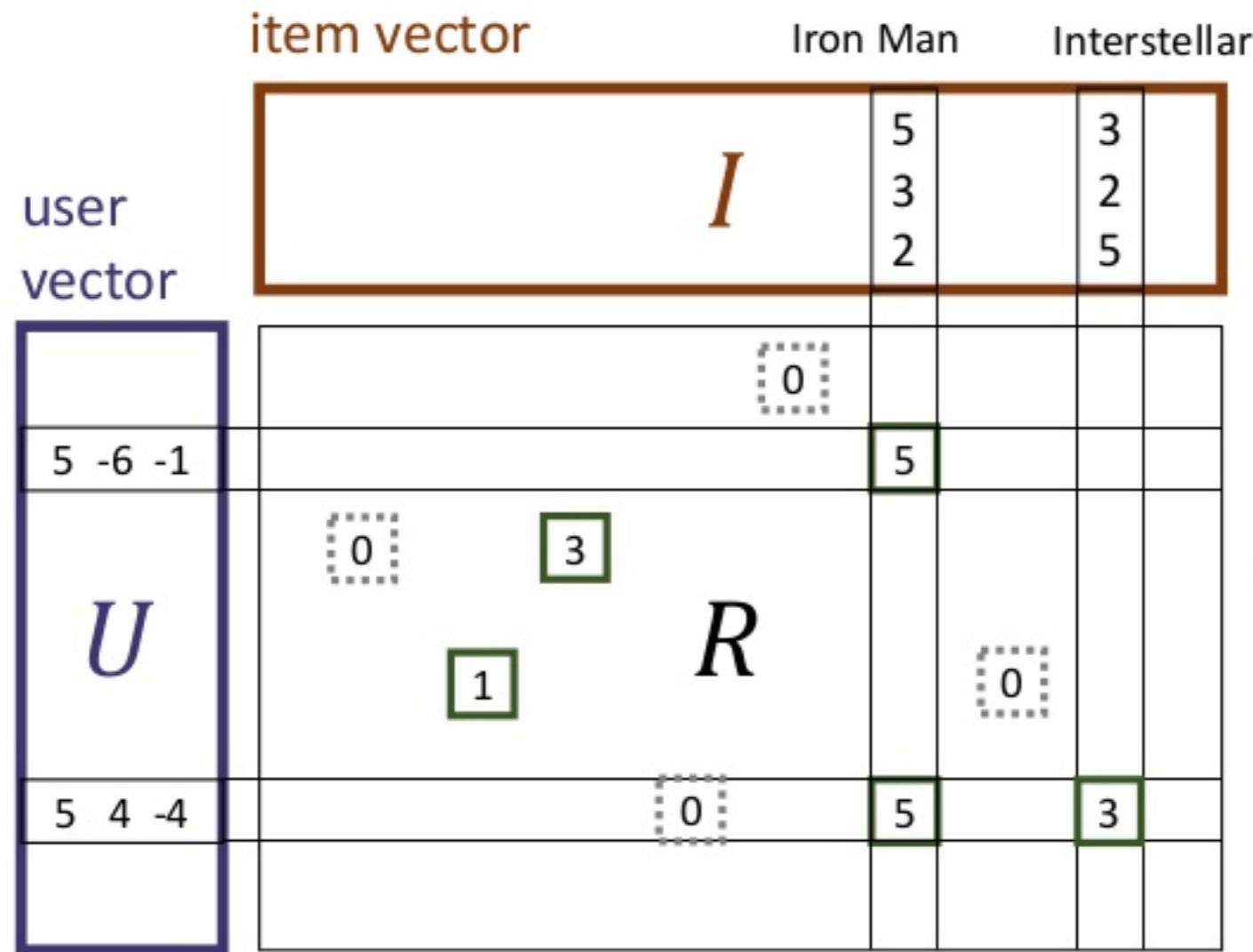
Recommendation with matrix factorization



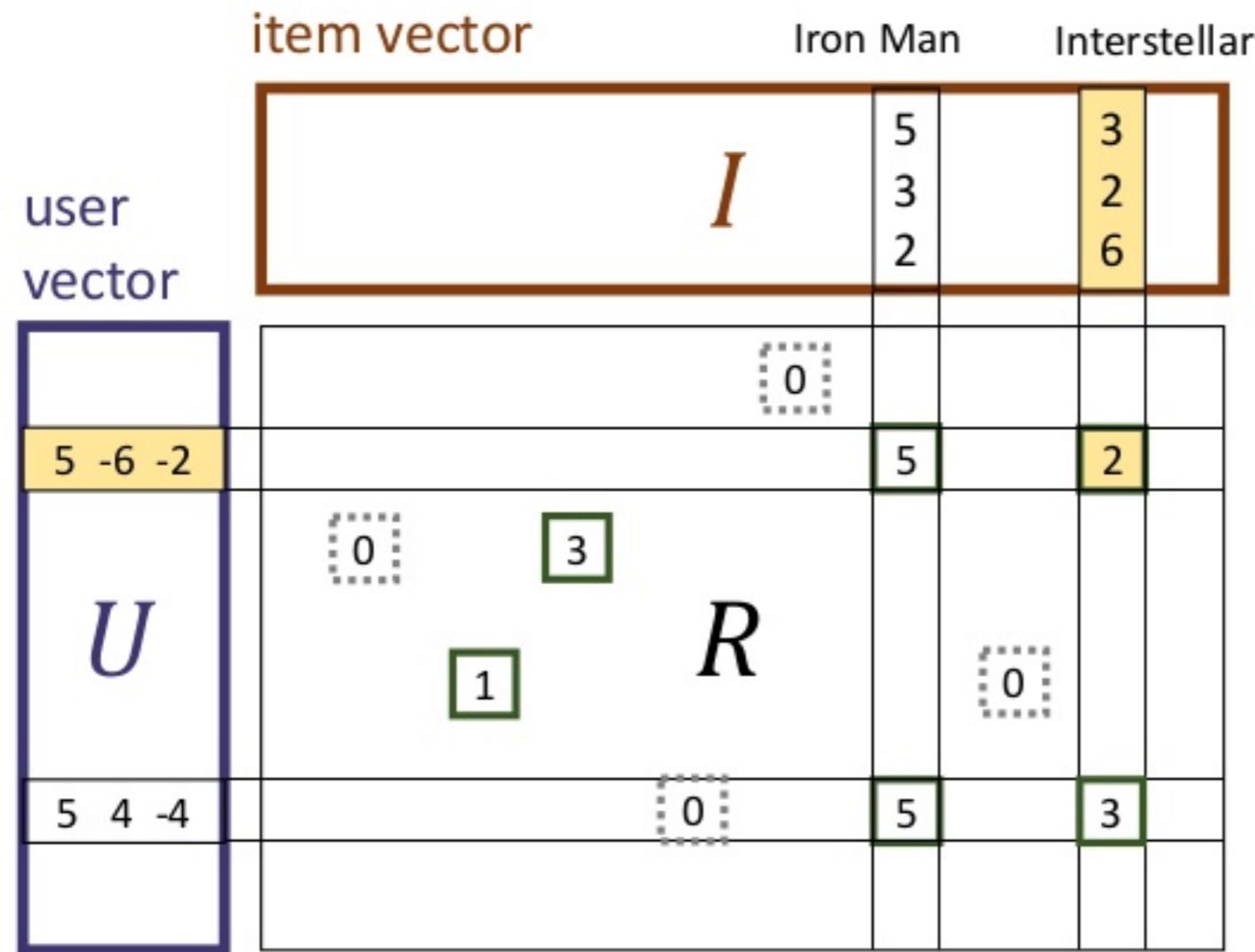
Recommendation with matrix factorization



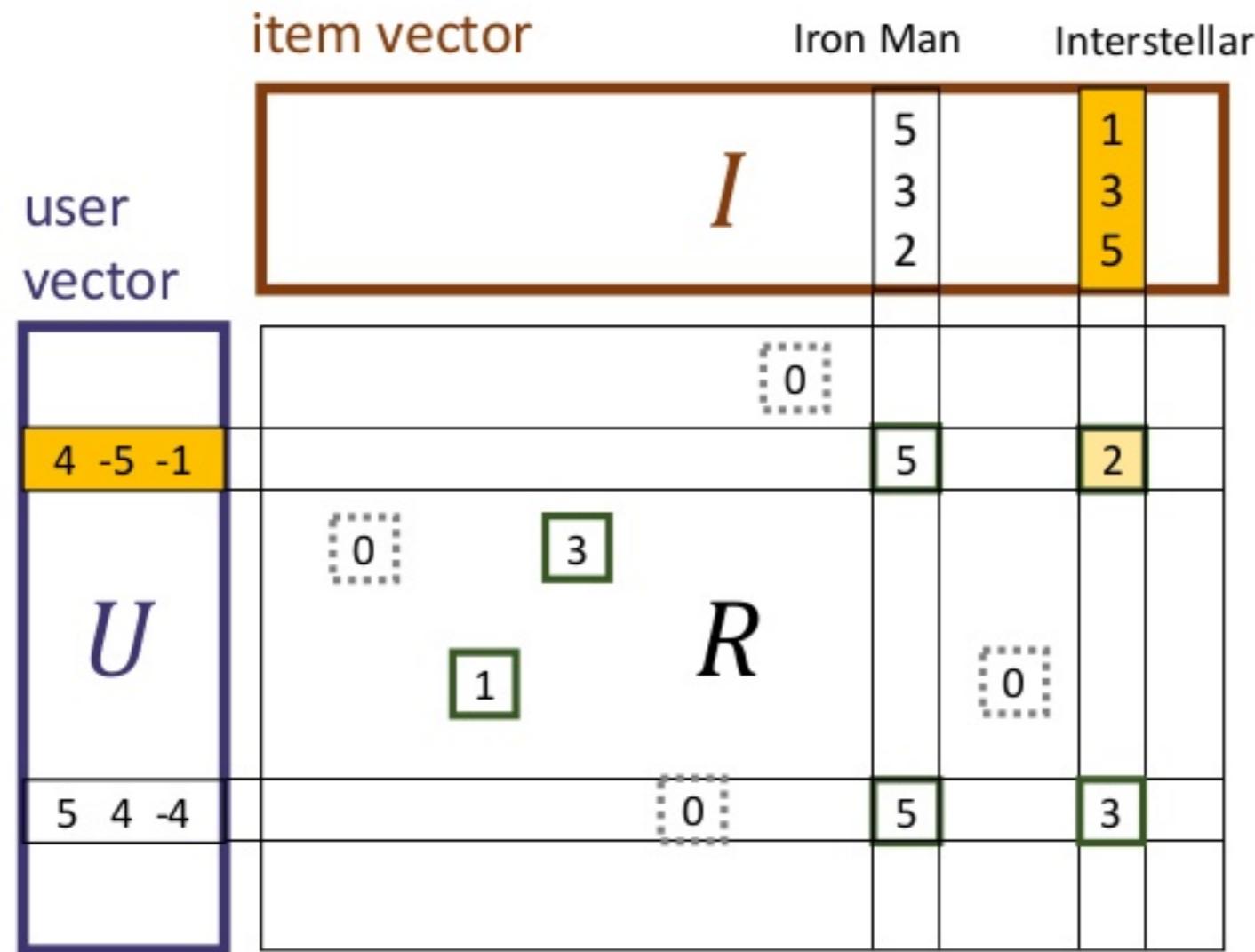
Matrix factorization training



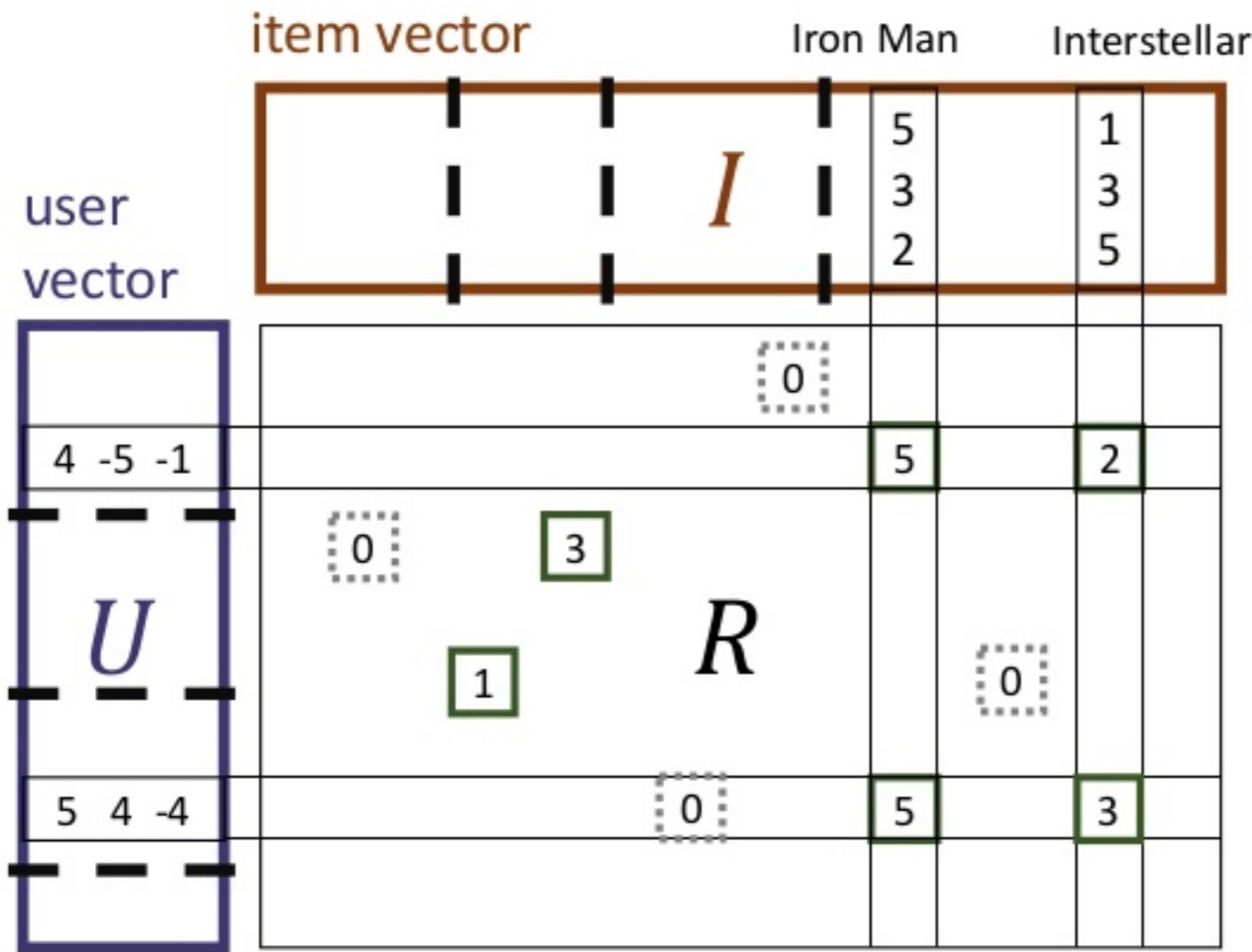
Matrix factorization training



Matrix factorization training



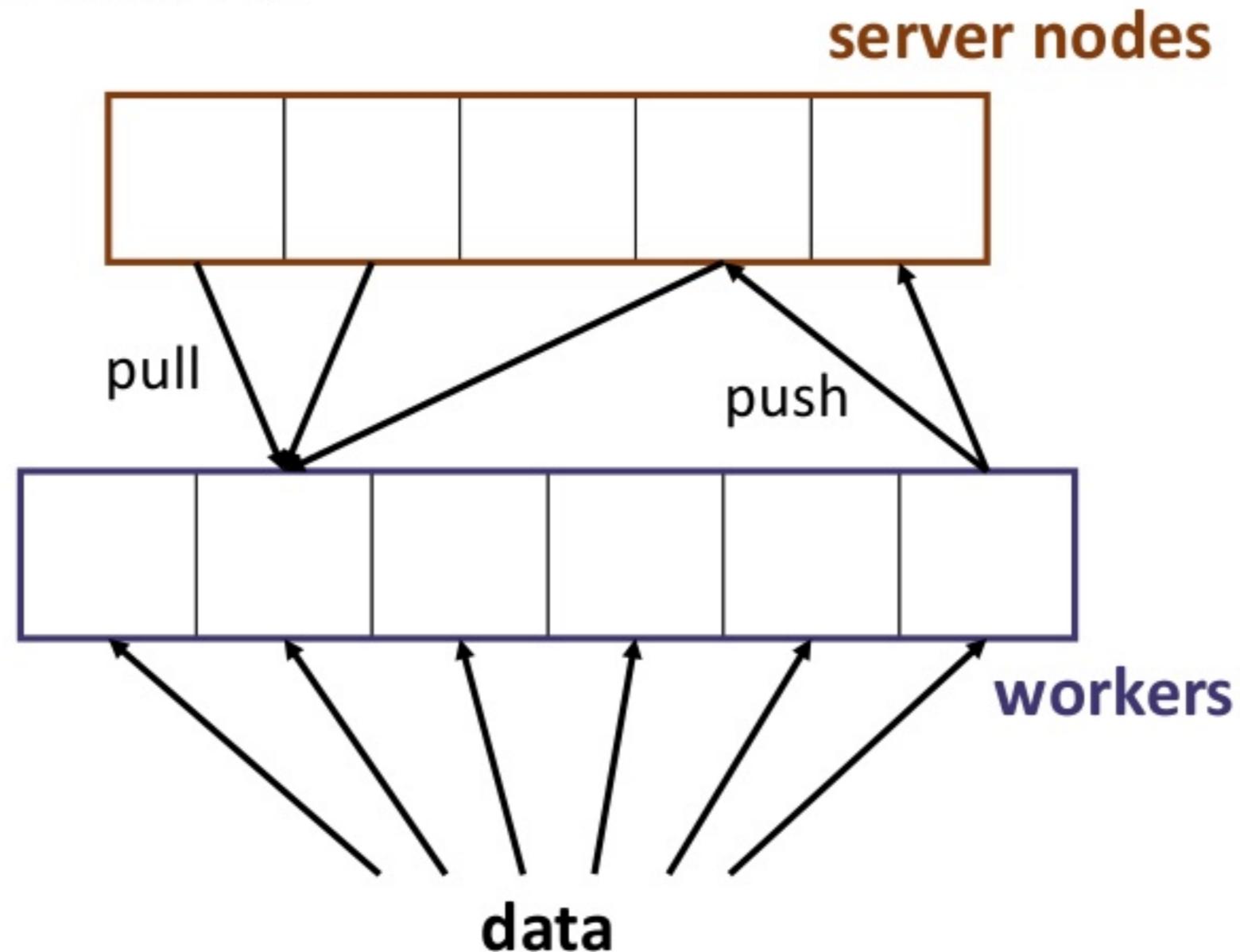
Matrix factorization training



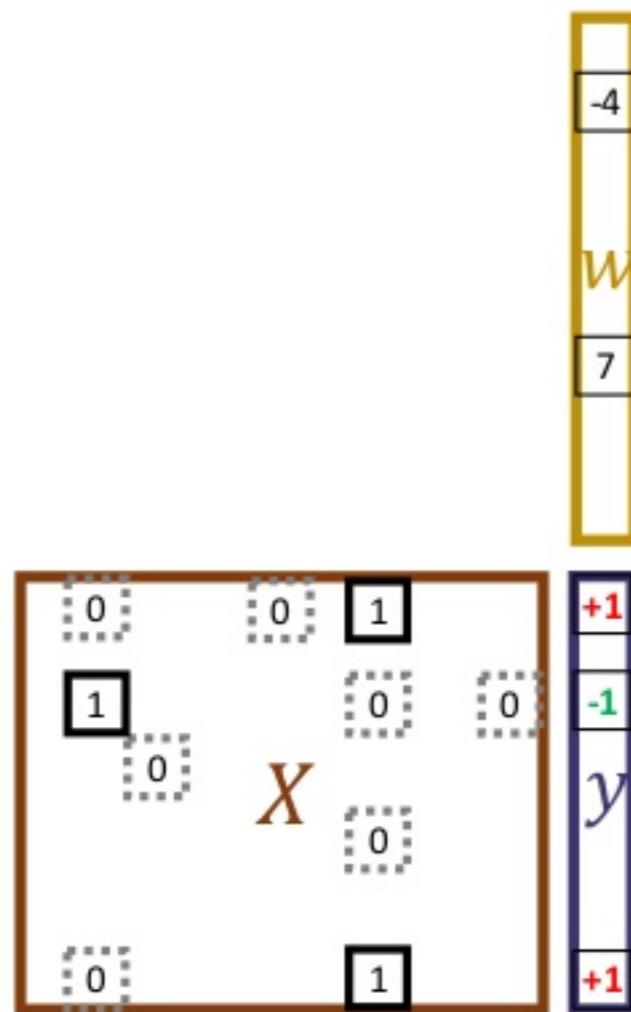
model-parallel

Parameter Server on Flink

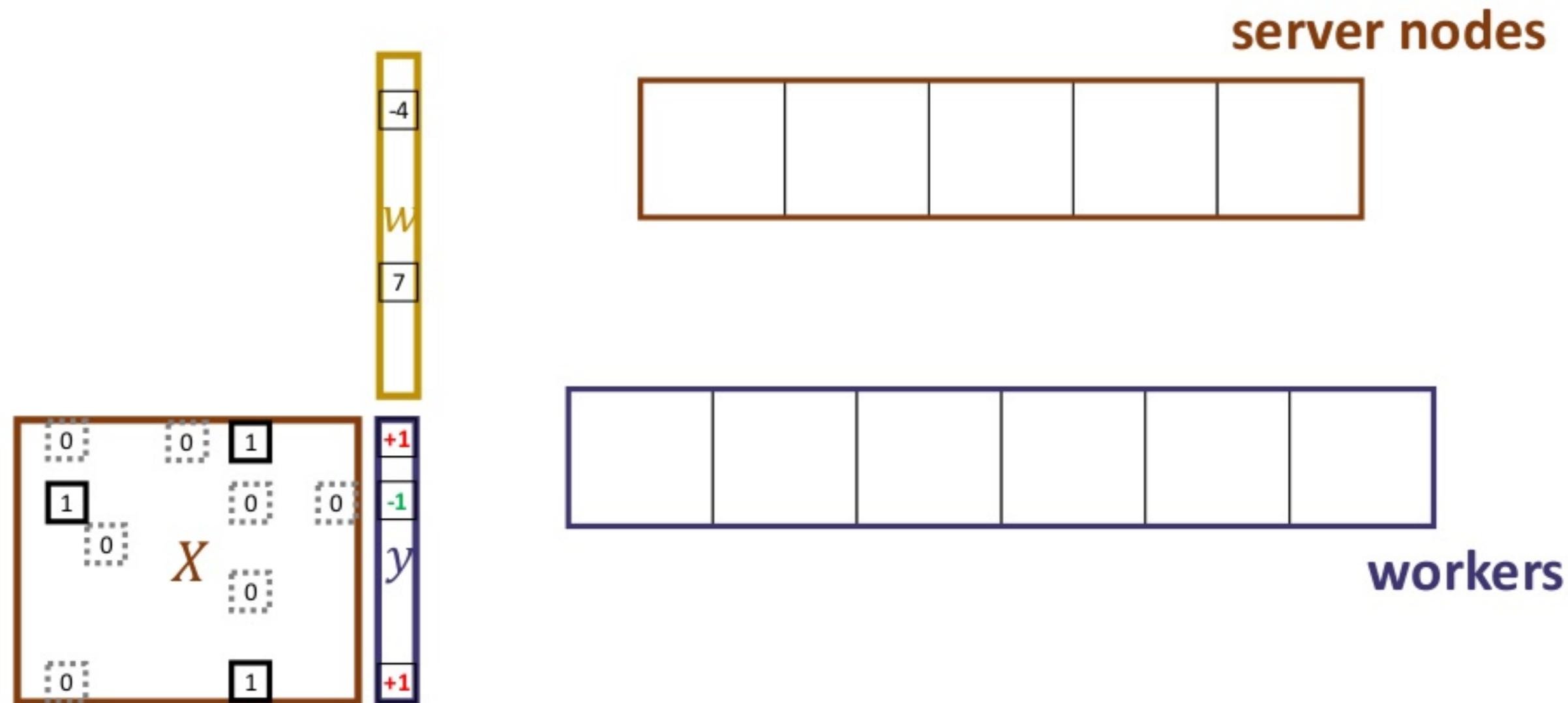
Parameter Server



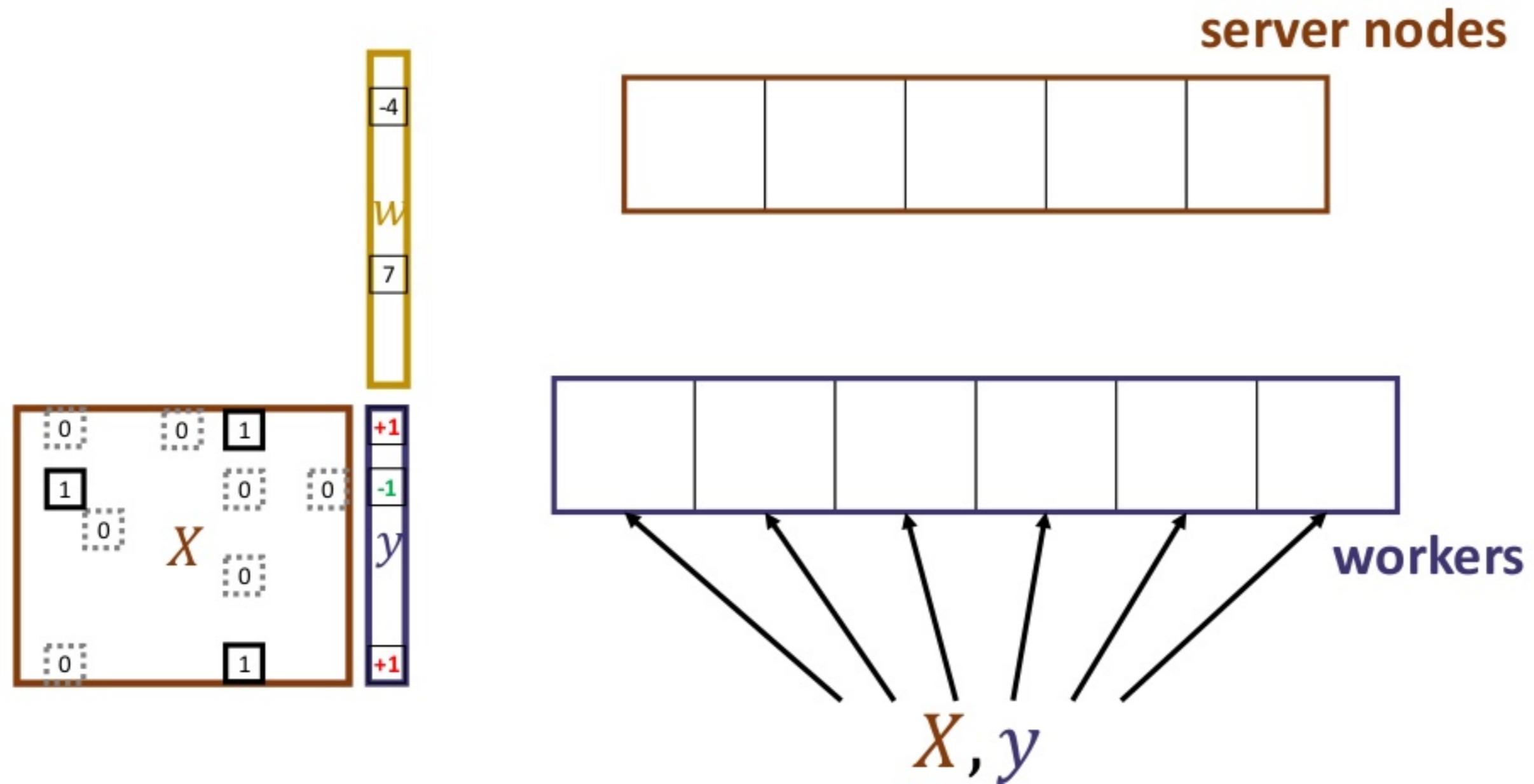
Passive-Aggressive with Parameter Server



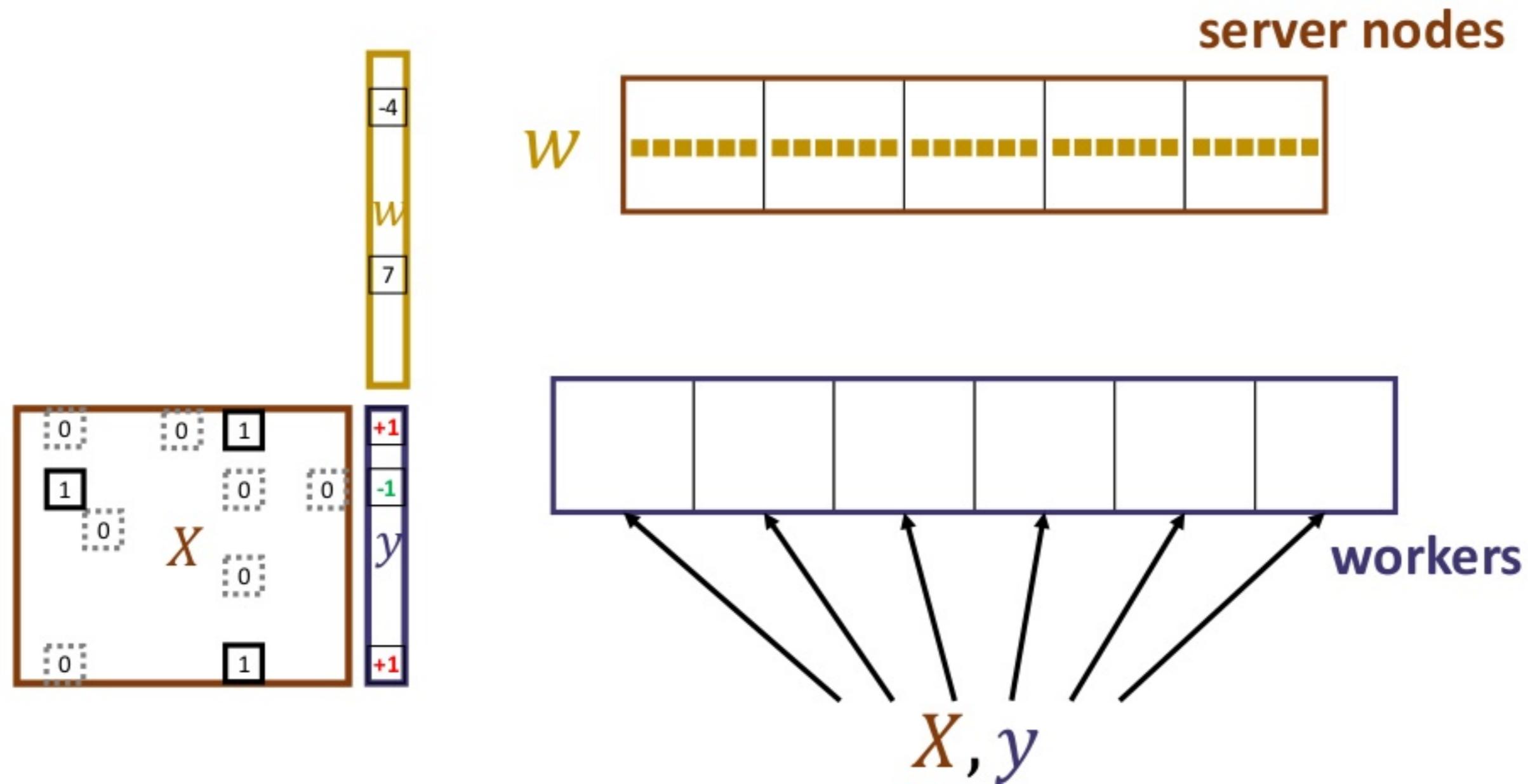
Passive-Aggressive with Parameter Server



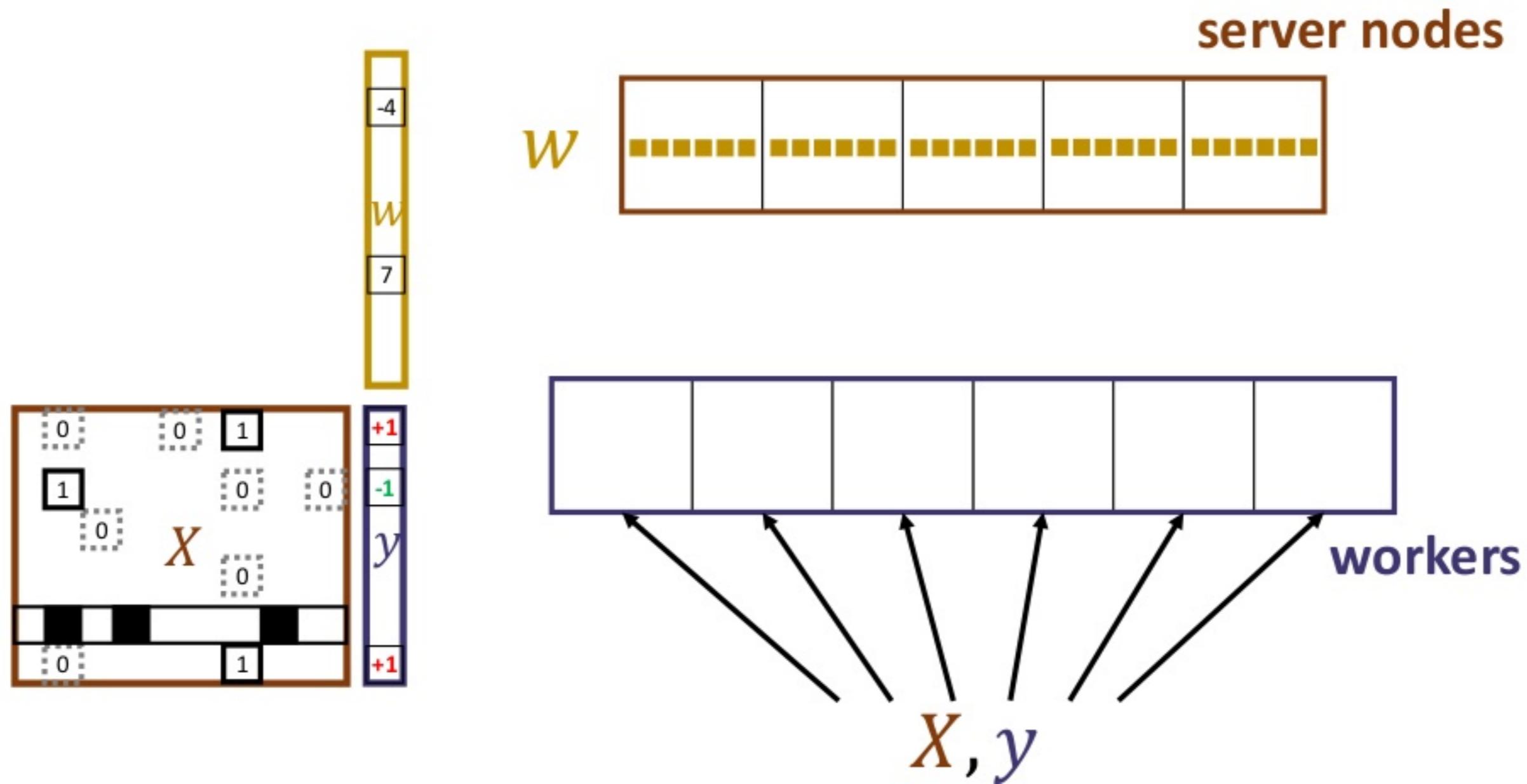
Passive-Aggressive with Parameter Server



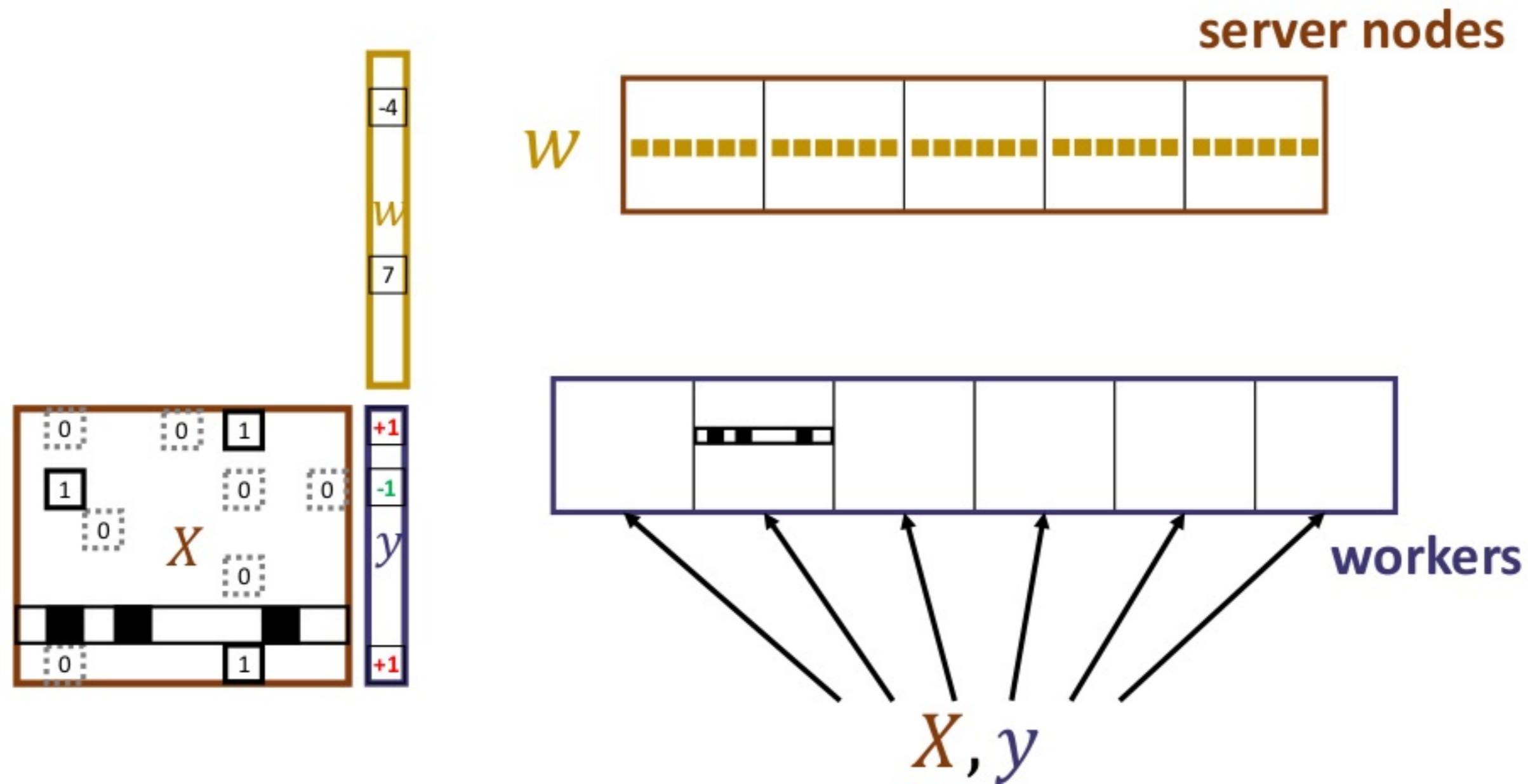
Passive-Aggressive with Parameter Server



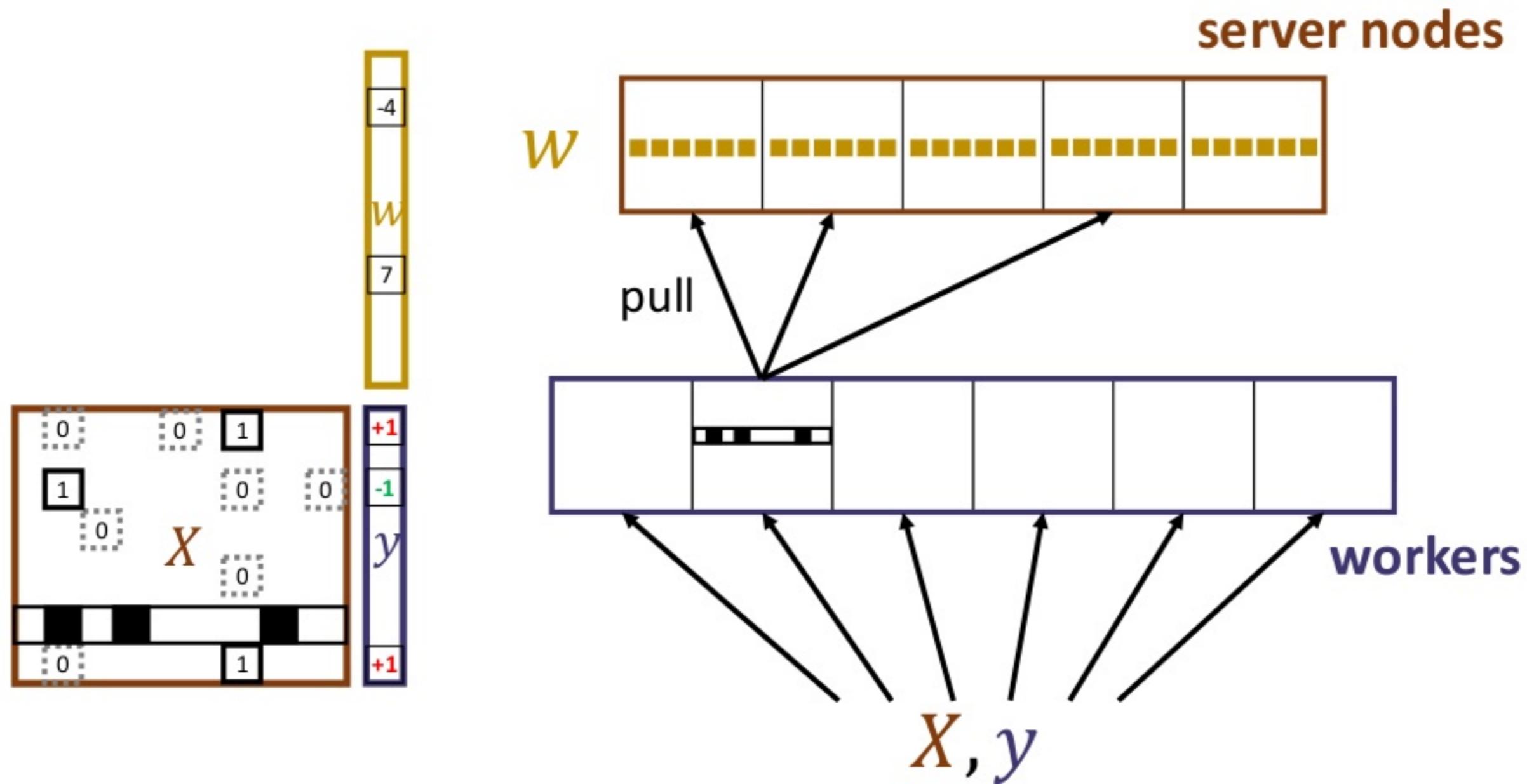
Passive-Aggressive with Parameter Server



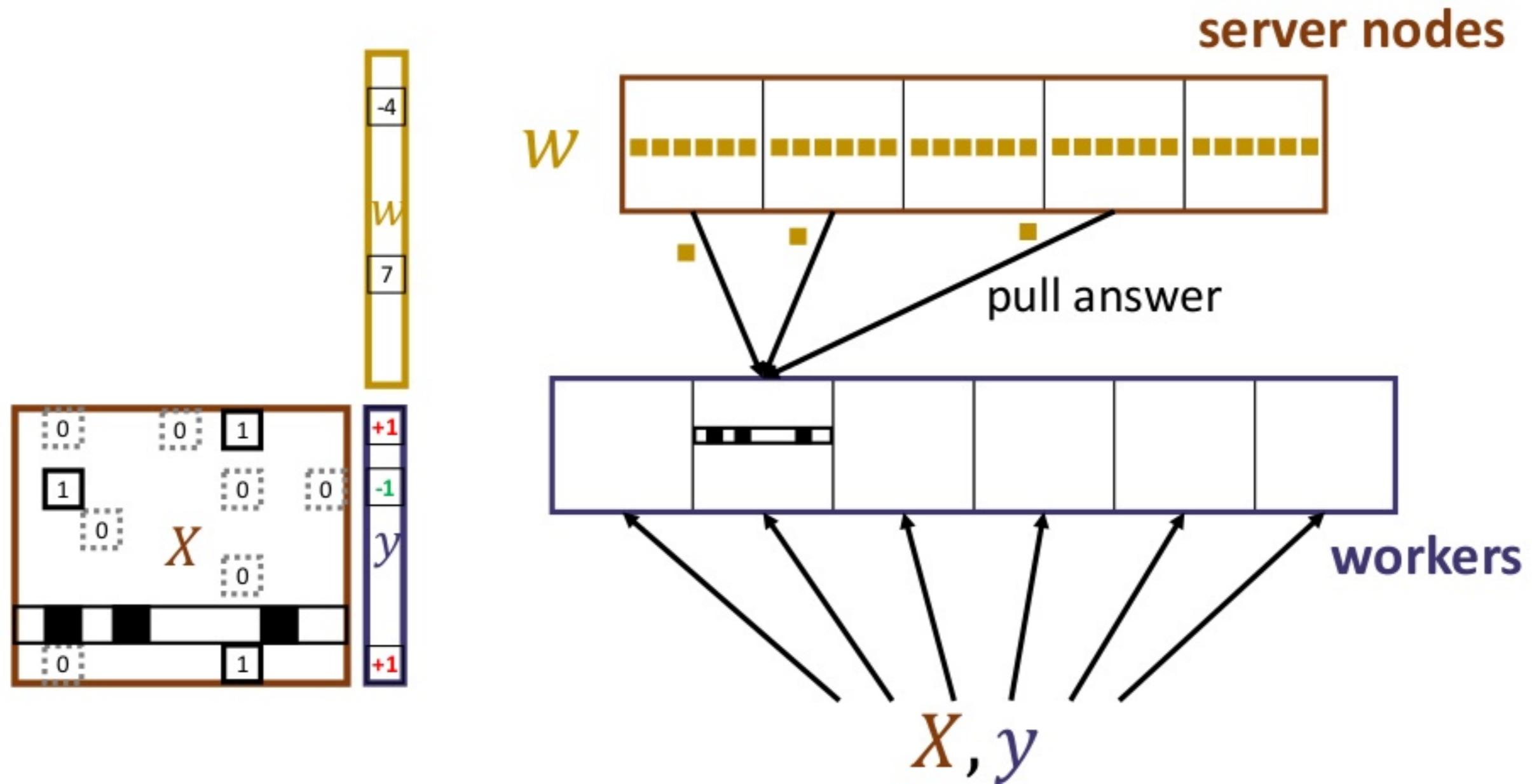
Passive-Aggressive with Parameter Server



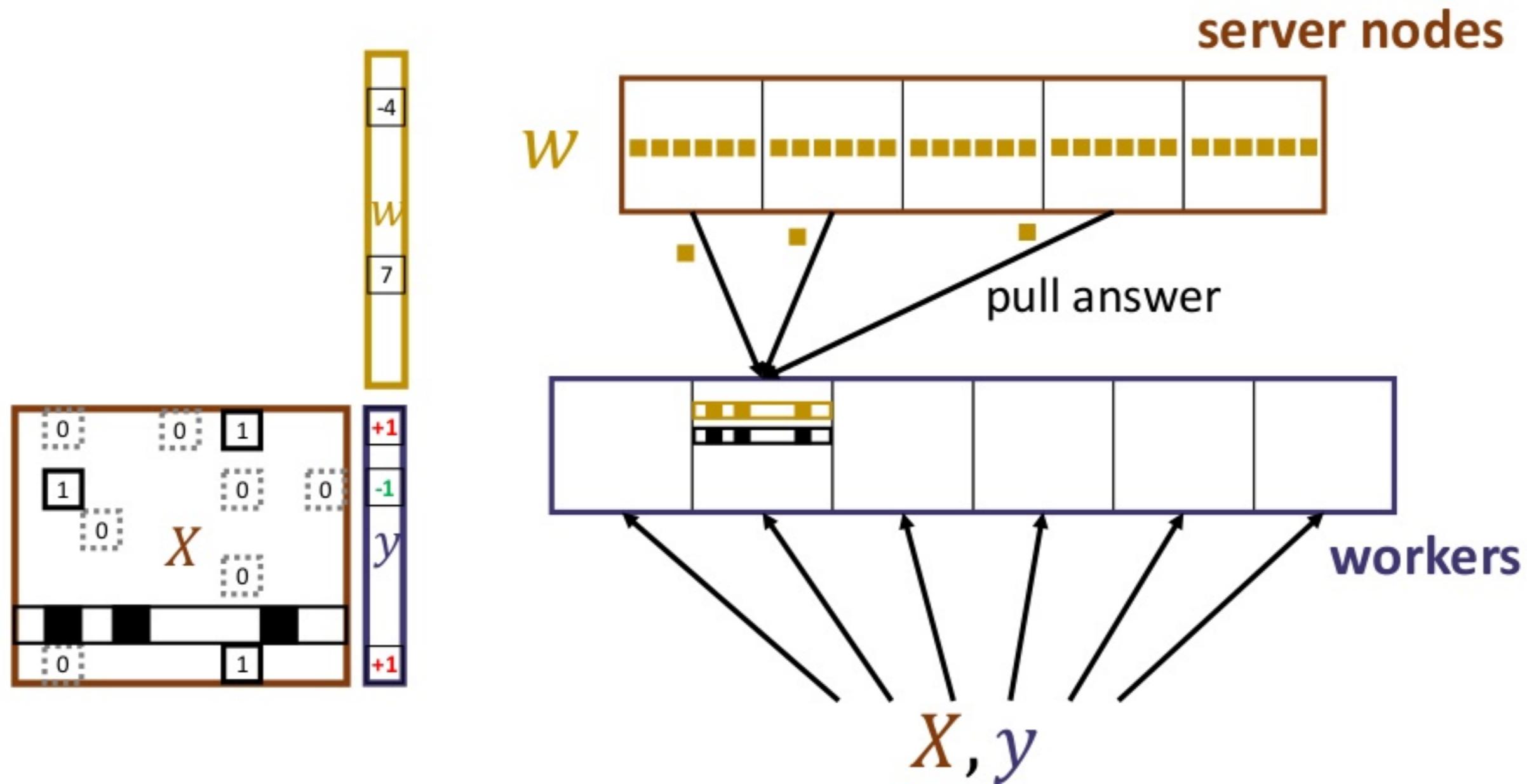
Passive-Aggressive with Parameter Server



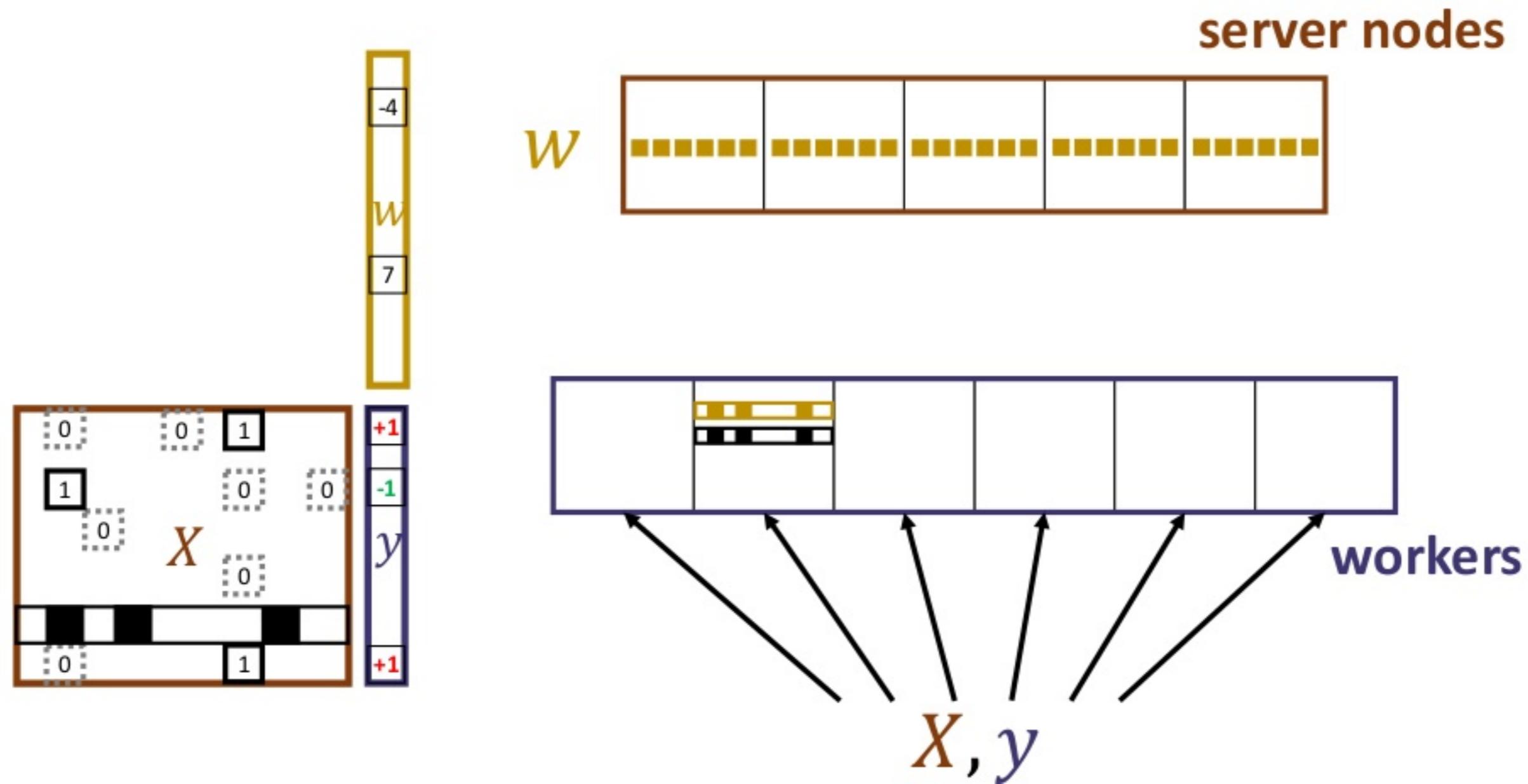
Passive-Aggressive with Parameter Server



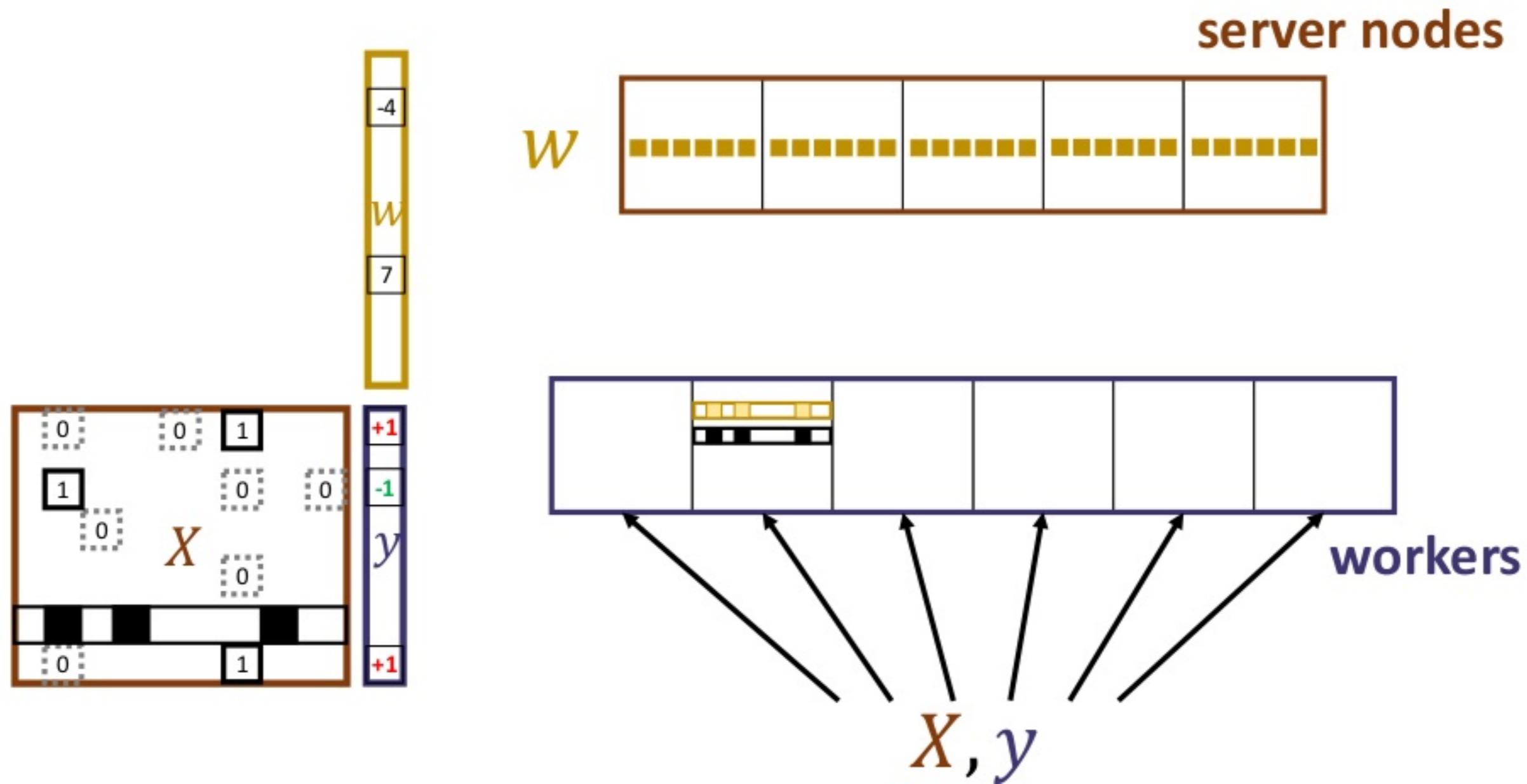
Passive-Aggressive with Parameter Server



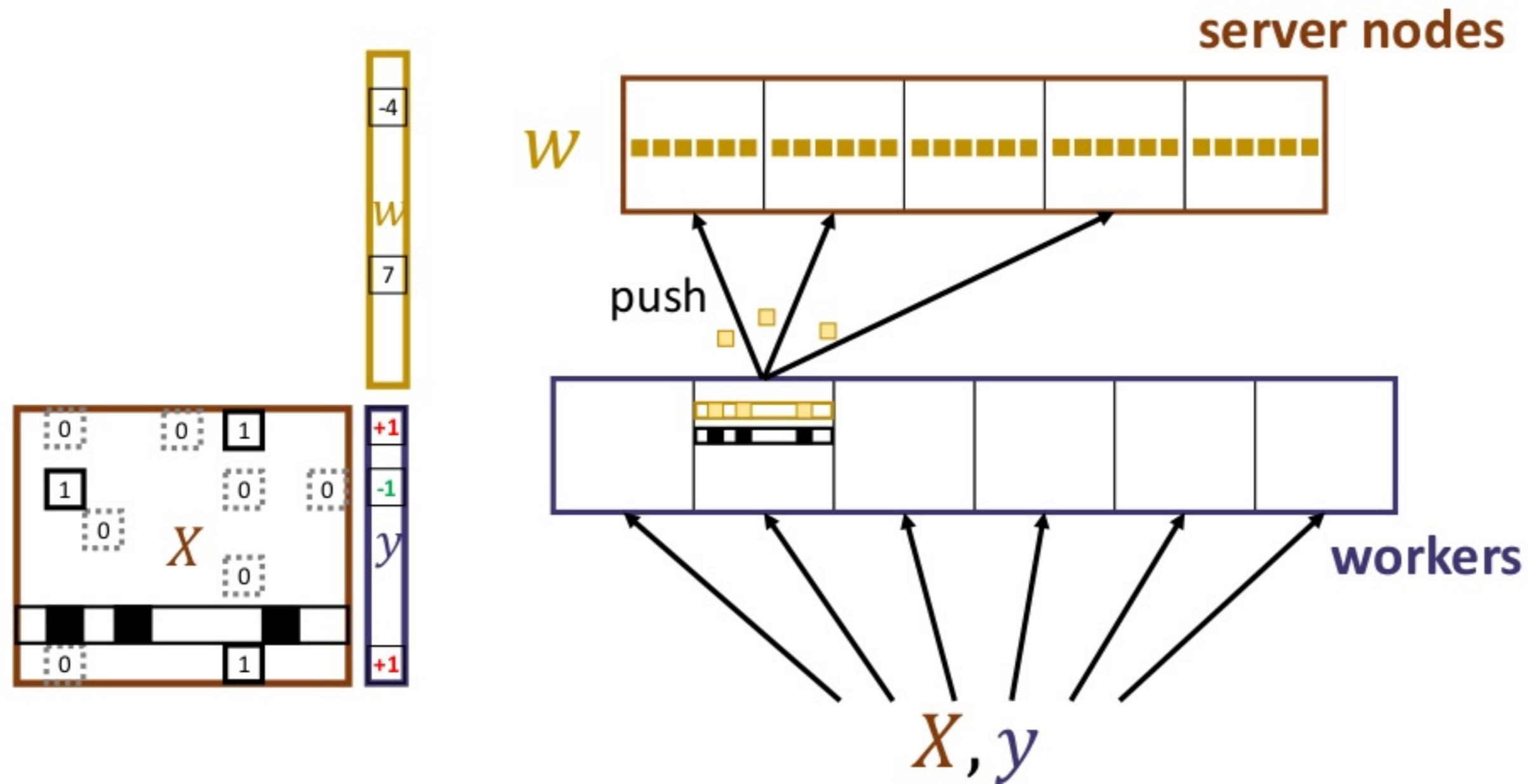
Passive-Aggressive with Parameter Server



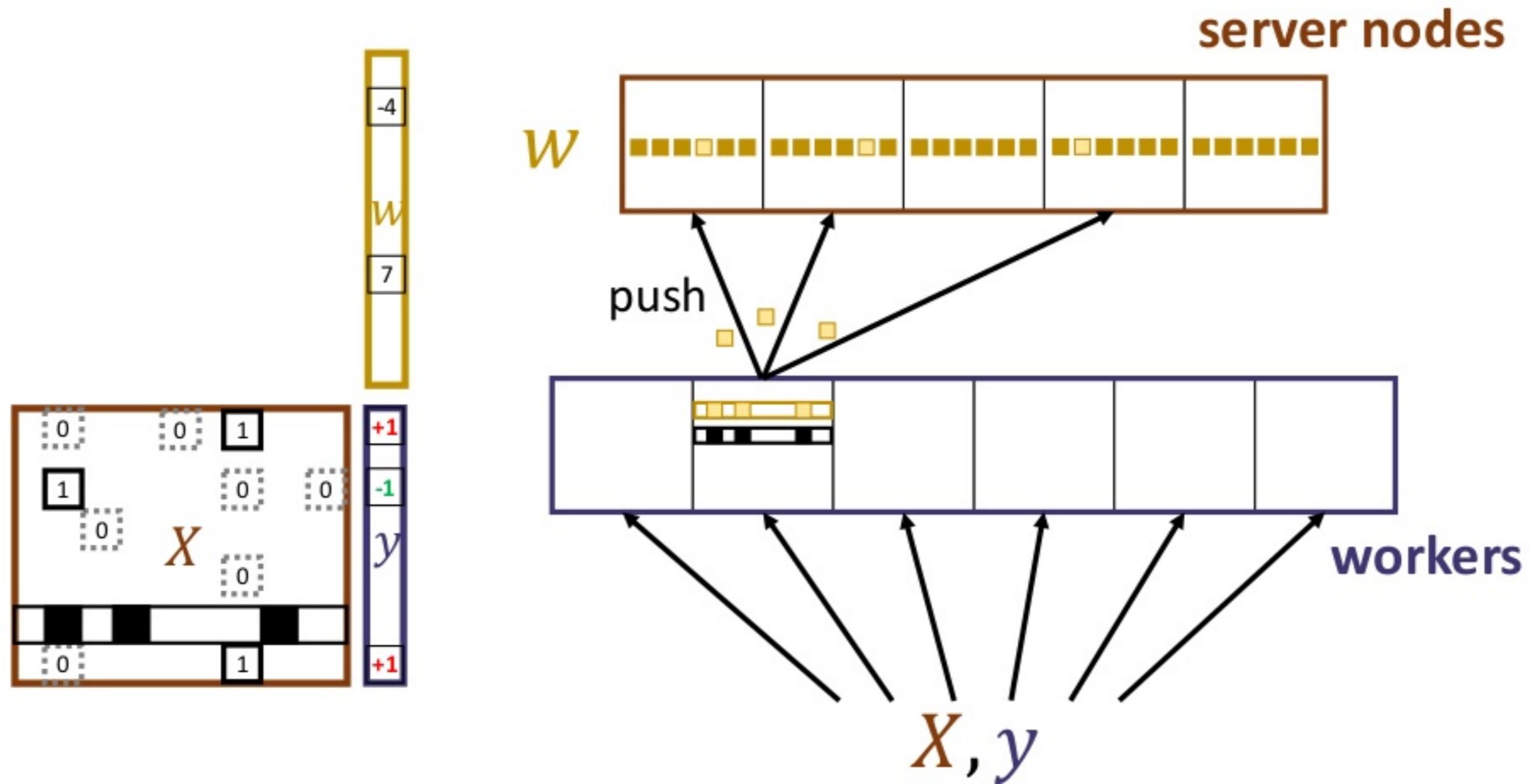
Passive-Aggressive with Parameter Server



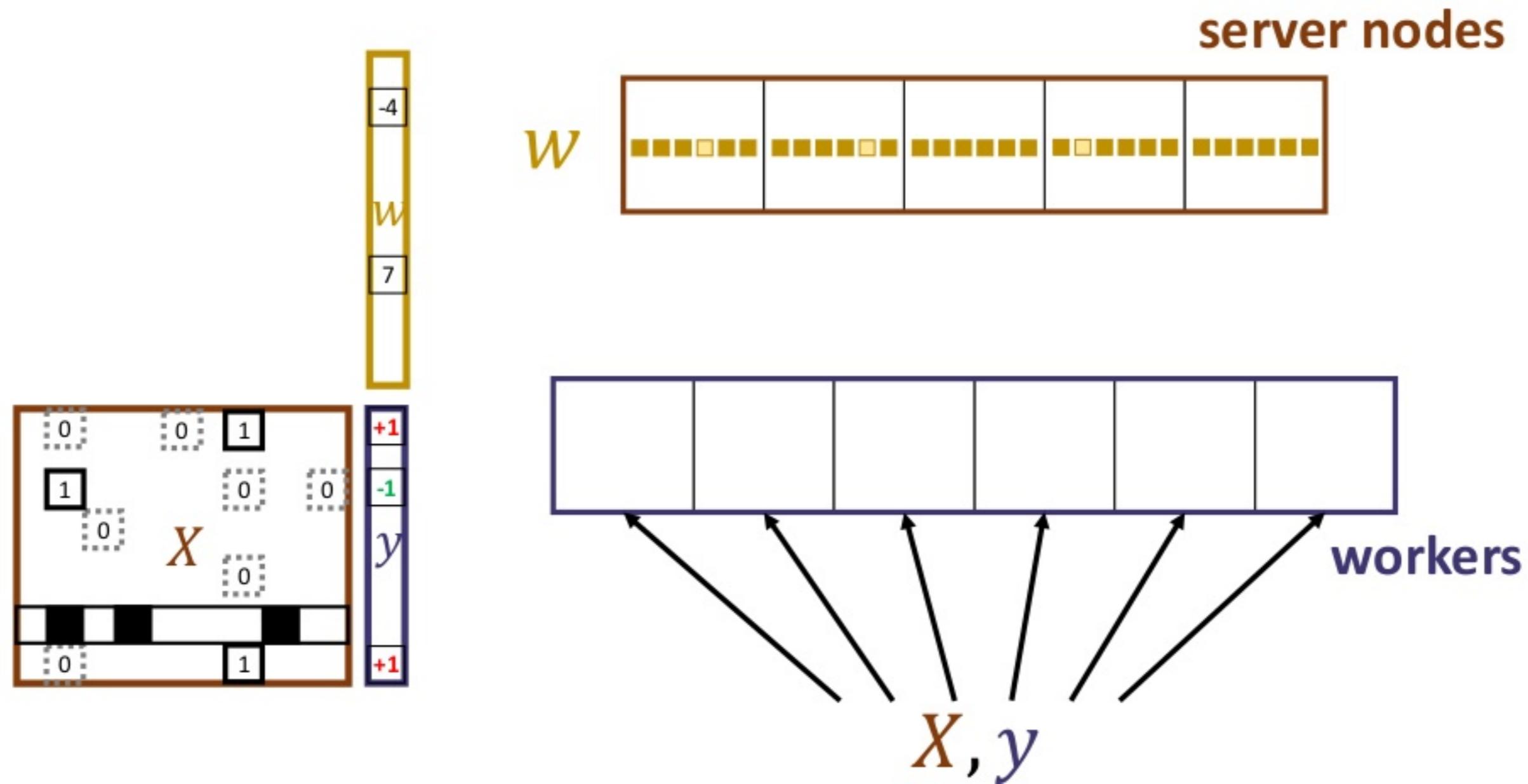
Passive-Aggressive with Parameter Server



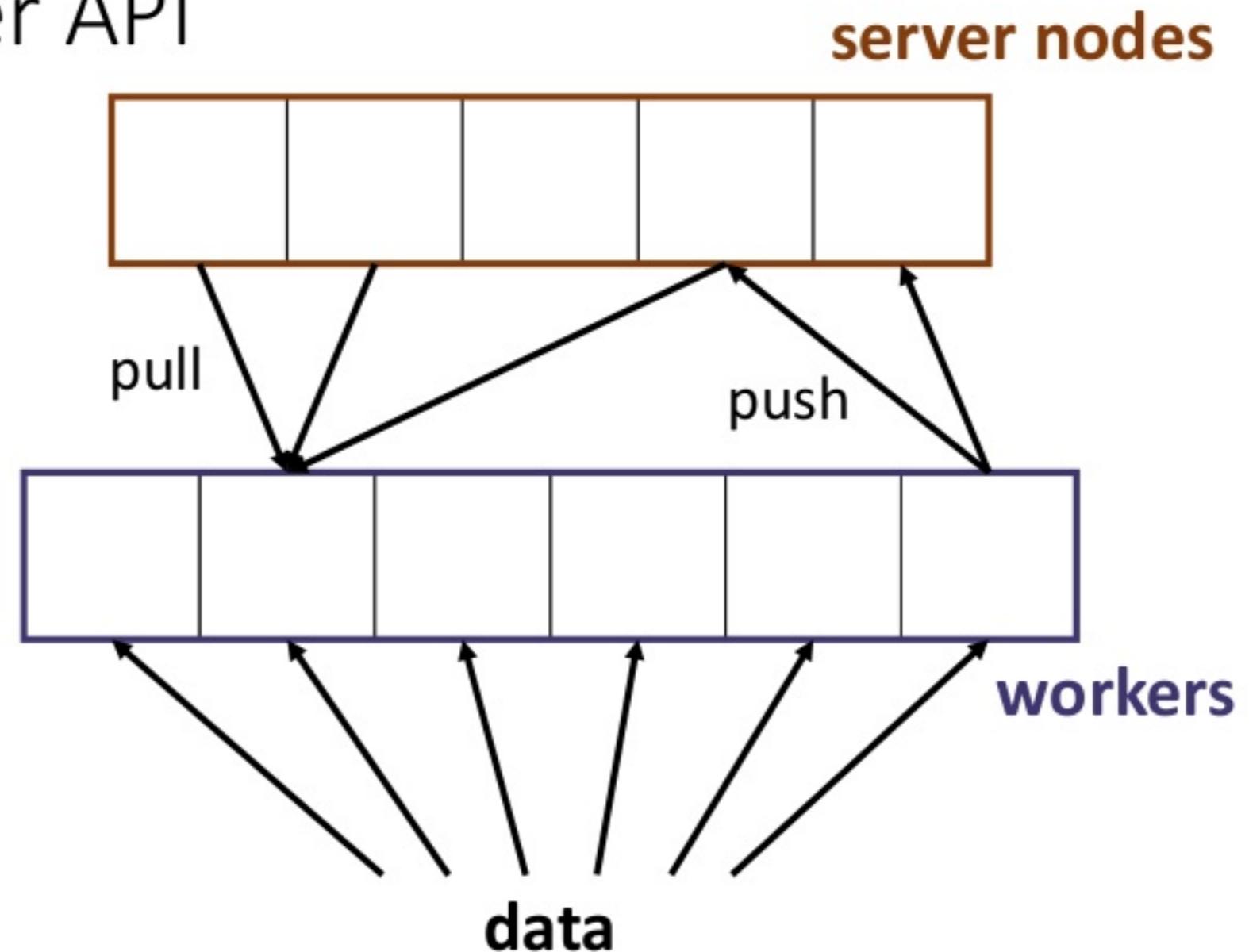
Passive-Aggressive with Parameter Server



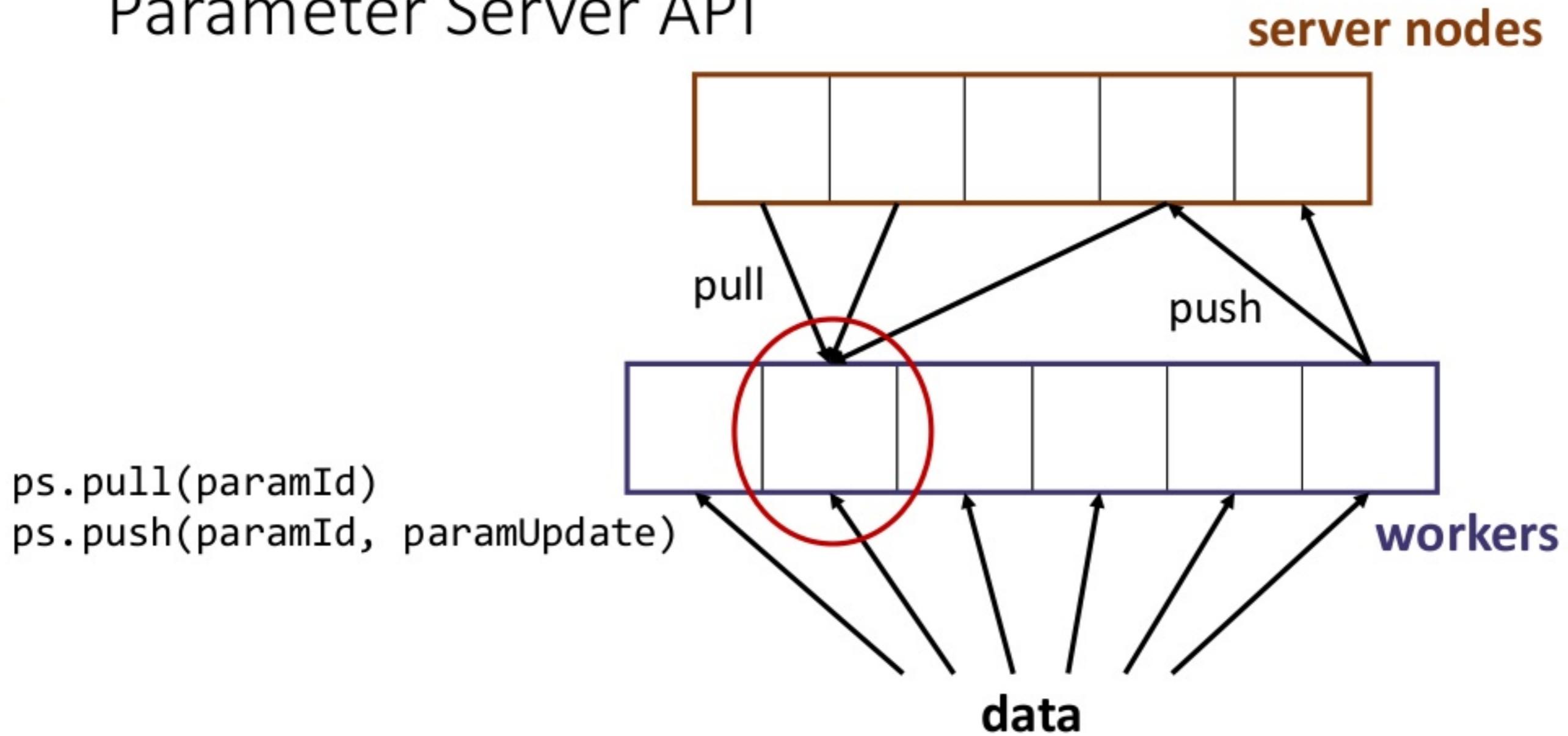
Passive-Aggressive with Parameter Server



Parameter Server API



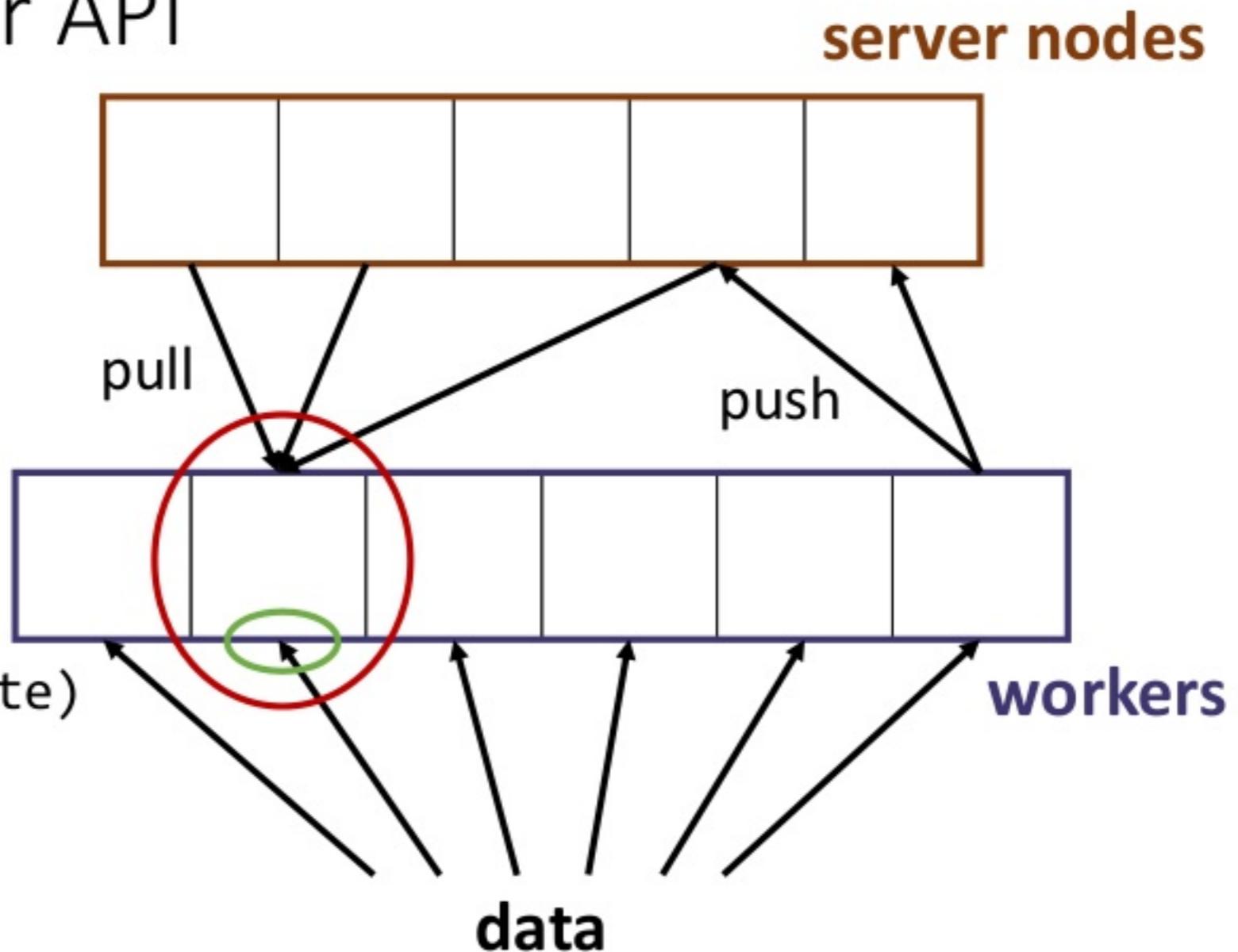
Parameter Server API



Parameter Server API

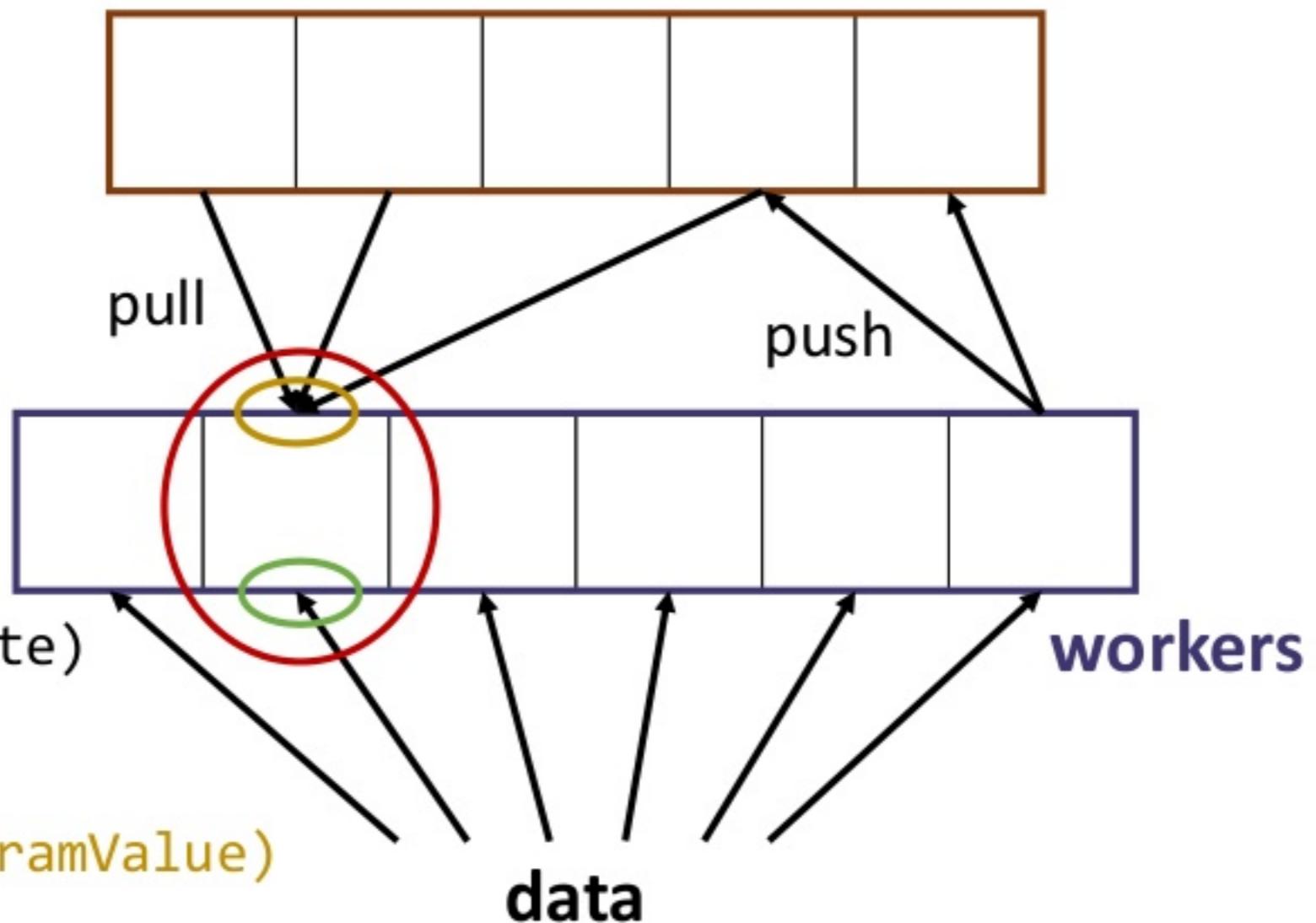
```
ps.pull(paramId)  
ps.push(paramId, paramUpdate)
```

```
def onRecv(data): Unit
```



Parameter Server API

server nodes



Passive-Aggressive code

```
def onRecv(x: LabeledVector) = {
```

```
    def onPullRecv(paramId: Int,  
                  param: Double) = {
```

Passive-Aggressive code

```
def onRecv(x: LabeledVector) = {  
    cacheLocally(x)
```

```
    def onPullRecv(paramId: Int,  
                  param: Double) = {
```

Passive-Aggressive code

```
def onRecv(x: LabeledVector) = {  
    cacheLocally(x)  
    x.indices.foreach {  
        i => ps.pull(i)  
    }  
}
```

```
def onPullRecv(paramId: Int,  
               param: Double) = {
```

Passive-Aggressive code

```
def onRecv(x: LabeledVector) = {  
    cacheLocally(x)  
    x.indices.foreach {  
        i => ps.pull(i)  
    }  
}
```

```
def onPullRecv(paramId: Int,  
               param: Double) = {  
    cacheOrCompute(paramId, param, {  
        (x, w) =>
```

Passive-Aggressive code

```
def onRecv(x: LabeledVector) = {  
    cacheLocally(x)  
    x.indices.foreach {  
        i => ps.pull(i)  
    }  
}
```

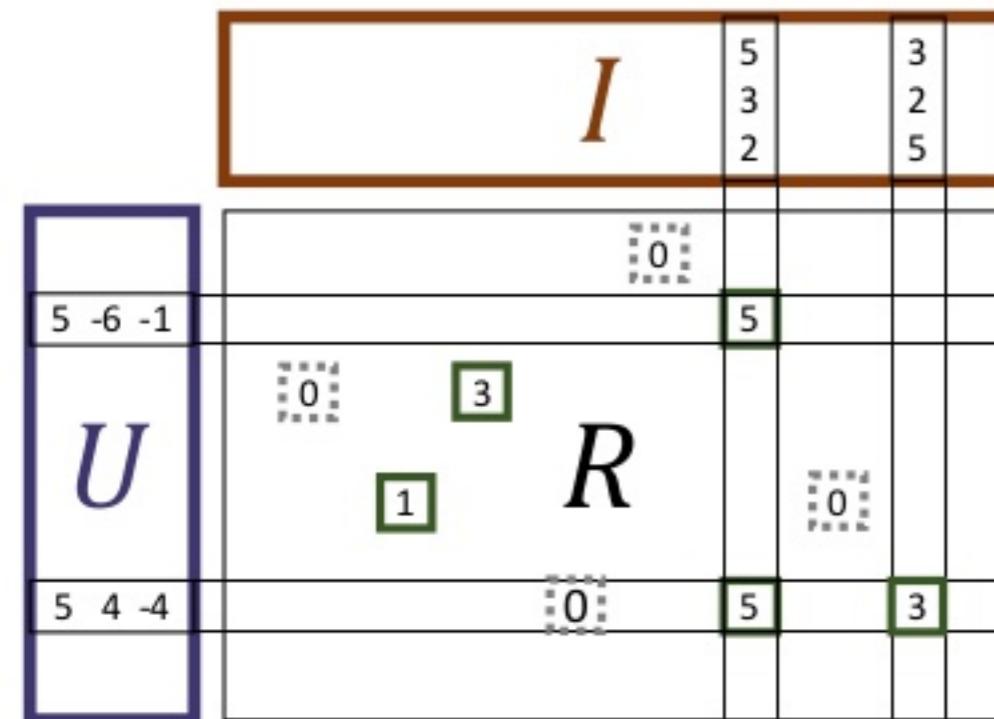
```
def onPullRecv(paramId: Int,  
              param: Double) = {  
    cacheOrCompute(paramId, param, {  
        (x, w) =>  
        val deltaW =  
            passiveAggressiveUpdate(x, w)  
    })  
}
```

Passive-Aggressive code

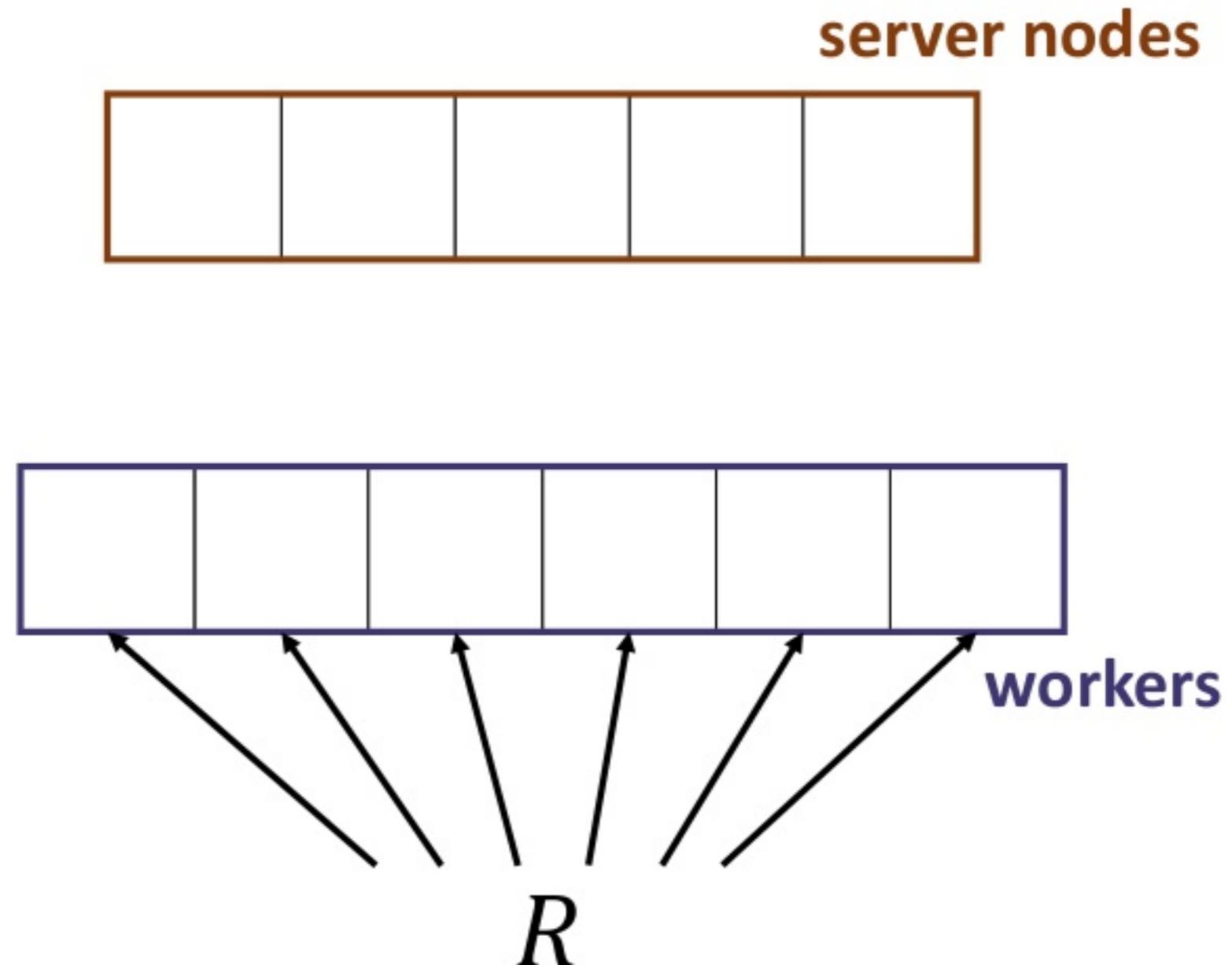
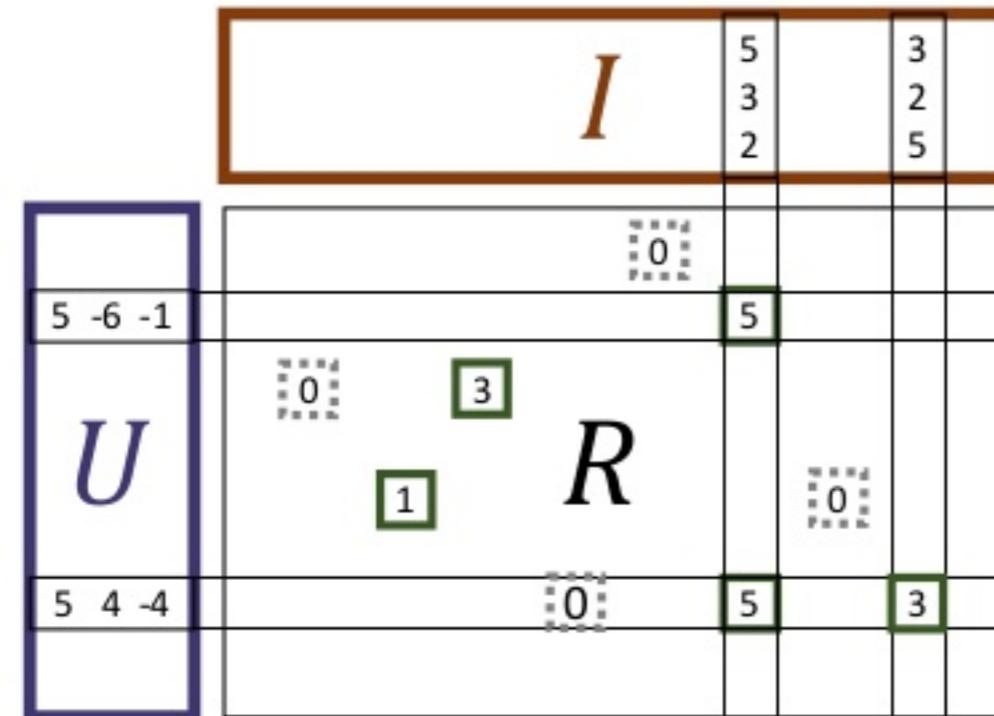
```
def onRecv(x: LabeledVector) = {  
    cacheLocally(x)  
    x.indices.foreach {  
        i => ps.pull(i)  
    }  
}
```

```
def onPullRecv(paramId: Int,  
              param: Double) = {  
    cacheOrCompute(paramId, param, {  
        (x, w) =>  
        val deltaW =  
            passiveAggressiveUpdate(x, w)  
        deltaW.foreach {  
            (pId, pDelta) =>  
                ps.push(pId, pDelta)  
        }  
    })  
}
```

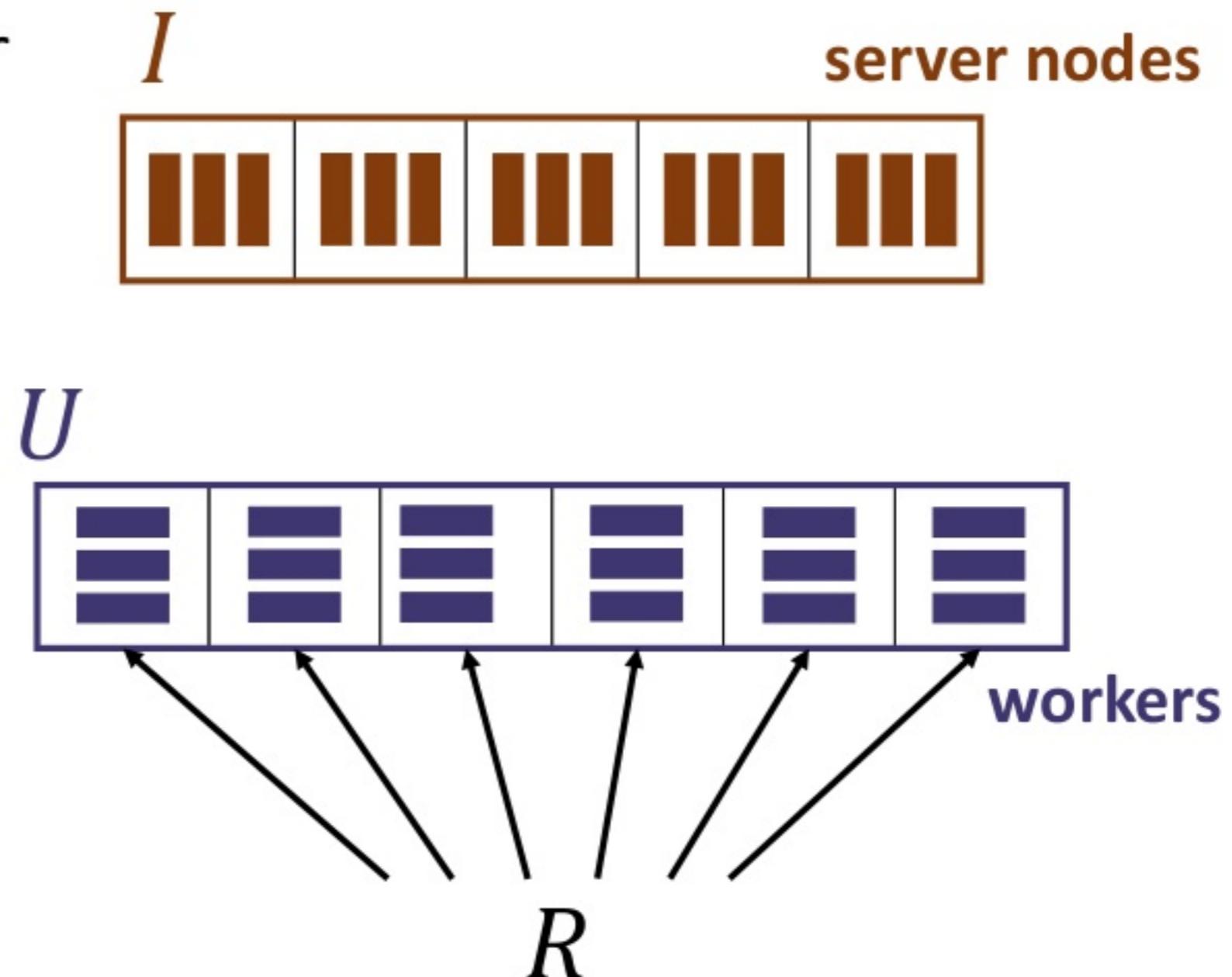
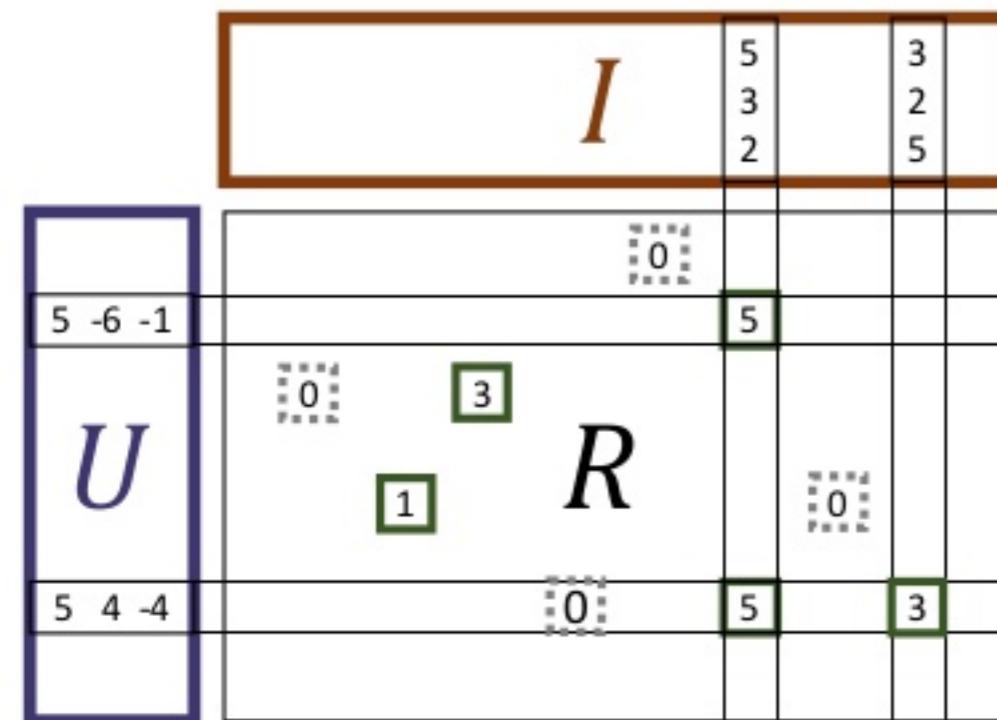
Matrix factorization with Parameter Server



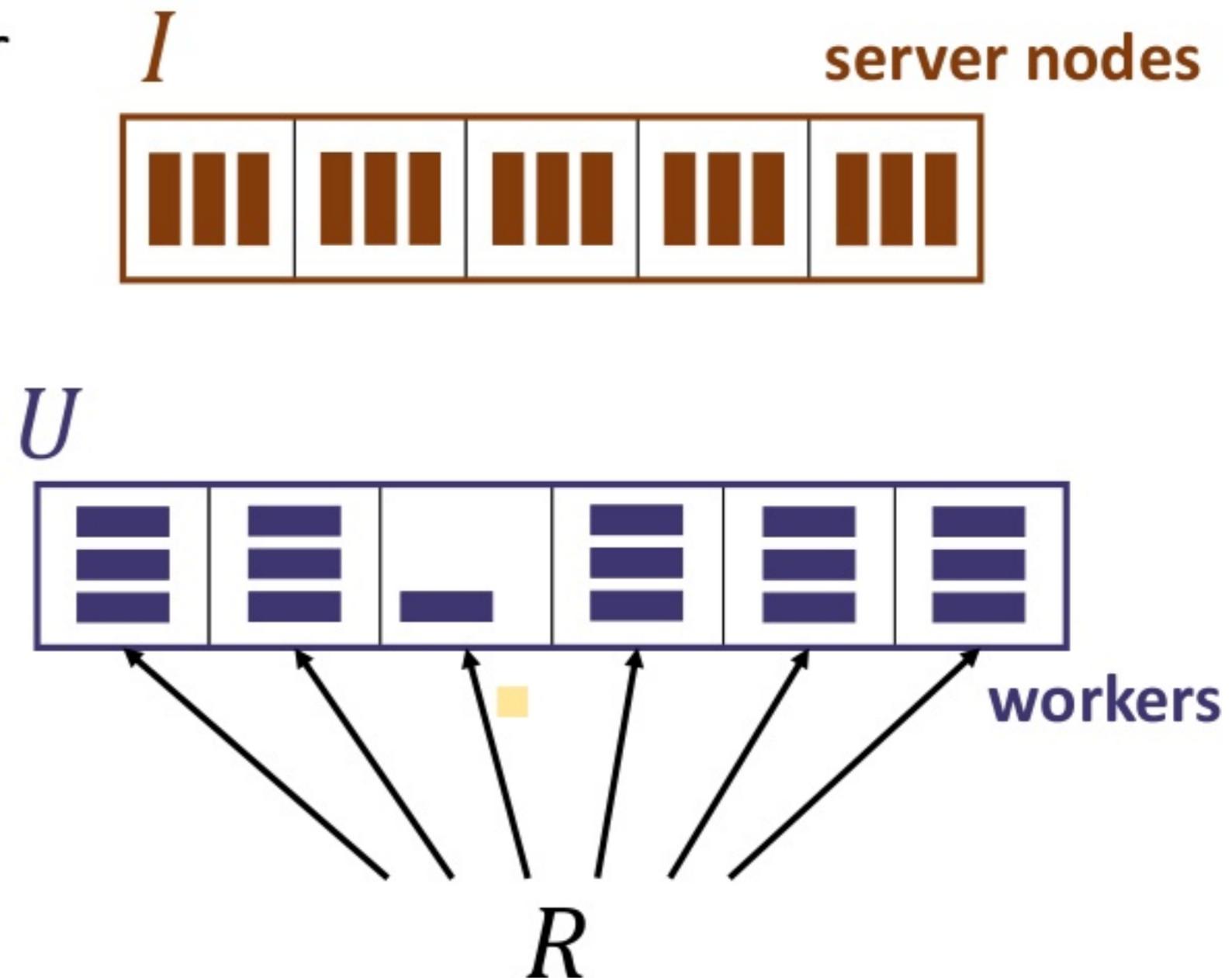
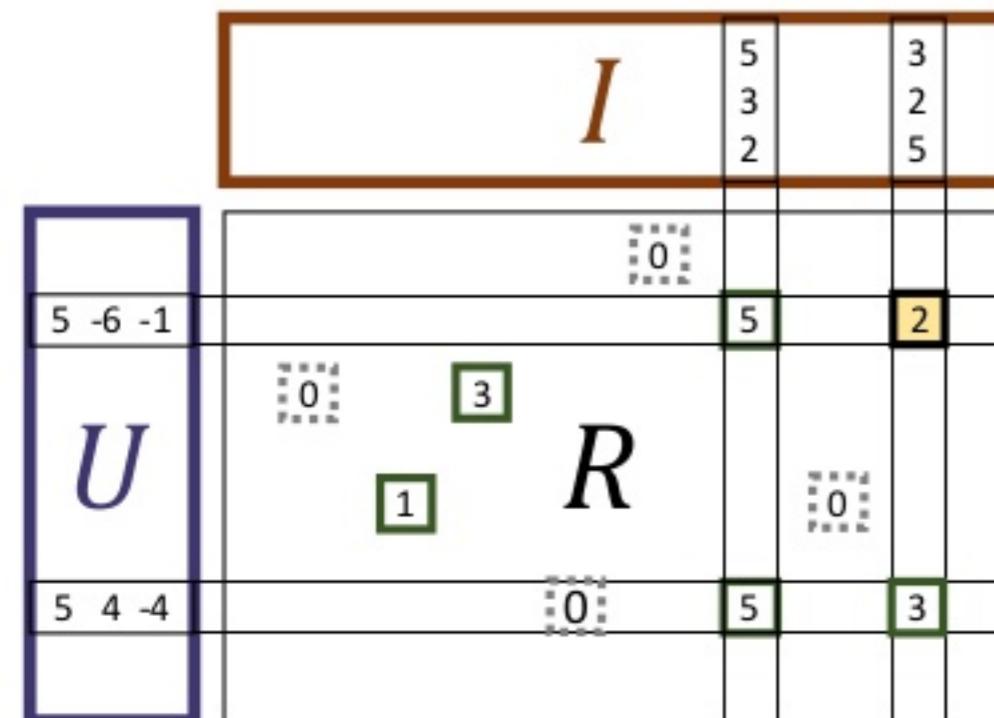
Matrix factorization with Parameter Server



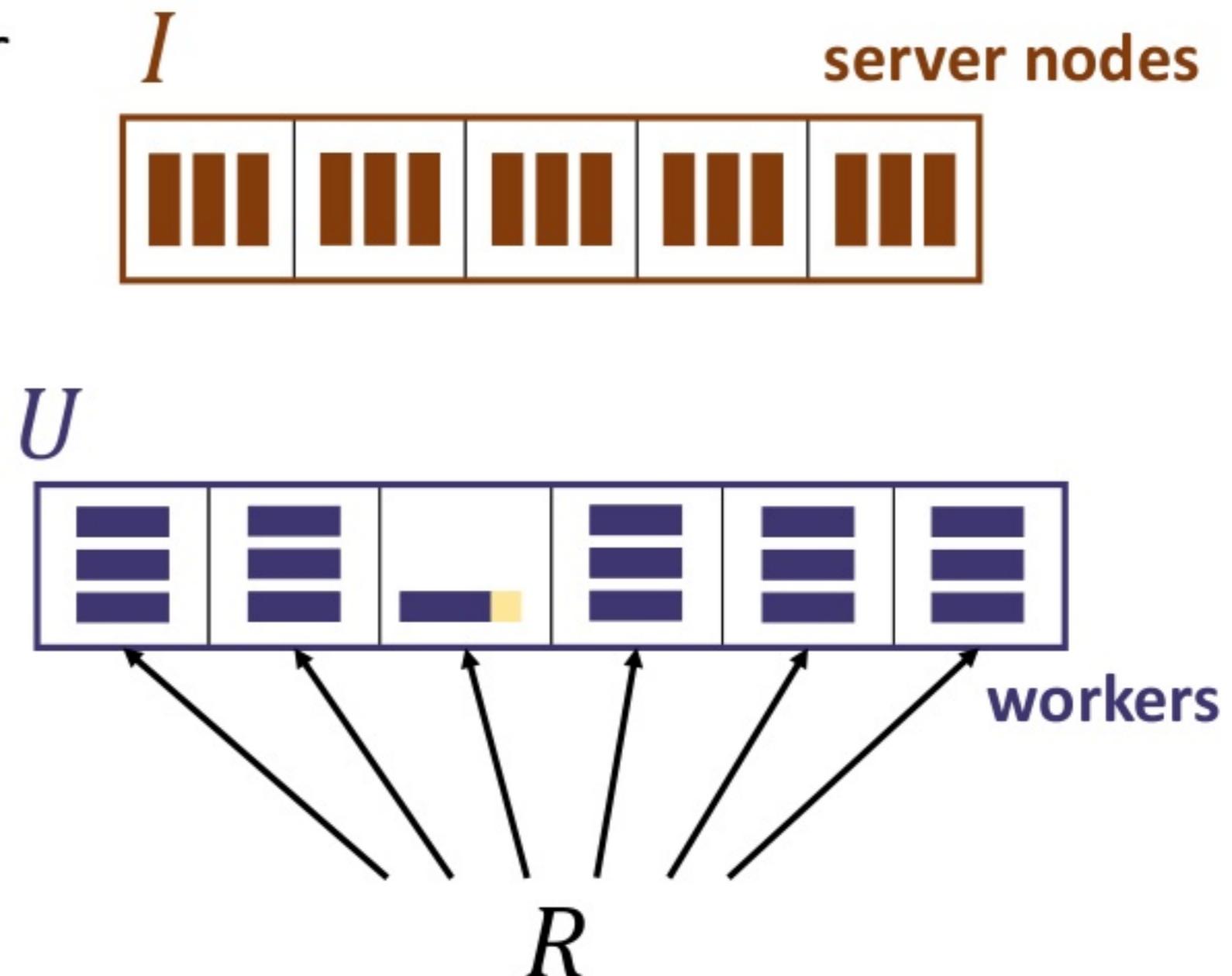
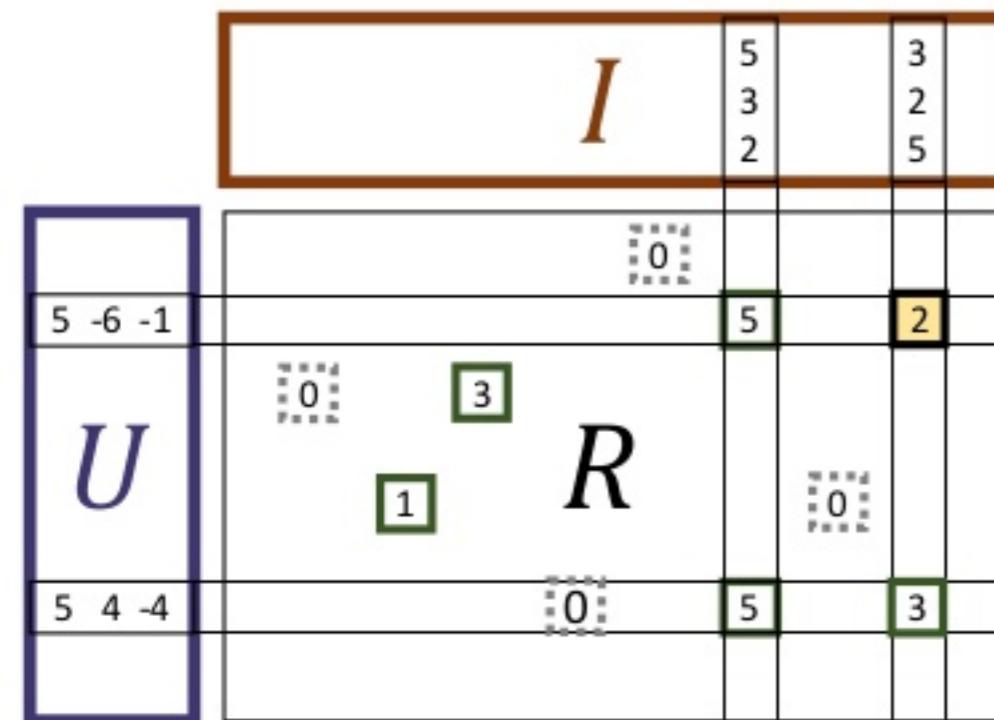
Matrix factorization with Parameter Server



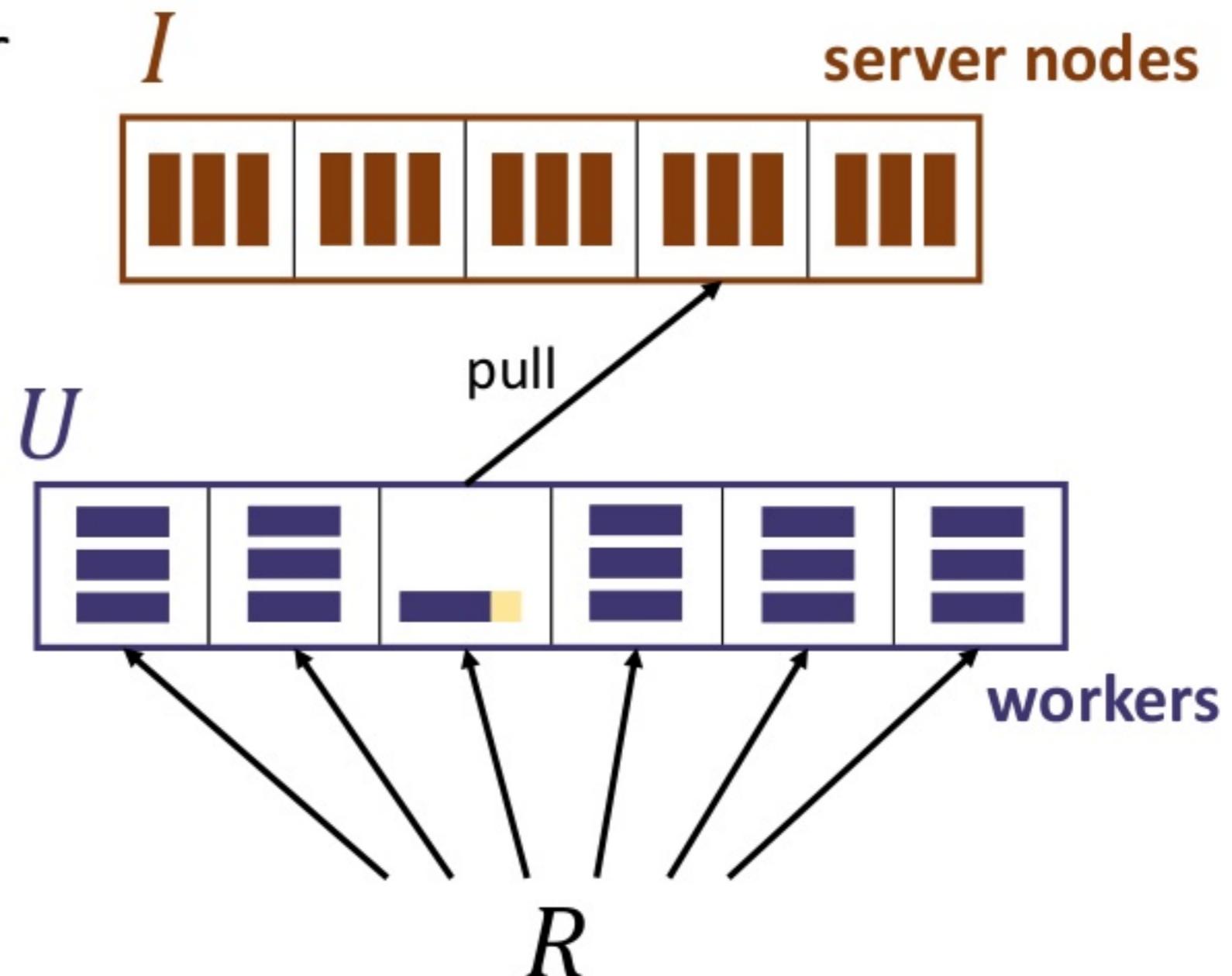
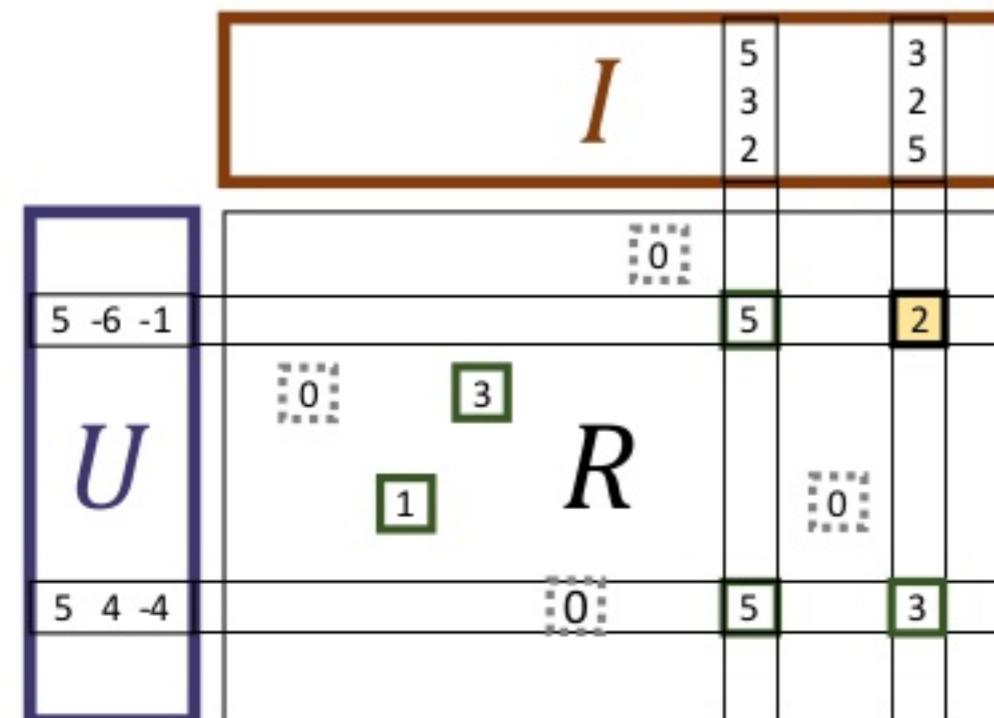
Matrix factorization with Parameter Server



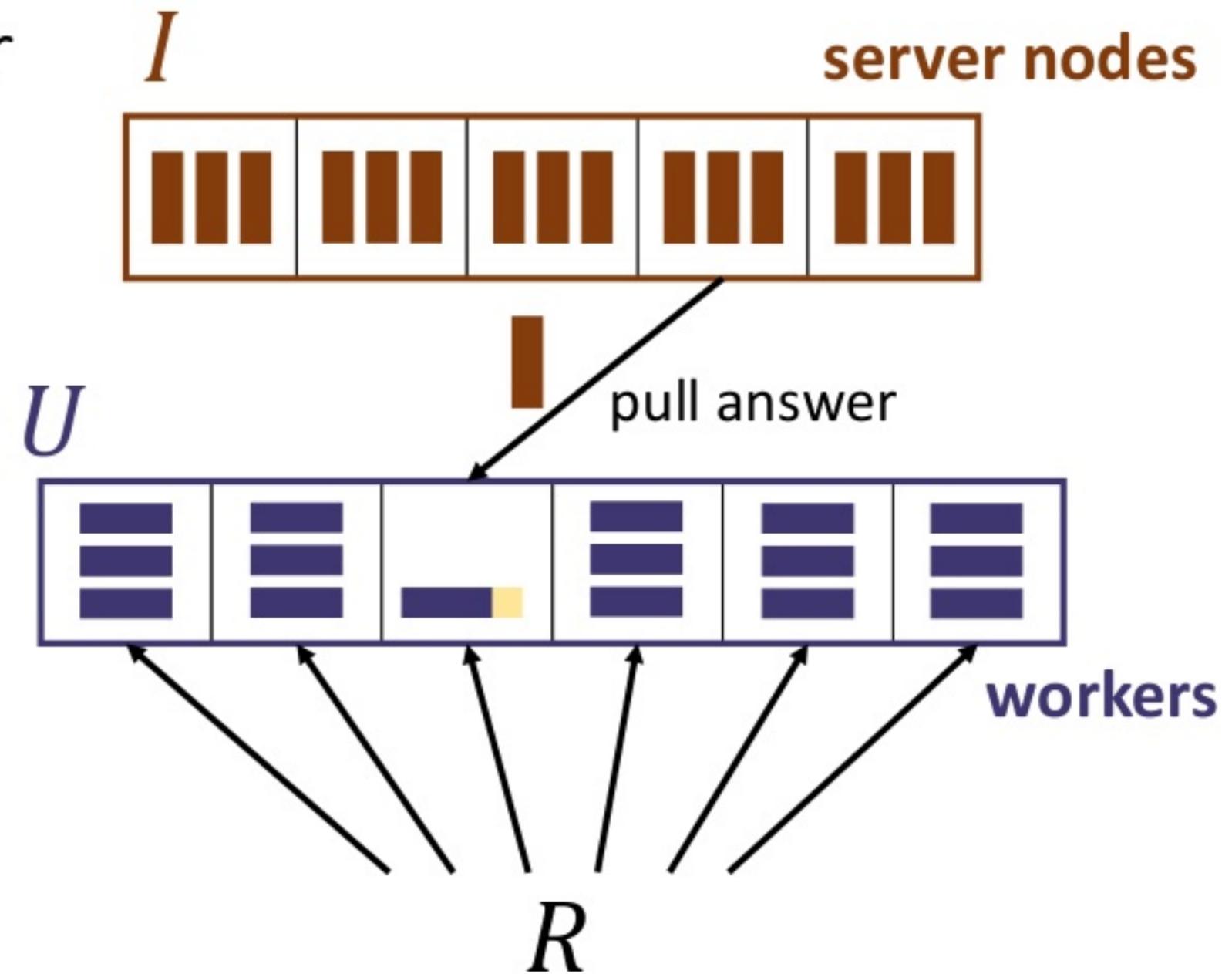
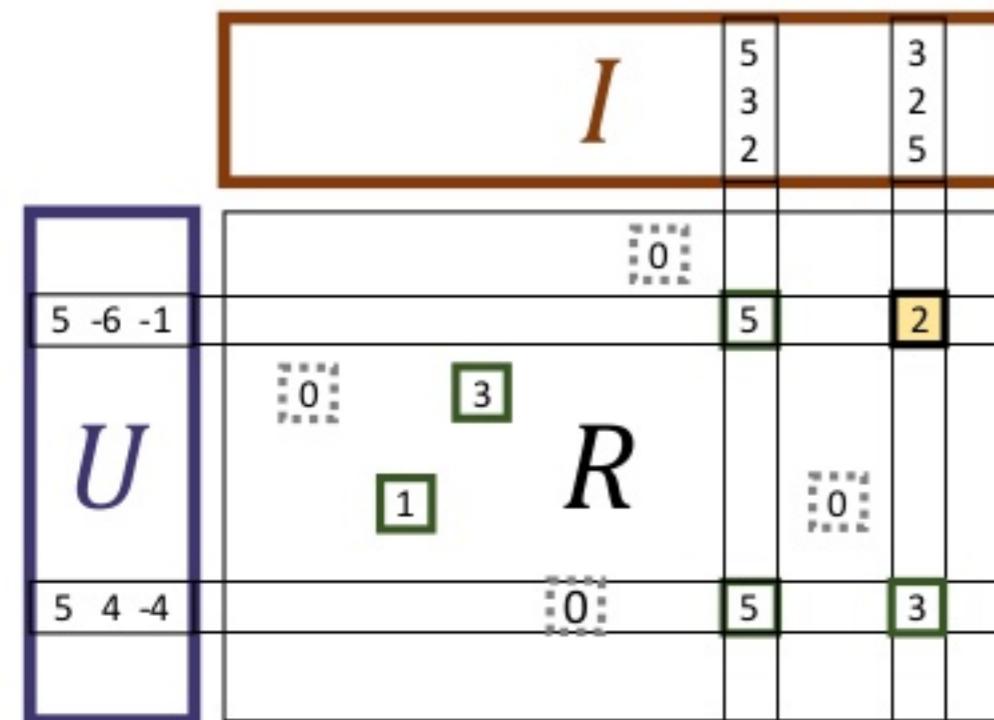
Matrix factorization with Parameter Server



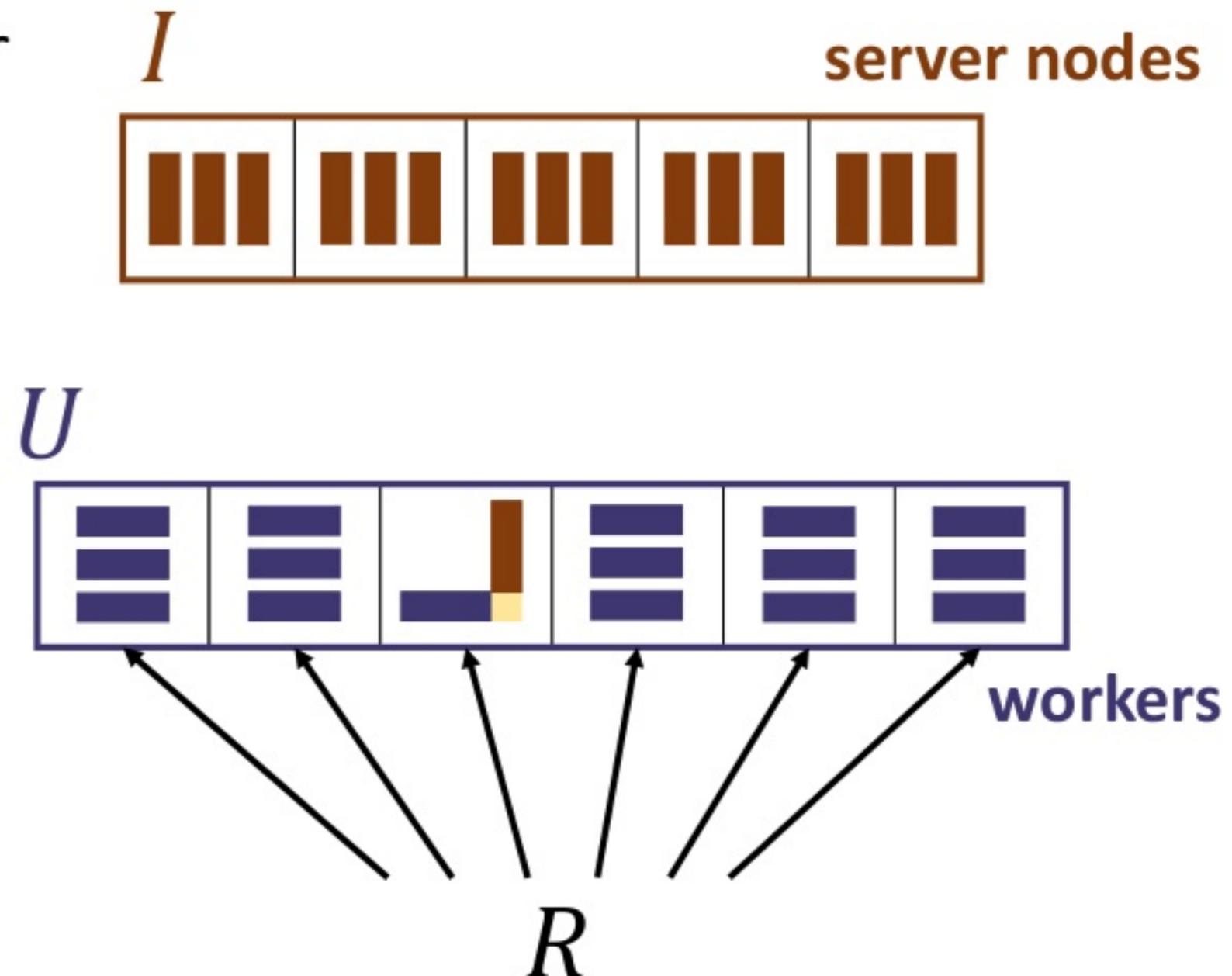
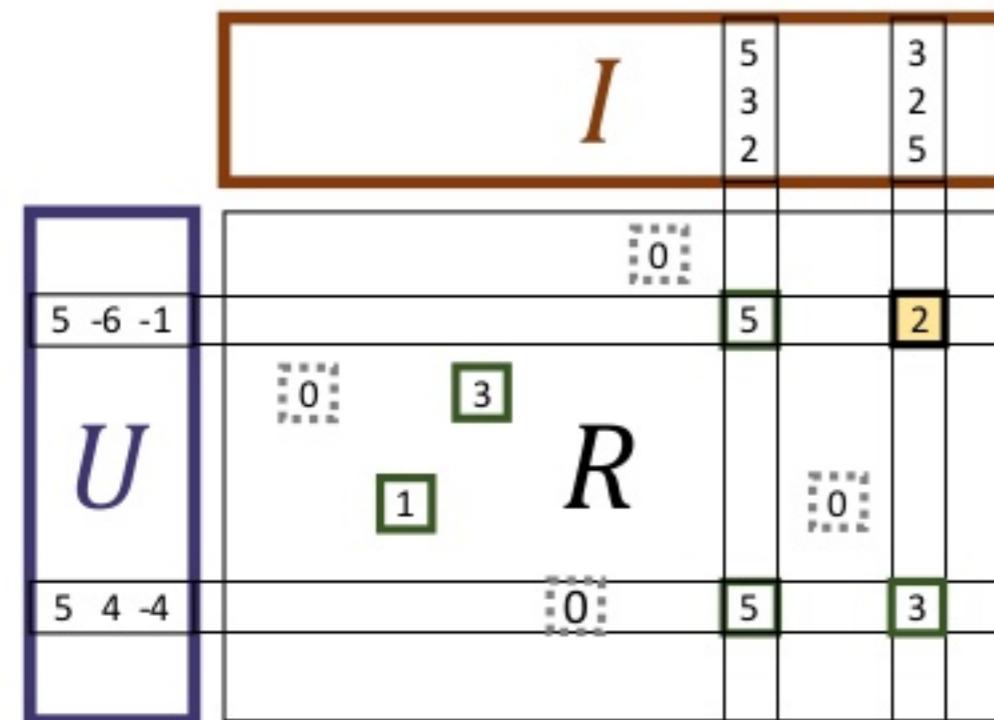
Matrix factorization with Parameter Server



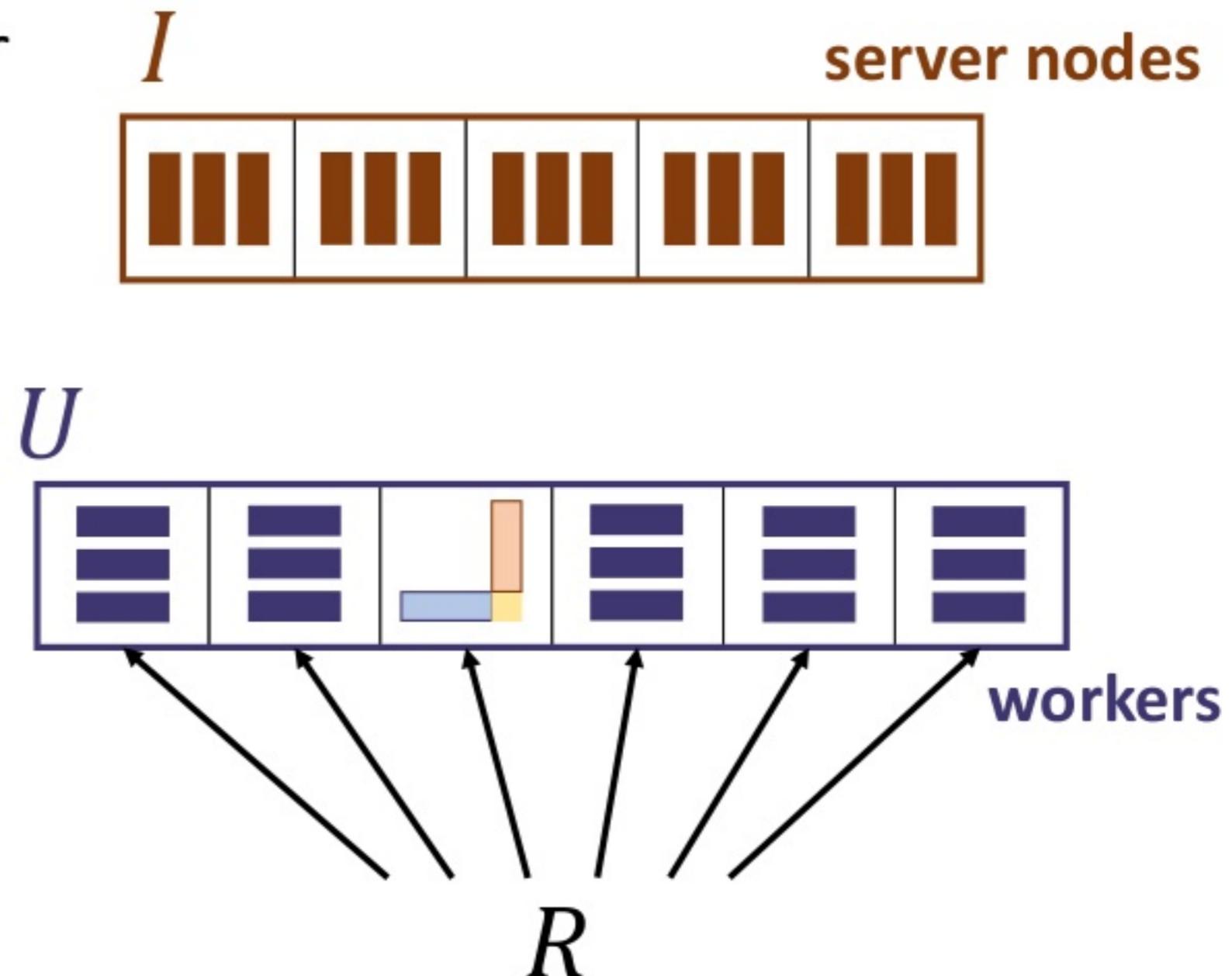
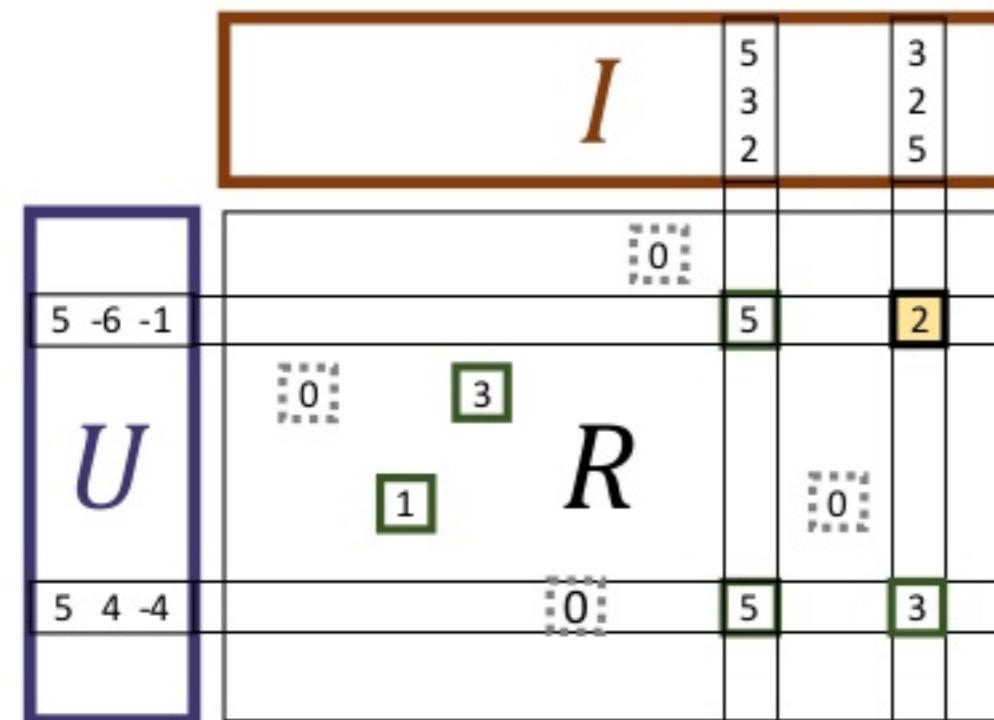
Matrix factorization with Parameter Server



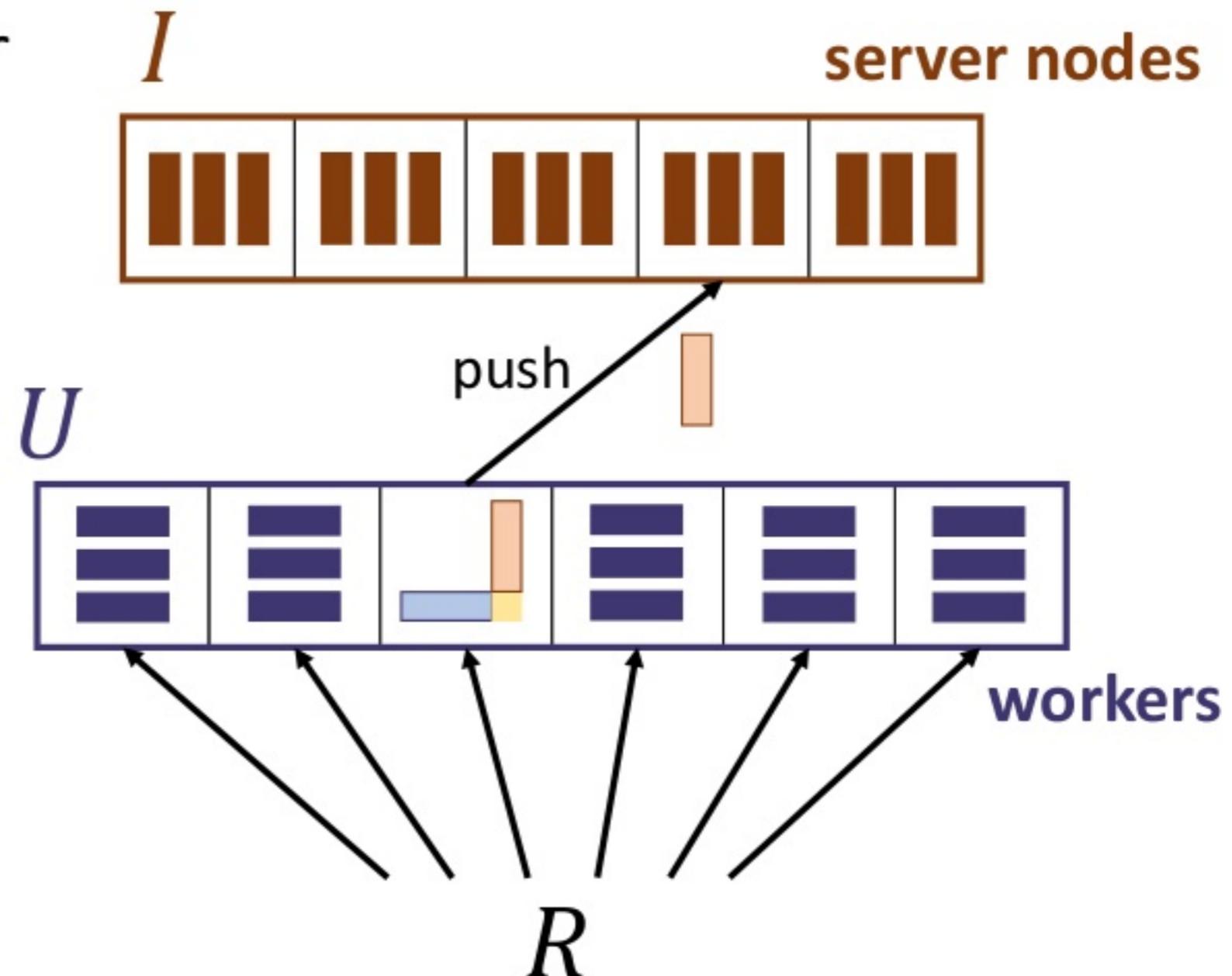
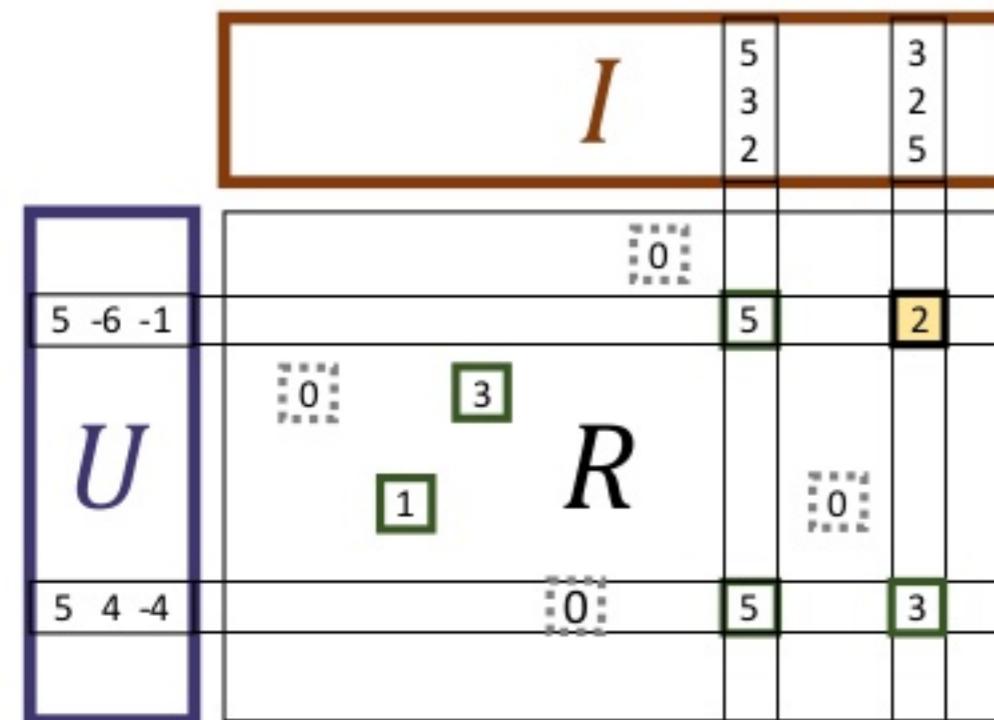
Matrix factorization with Parameter Server



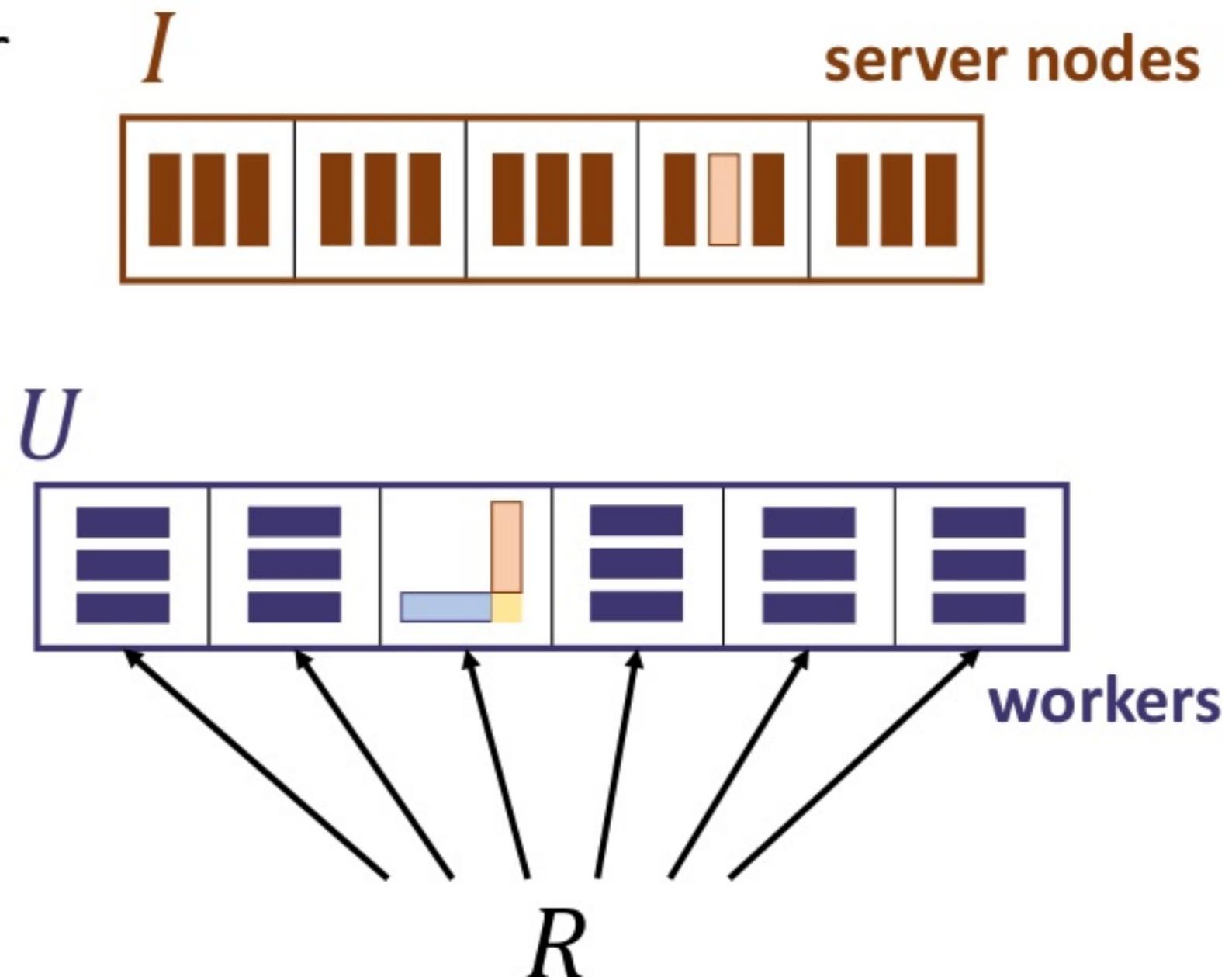
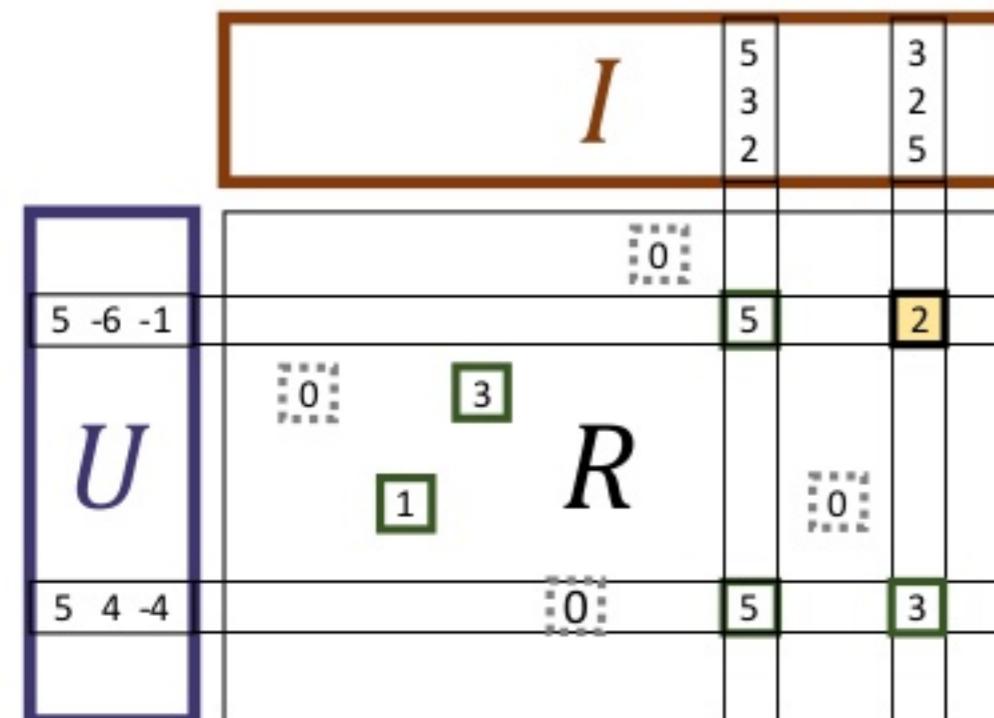
Matrix factorization with Parameter Server



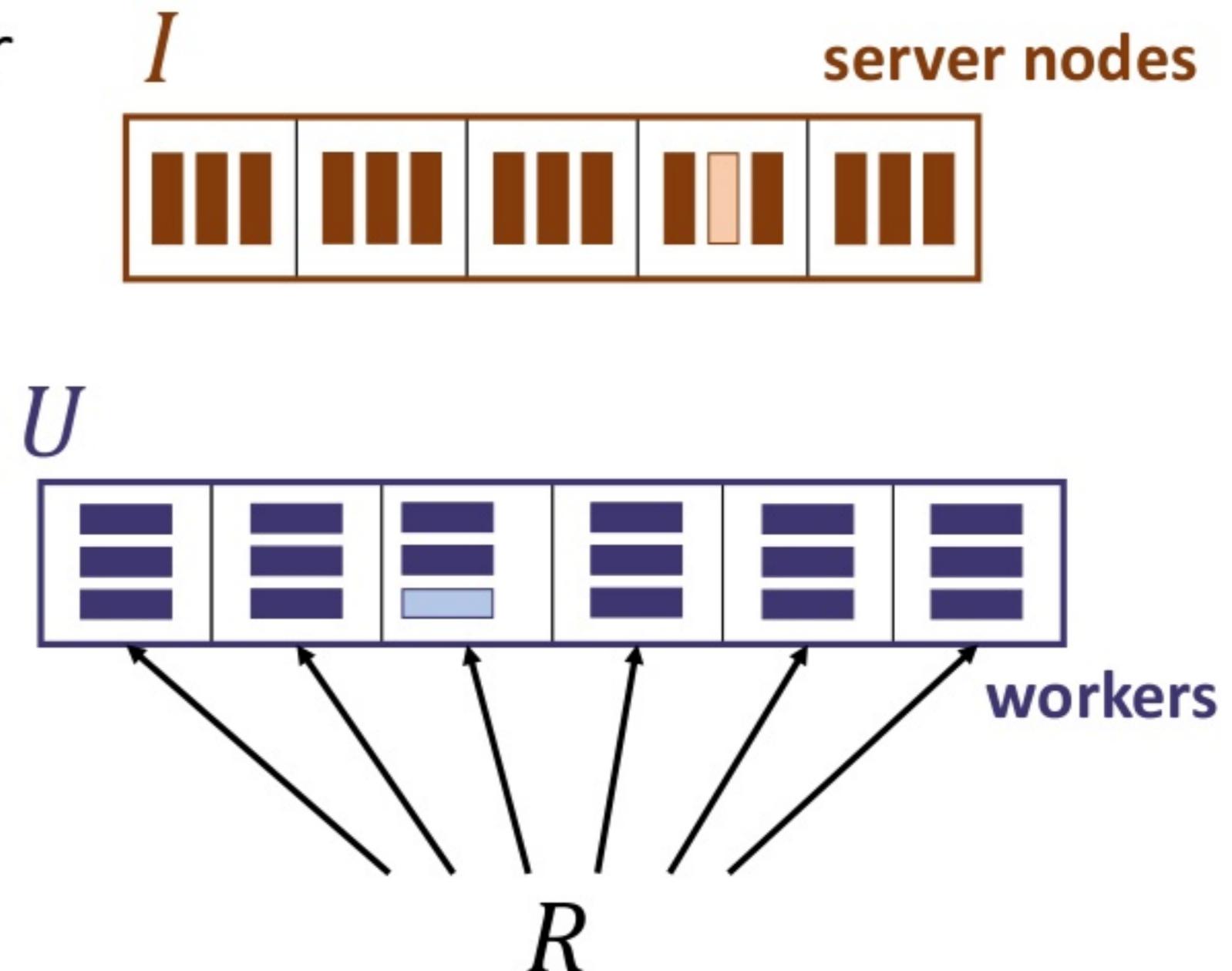
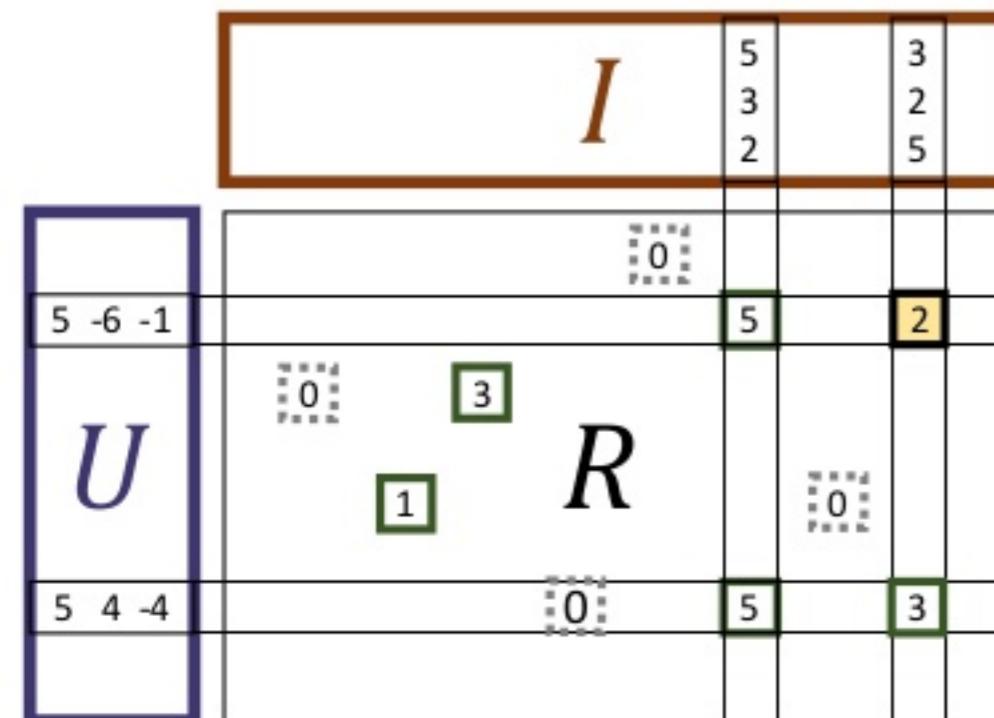
Matrix factorization with Parameter Server



Matrix factorization with Parameter Server



Matrix factorization with Parameter Server



Matrix Factorization code (SGD)

```
def onRecv(r: Rating) = {
```

```
def onPullRecv(paramId: Int,  
               param: Vector) = {
```

Matrix Factorization code (SGD)

```
def onRecv(r: Rating) = {  
    waitQueues(r.itemId).add(r)
```

```
def onPullRecv(paramId: Int,  
              param: Vector) = {
```

Matrix Factorization code (SGD)

```
def onRecv(r: Rating) = {  
    waitQueues(r.itemId).add(r)  
    ps.pull(r.itemId)  
}
```

```
def onPullRecv(paramId: Int,  
              param: Vector) = {
```

Matrix Factorization code (SGD)

```
def onRecv(r: Rating) = {  
    waitQueues(r.itemId).add(r)  
    ps.pull(r.itemId)  
}
```

```
def onPullRecv(paramId: Int,  
              param: Vector) = {  
    val itemId = paramId  
    val item = param
```

Matrix Factorization code (SGD)

```
def onRecv(r: Rating) = {  
    waitQueues(r.itemId).add(r)  
    ps.pull(r.itemId)  
}
```

```
def onPullRecv(paramId: Int,  
              param: Vector) = {  
    val itemId = paramId  
    val item = param  
  
    val (r, userId, _) =  
        waitQueues(itemId).pop()
```

Matrix Factorization code (SGD)

```
def onRecv(r: Rating) = {  
    waitQueues(r.itemId).add(r)  
    ps.pull(r.itemId)  
}
```

```
def onPullRecv(paramId: Int,  
              param: Vector) = {  
    val itemId = paramId  
    val item = param  
  
    val (r, userId, _) =  
        waitQueues(itemId).pop()  
    val user = users(userId)
```

Matrix Factorization code (SGD)

```
def onRecv(r: Rating) = {  
    waitQueues(r.itemId).add(r)  
    ps.pull(r.itemId)  
}
```

```
def onPullRecv(paramId: Int,  
              param: Vector) = {  
    val itemId = paramId  
    val item = param  
  
    val (r, userId, _) =  
        waitQueues(itemId).pop()  
    val user = users(userId)  
    val (userDelta, itemDelta) =  
        updateWithSGD(user, item, r)}
```

Matrix Factorization code (SGD)

```
def onRecv(r: Rating) = {  
    waitQueues(r.itemId).add(r)  
    ps.pull(r.itemId)  
}
```

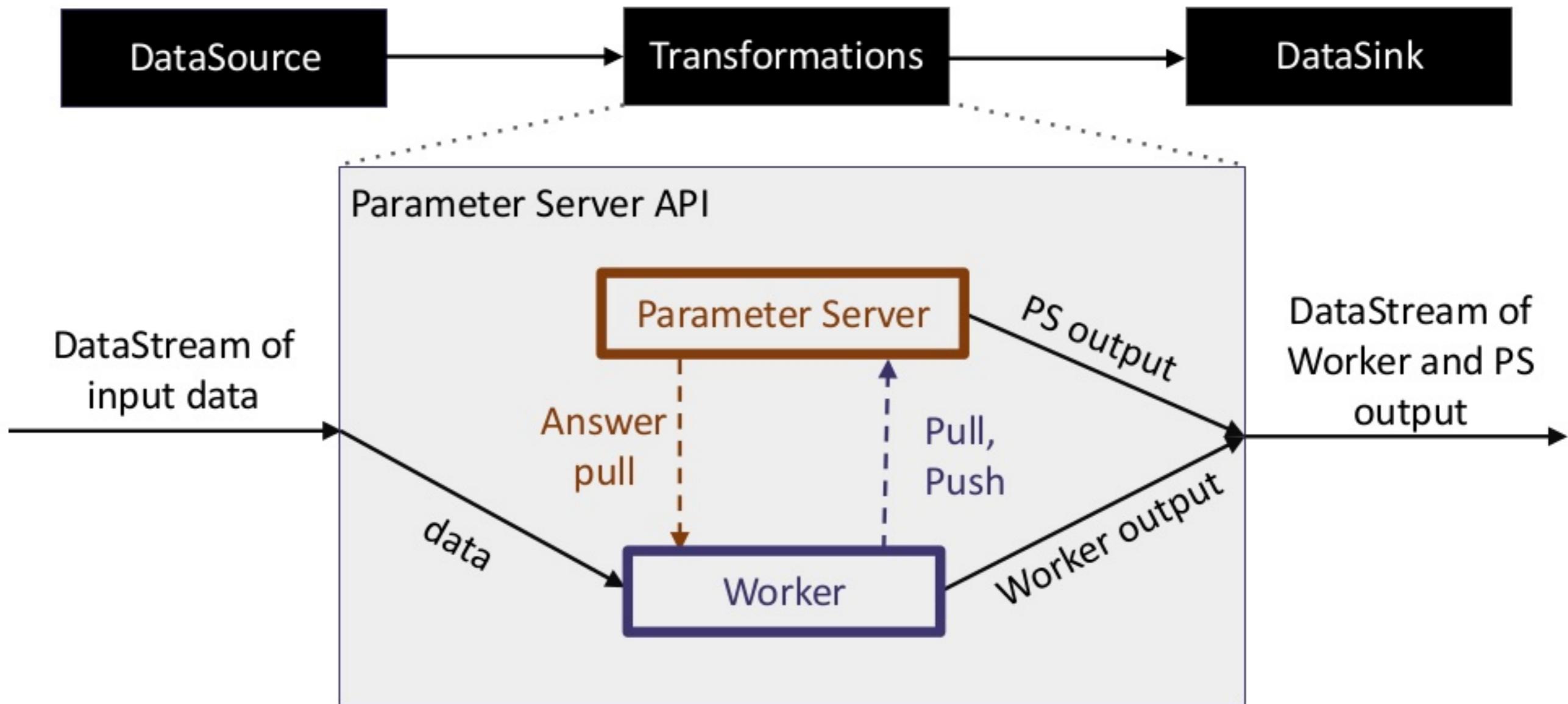
```
def onPullRecv(paramId: Int,  
              param: Vector) = {  
    val itemId = paramId  
    val item = param  
  
    val (r, userId, _) =  
        waitQueues(itemId).pop()  
    val user = users(userId)  
    val (userDelta, itemDelta) =  
        updateWithSGD(user, item, r)  
    ps.push(itemId, itemDelta)}
```

Matrix Factorization code (SGD)

```
def onRecv(r: Rating) = {  
    waitQueues(r.itemId).add(r)  
    ps.pull(r.itemId)  
}
```

```
def onPullRecv(paramId: Int,  
              param: Vector) = {  
    val itemId = paramId  
    val item = param  
  
    val (r, userId, _) =  
        waitQueues(itemId).pop()  
    val user = users(userId)  
    val (userDelta, itemDelta) =  
        updateWithSGD(user, item, r)  
    ps.push(itemId, itemDelta)  
    users(userId) += userDelta  
}
```

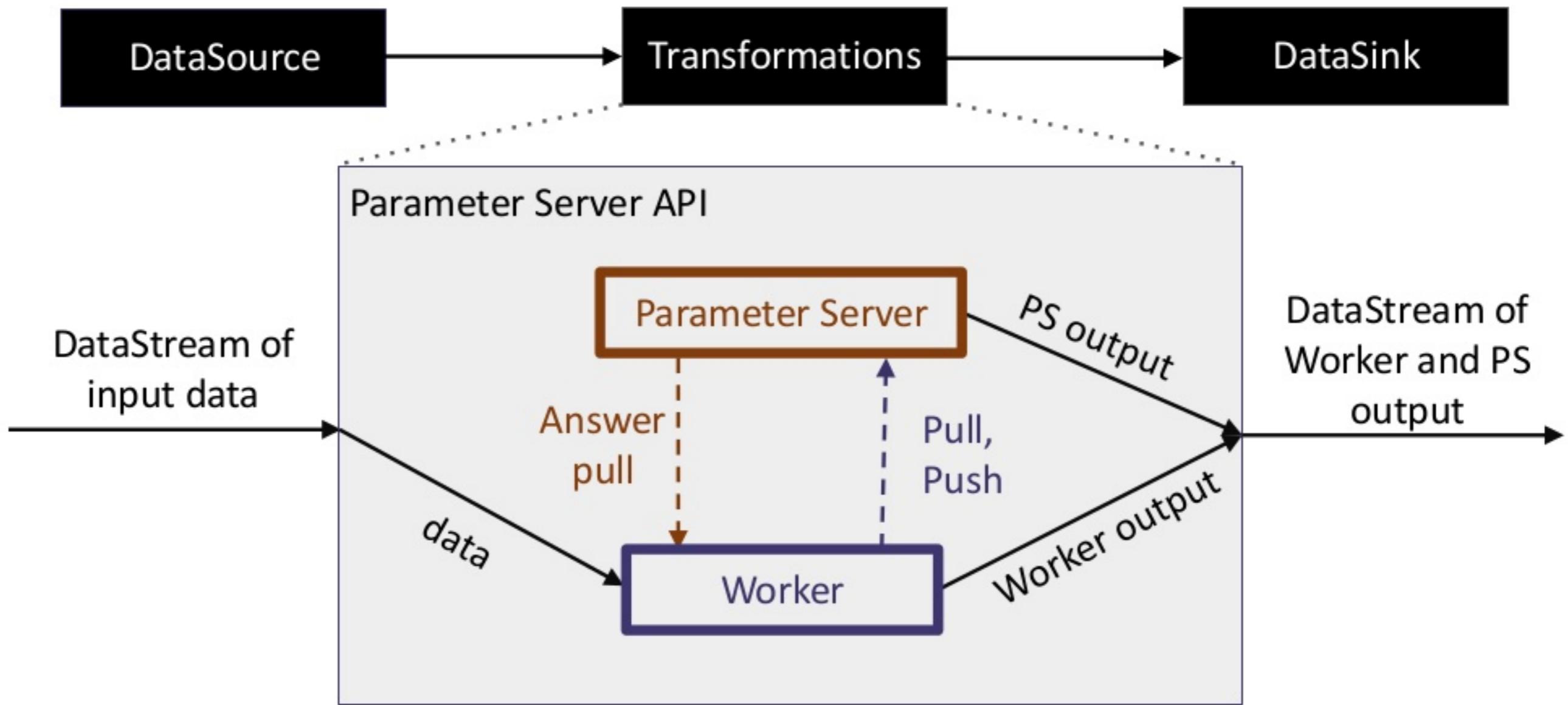
Integration with Flink



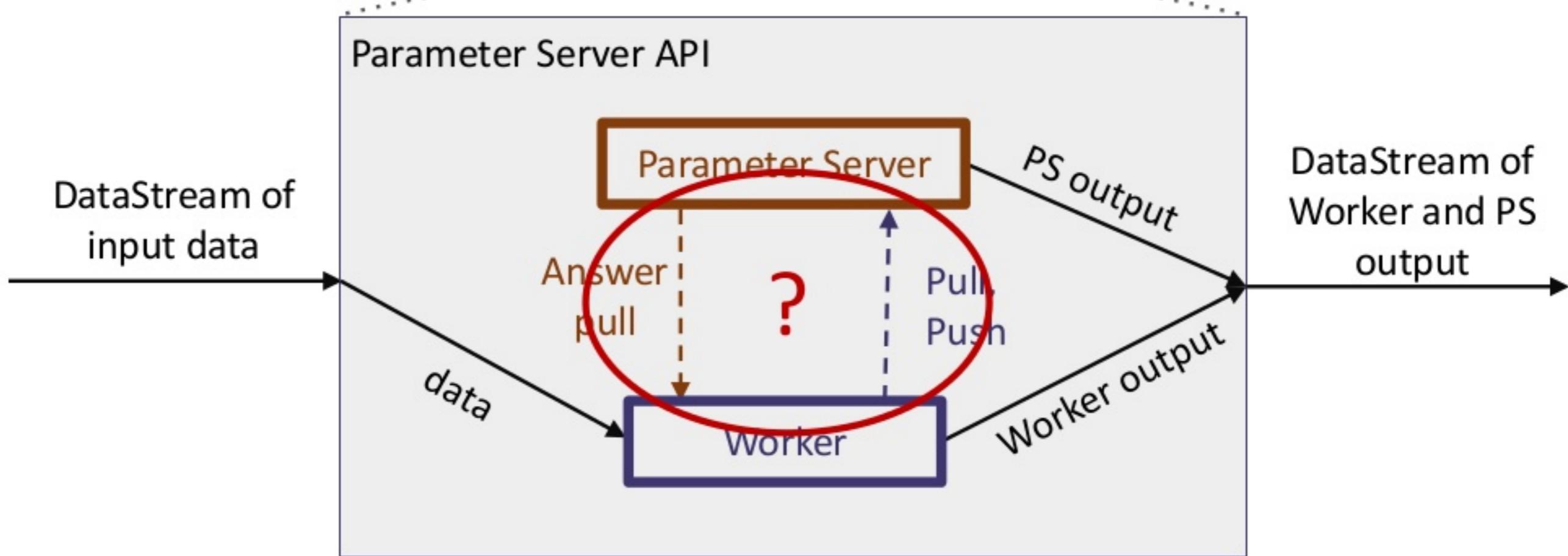
Integration with Flink

```
val input: DataStream[Data] = ...  
  
val output: DataStream[Either[PSOutput, WorkerOutput]] =  
  psTransform(input, onRecv, onPullRecv)
```

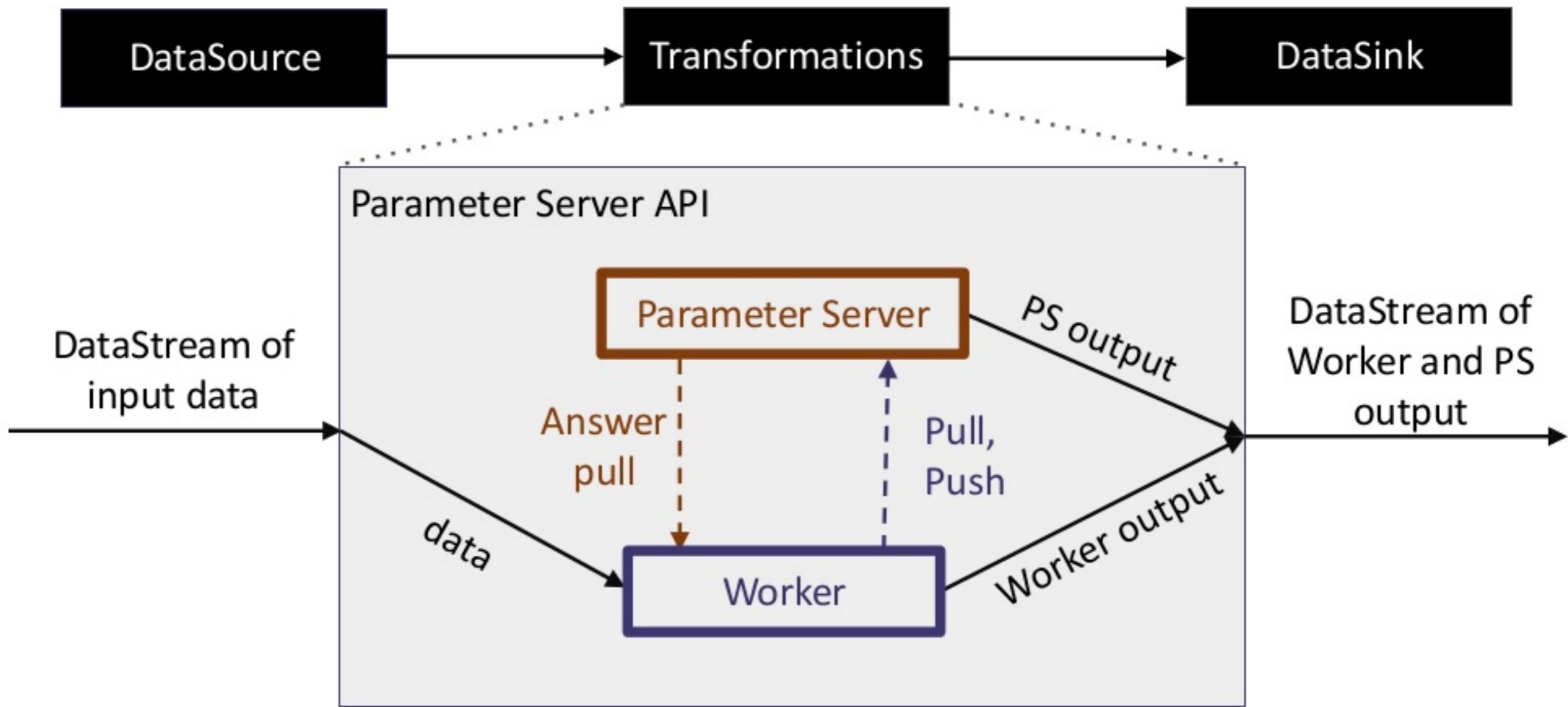
Implementation?



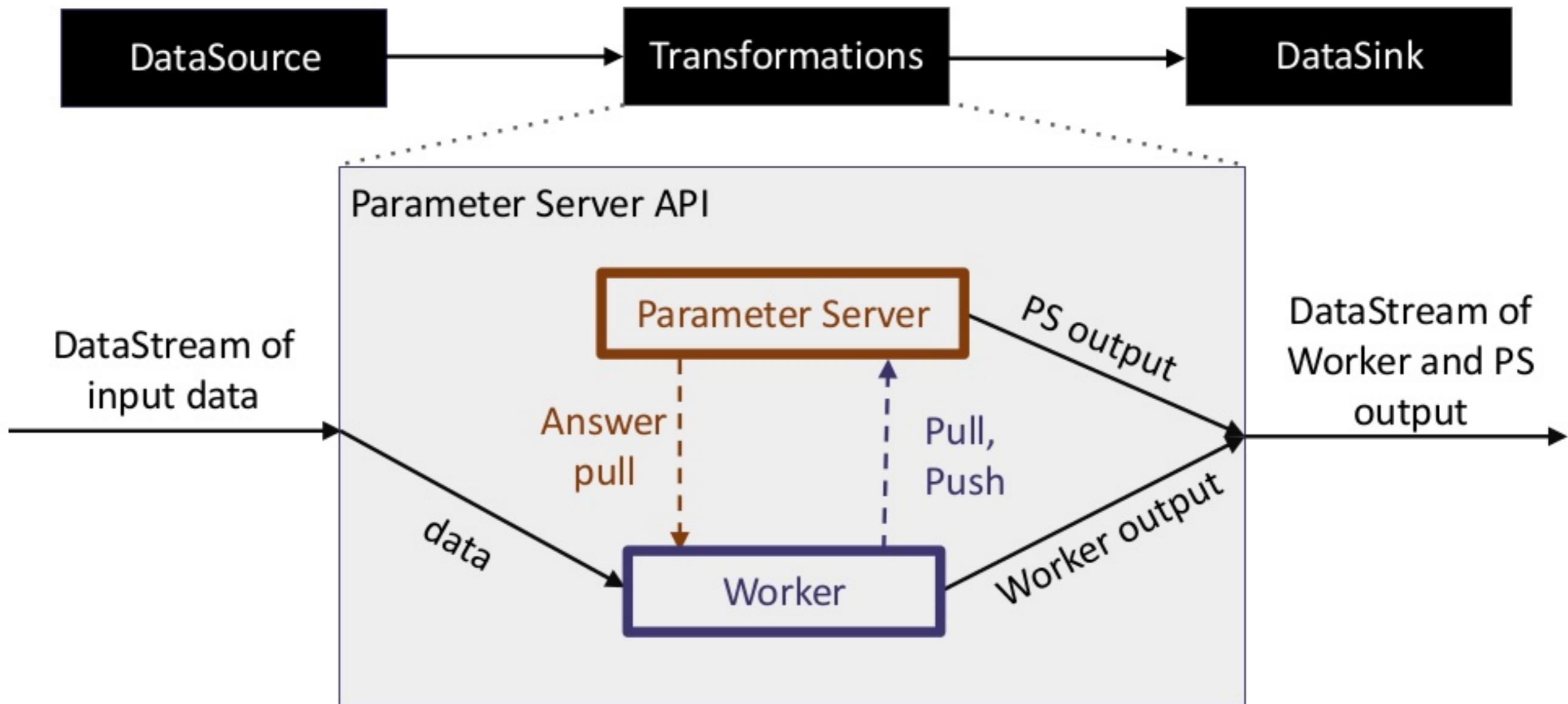
Implementation?



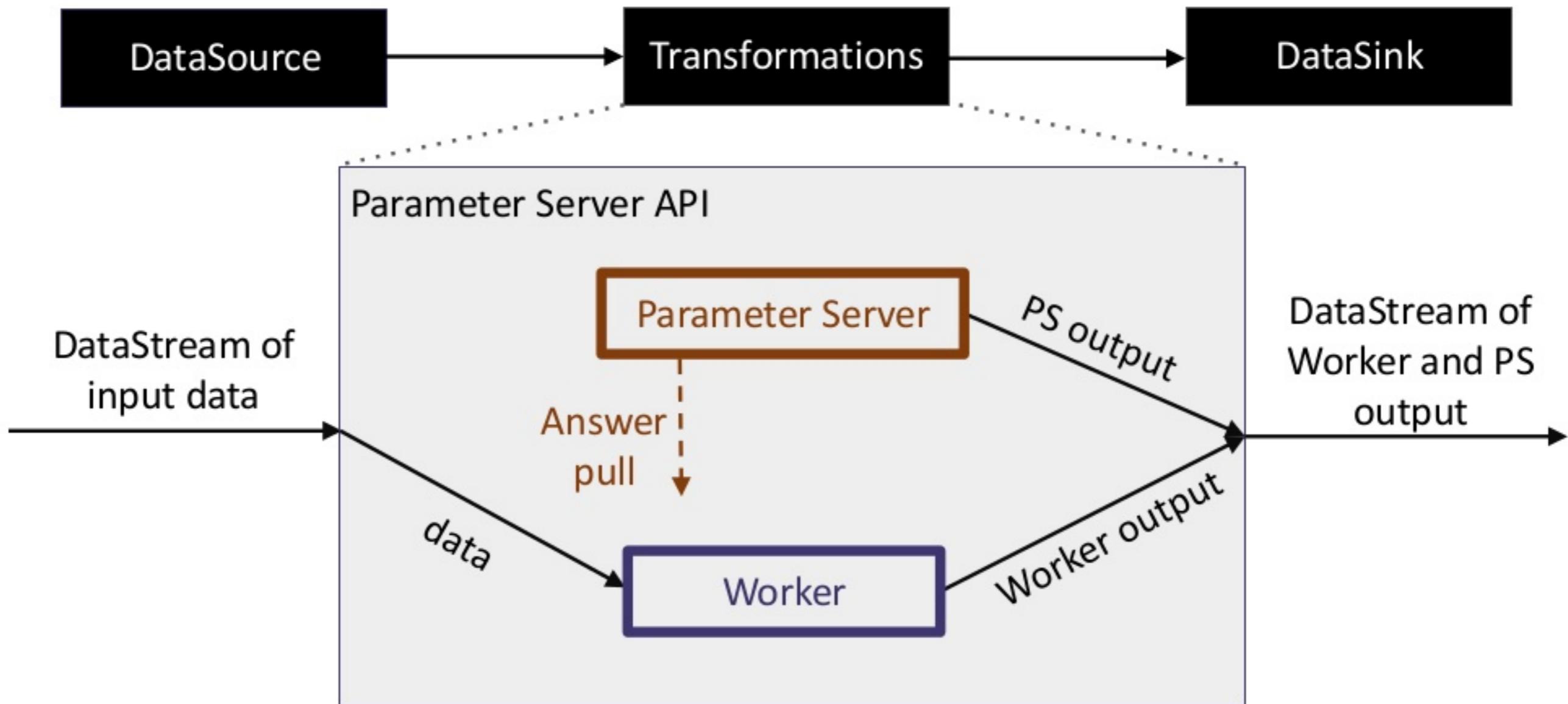
Implementation: Loops API



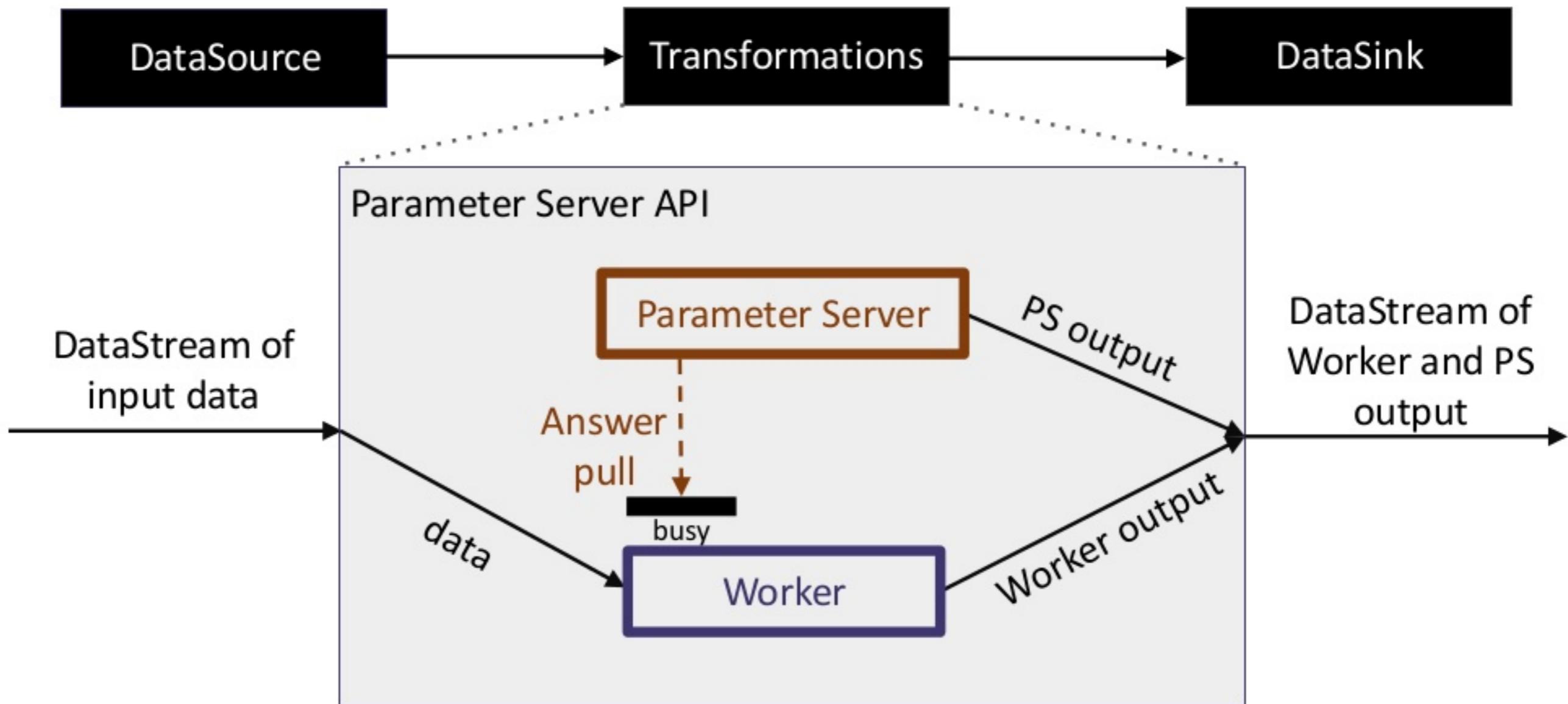
Implementation: Loops API NOT MATURE



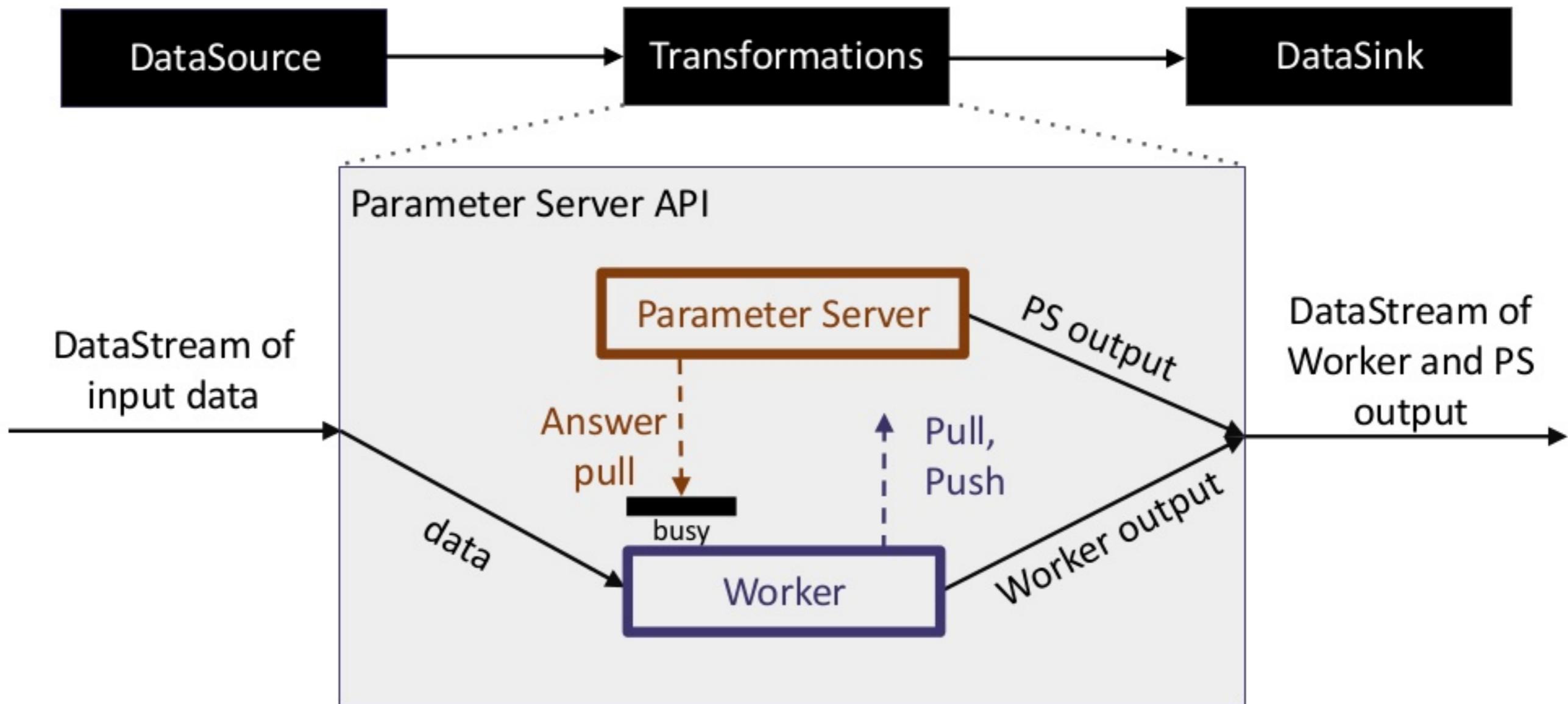
Implementation: Loops API NOT MATURE



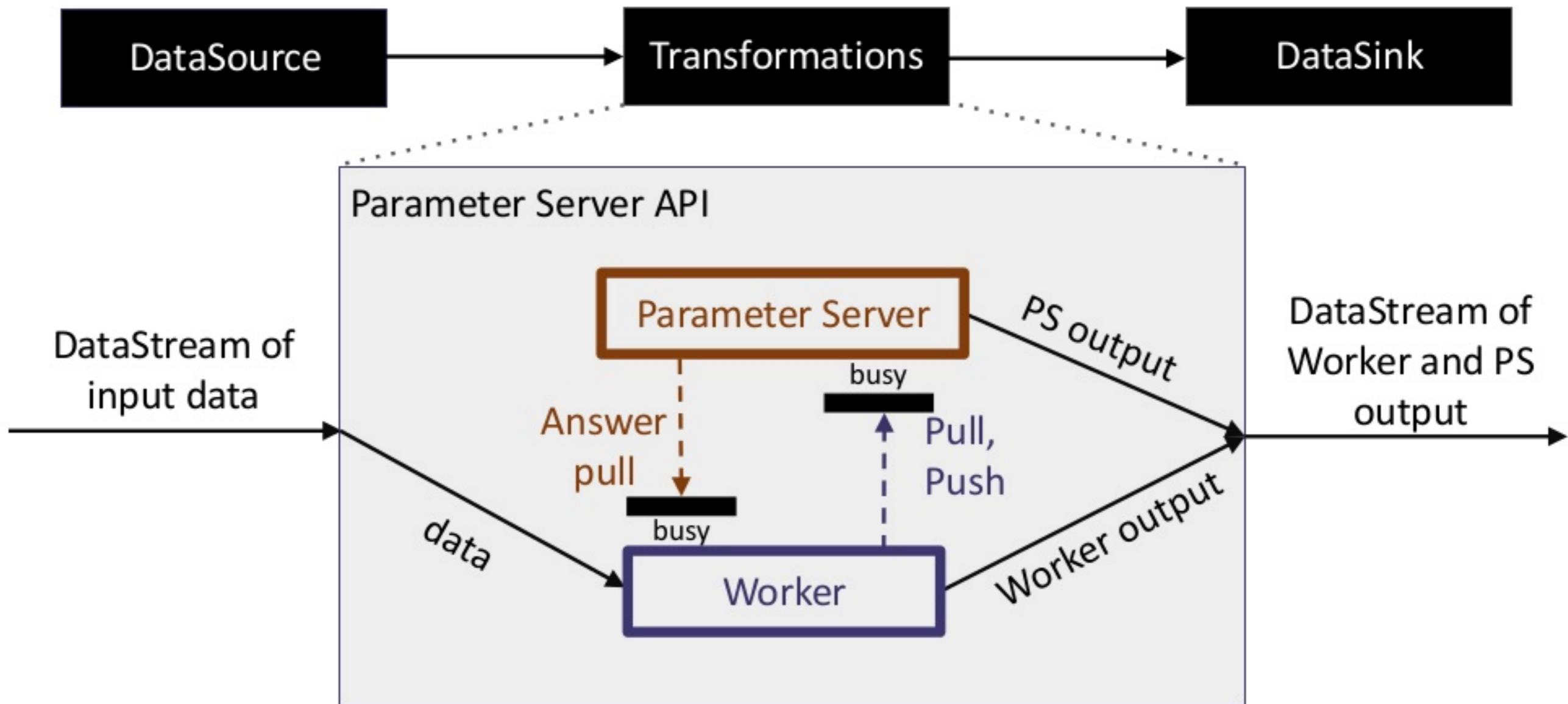
Implementation: Loops API NOT MATURE



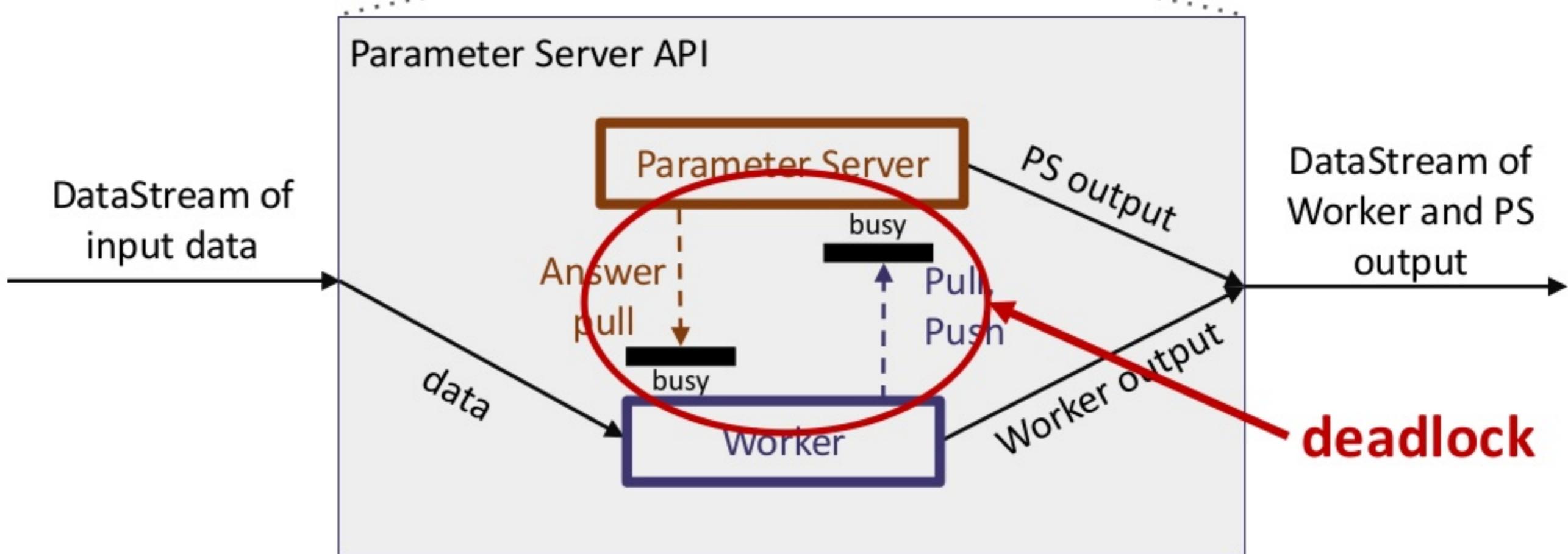
Implementation: Loops API NOT MATURE



Implementation: Loops API NOT MATURE

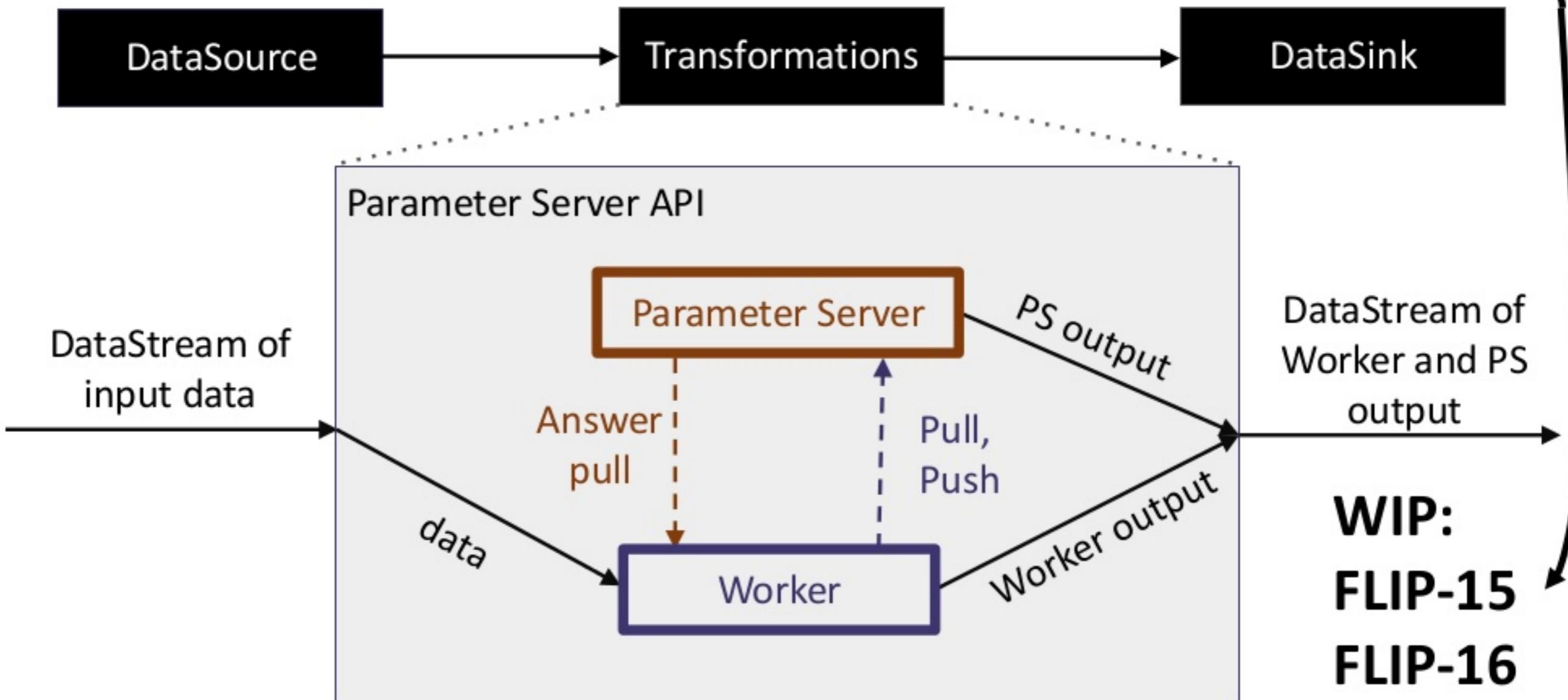


Implementation: Loops API NOT MATURE



Implementation: Loops API

NOT MATURE



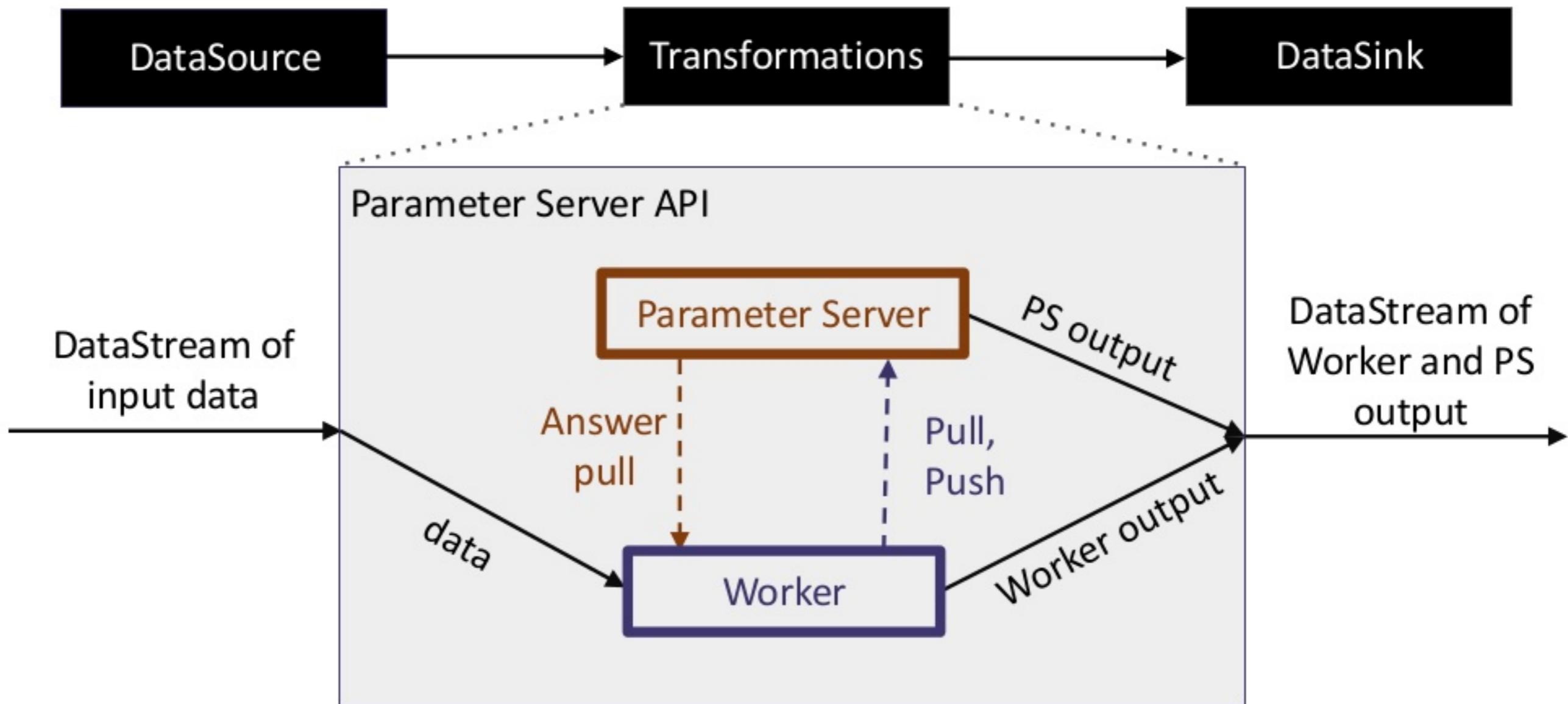
Batch on streaming?

Batch vs streaming?

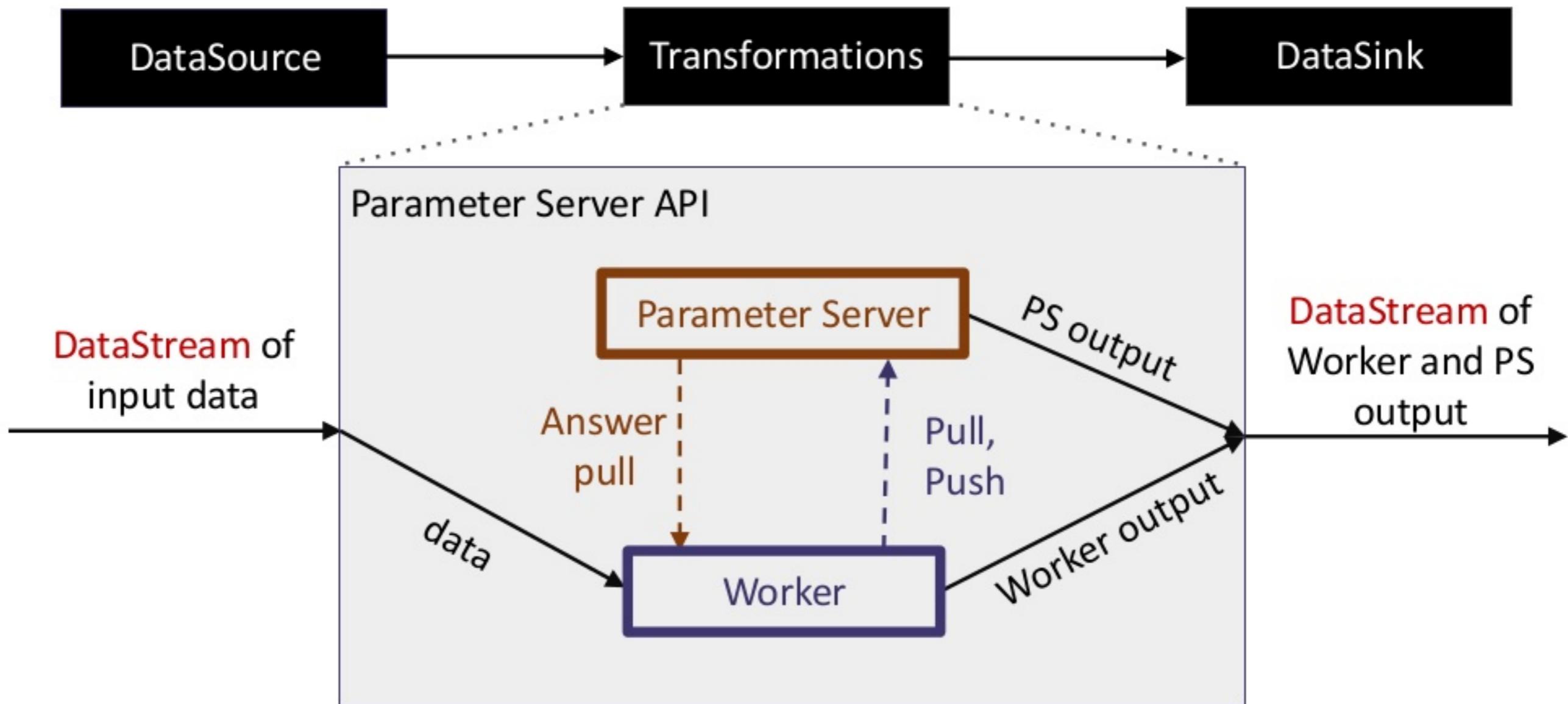
Batch vs streaming?
Offline vs online?



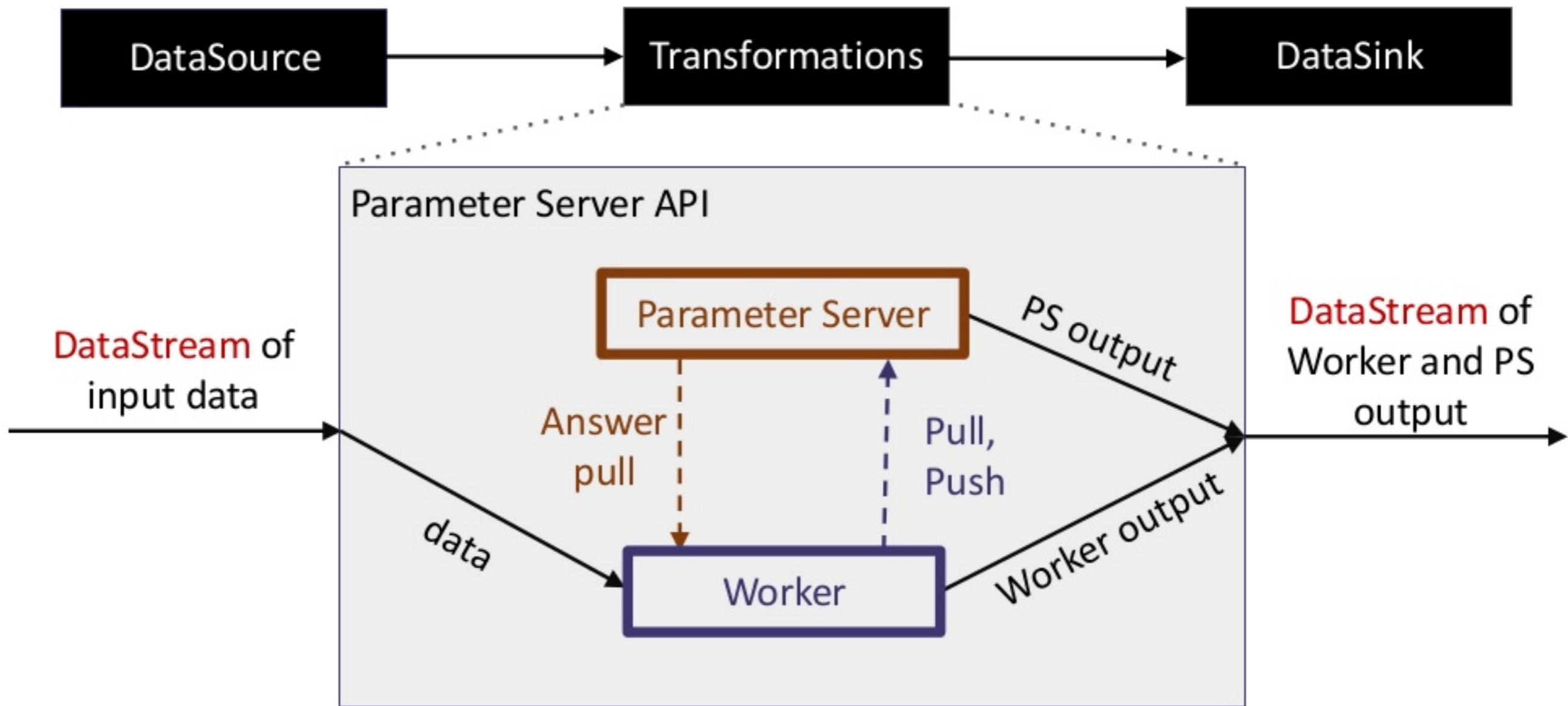
Online on streaming



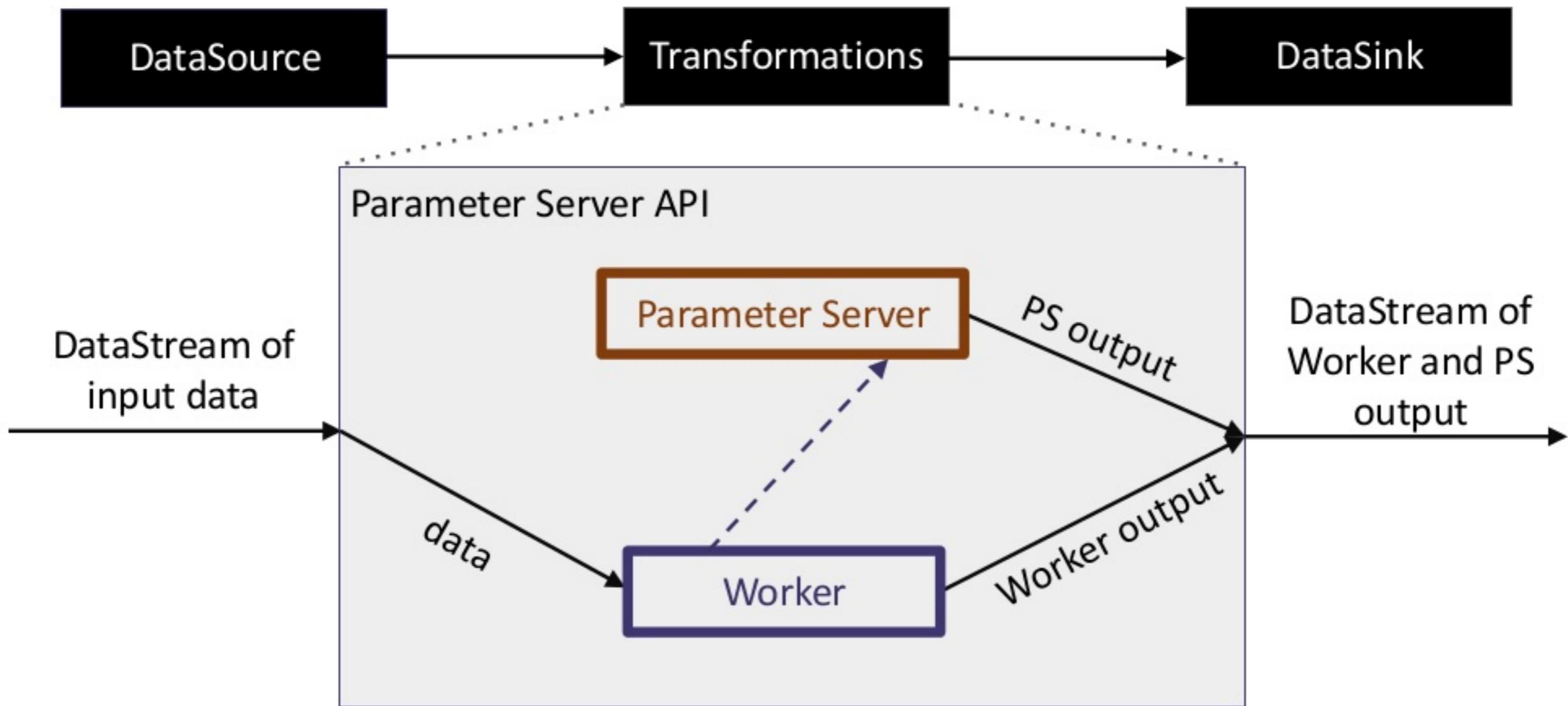
Online on streaming



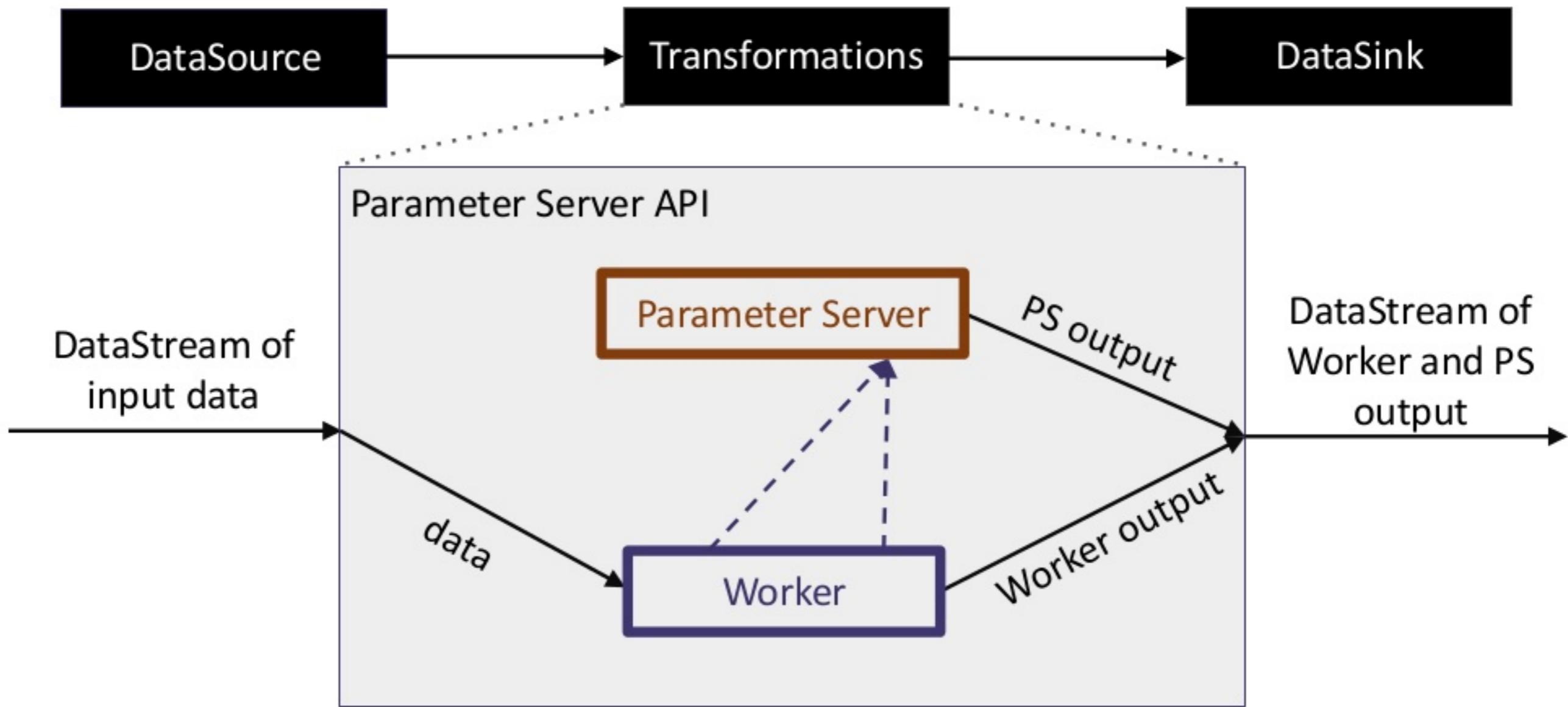
Offline on streaming?



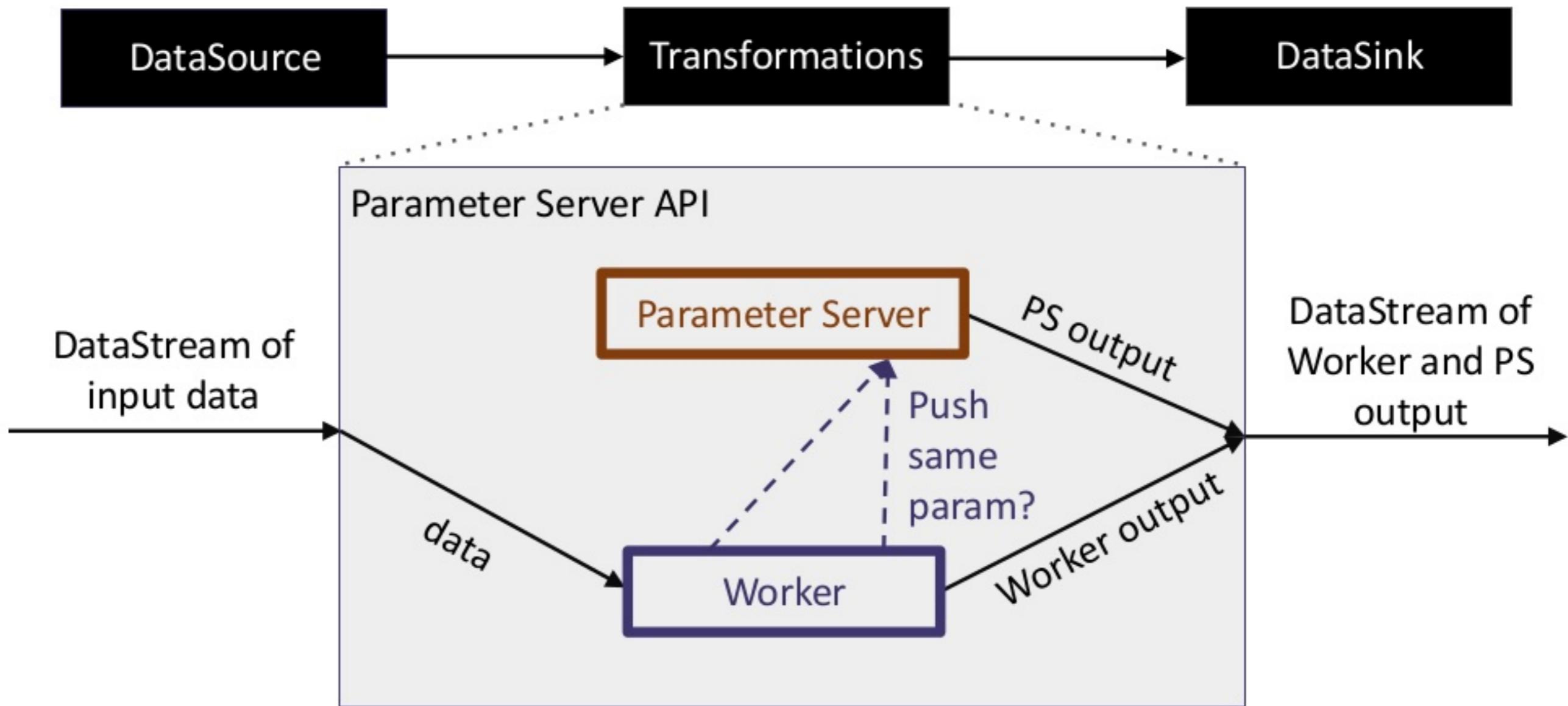
Offline on streaming?



Offline on streaming?

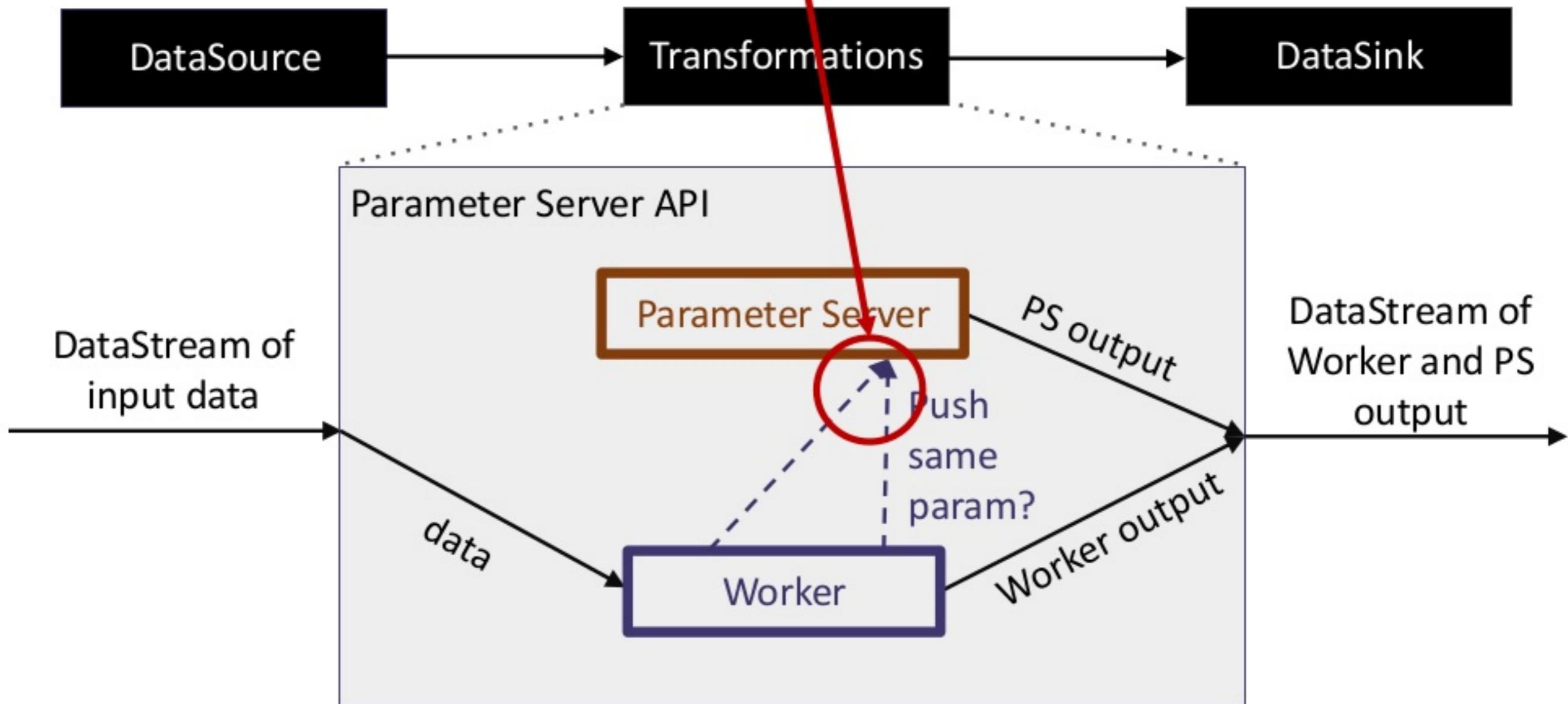


Offline on streaming?



Offline on streaming?

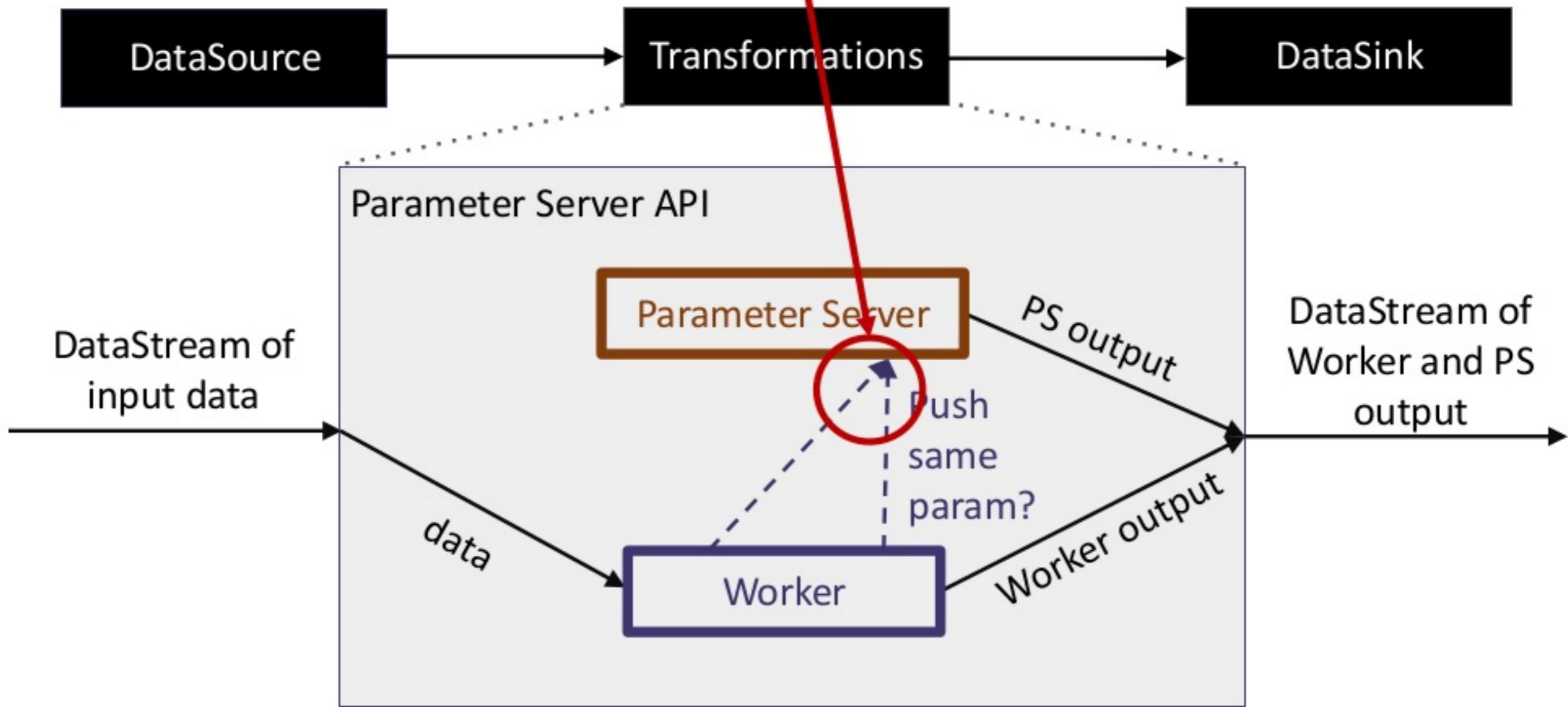
Write conflict!



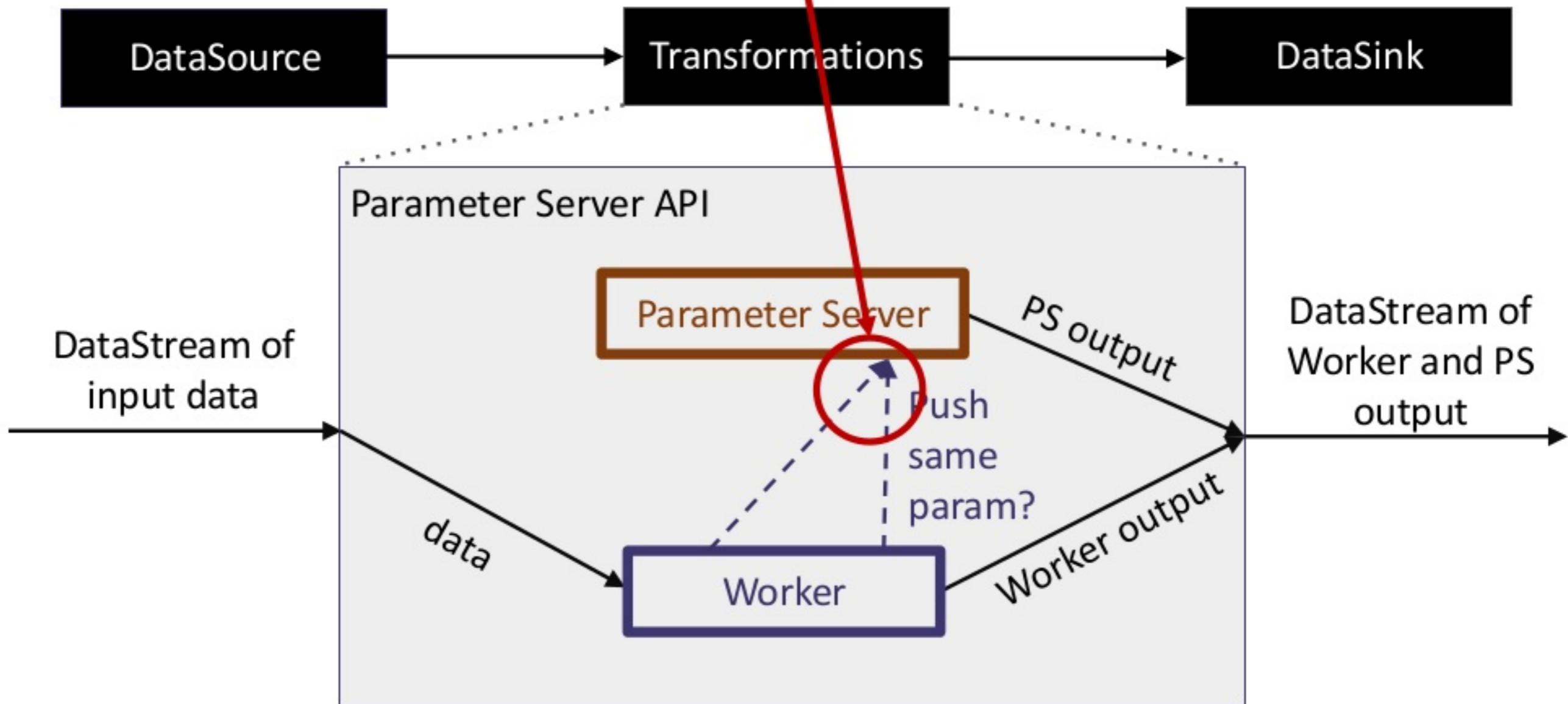
Offline on streaming?

Write conflict!

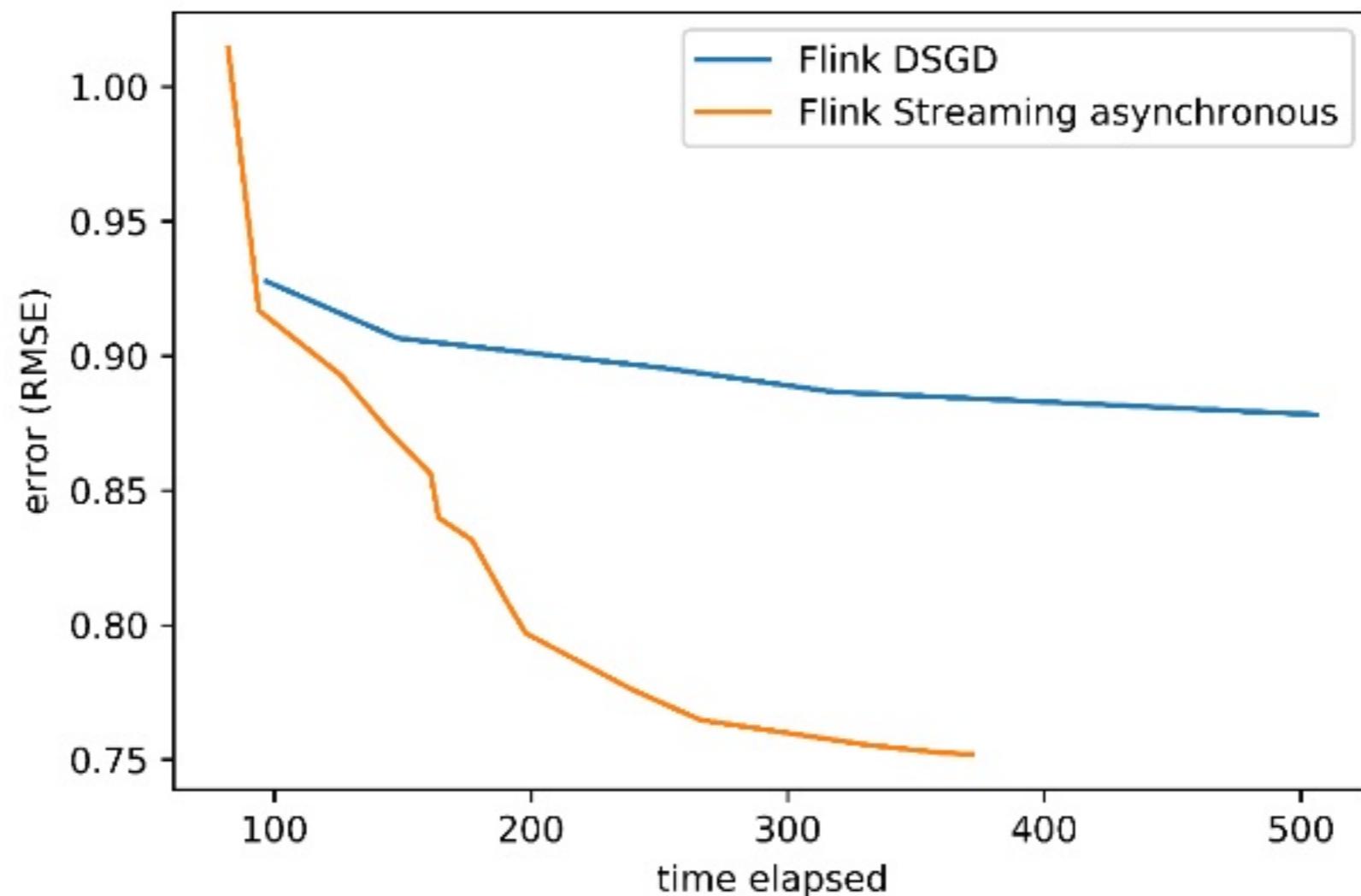
Synchronization?



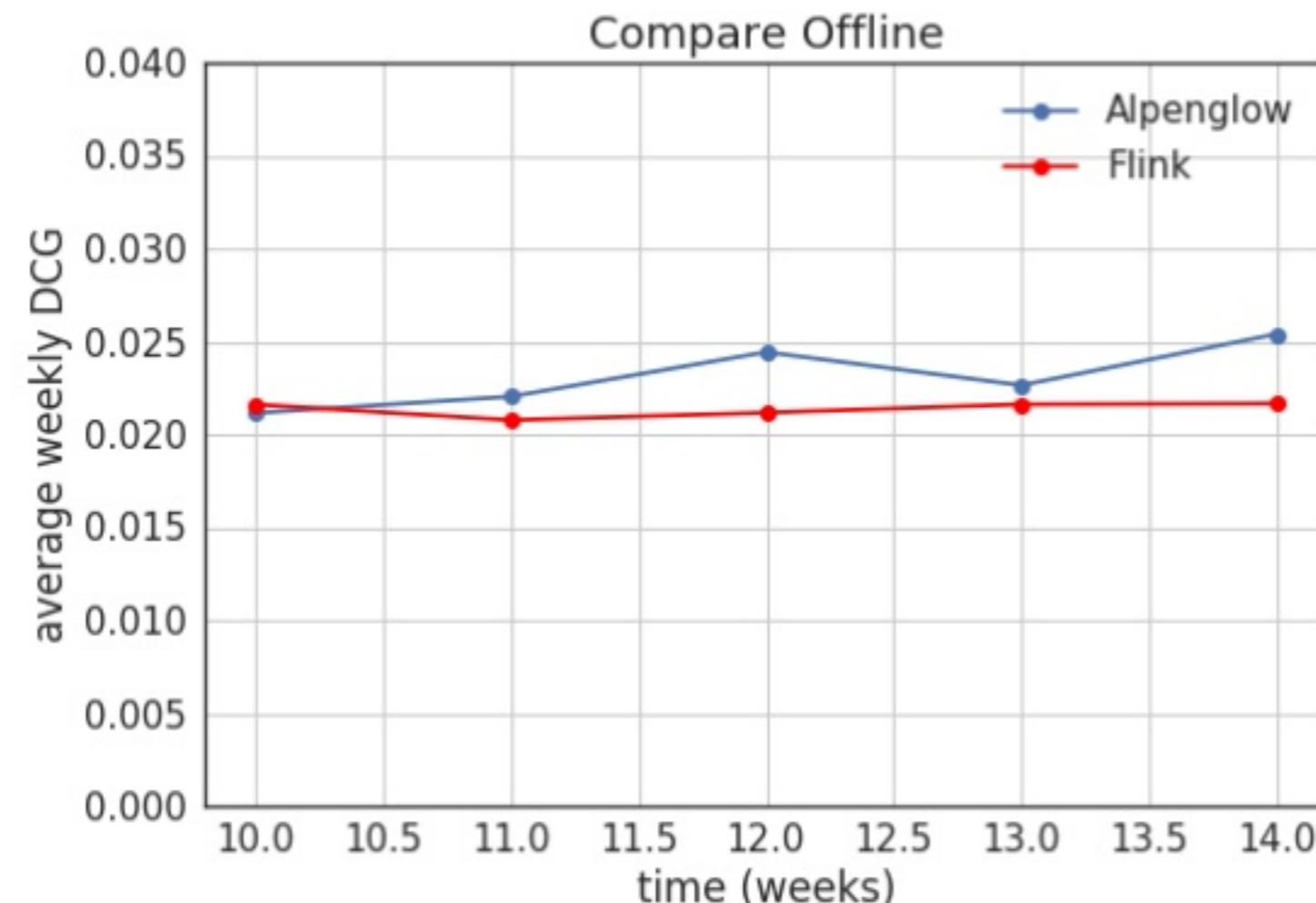
Offline on streaming? **Asynchronous training!**



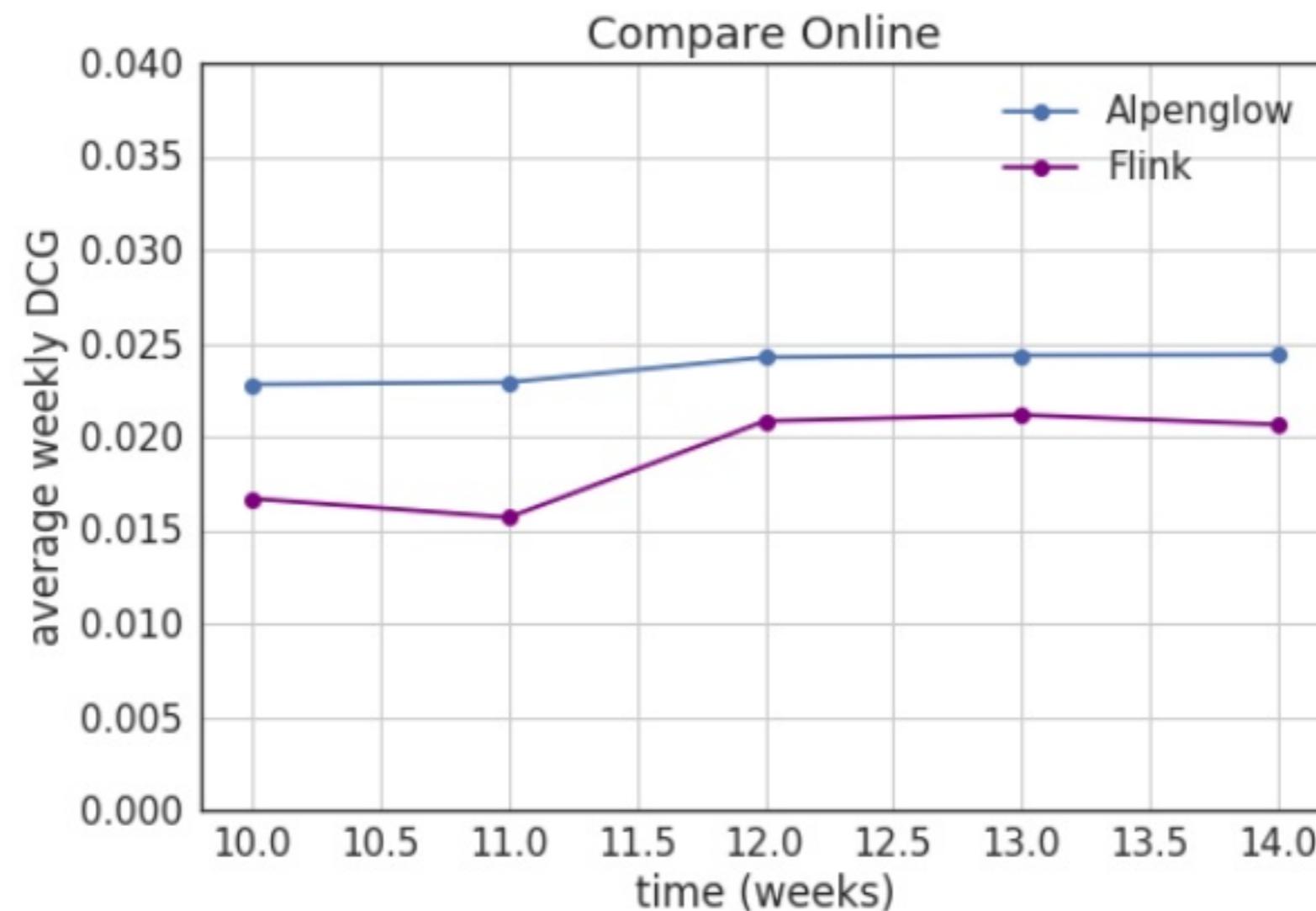
Flink Batch vs Streaming for Offline



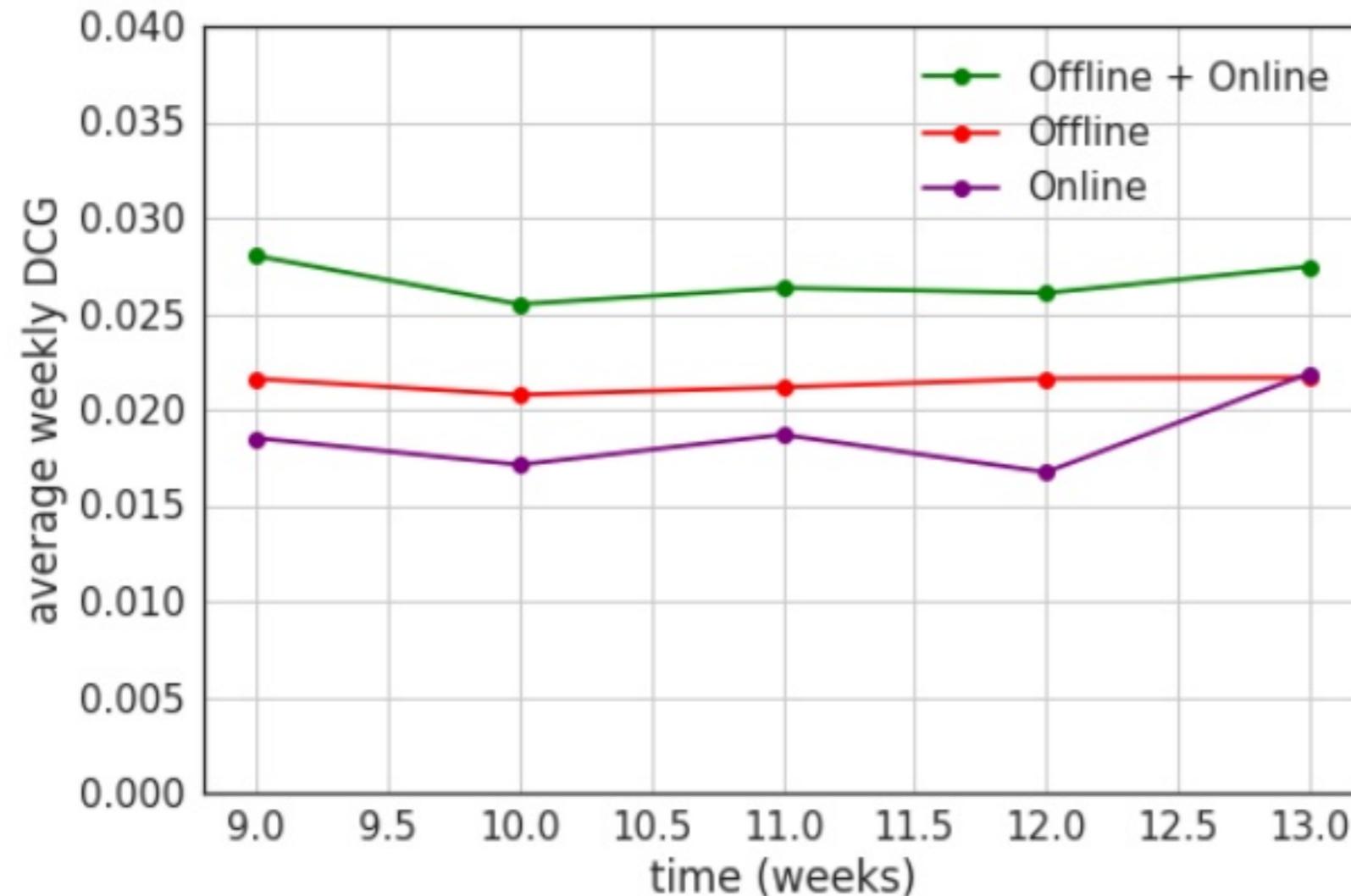
Async matrix factorization



Async matrix factorization



Combine offline+online!



Thank you for your attention

Source code:

<https://github.com/gaborhermann/flink-parameter-server>

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Dániel Berecz
berecz.daniel@sztaki.mta.hu



<https://github.com/rpalovics/Alpenglow>

Li et al.: "Scaling Distributed Machine Learning with the Parameter Server" 2014.

Schelter et al.: "Factorbird - A Parameter Server Approach to Distributed Matrix Factorization." 2014.

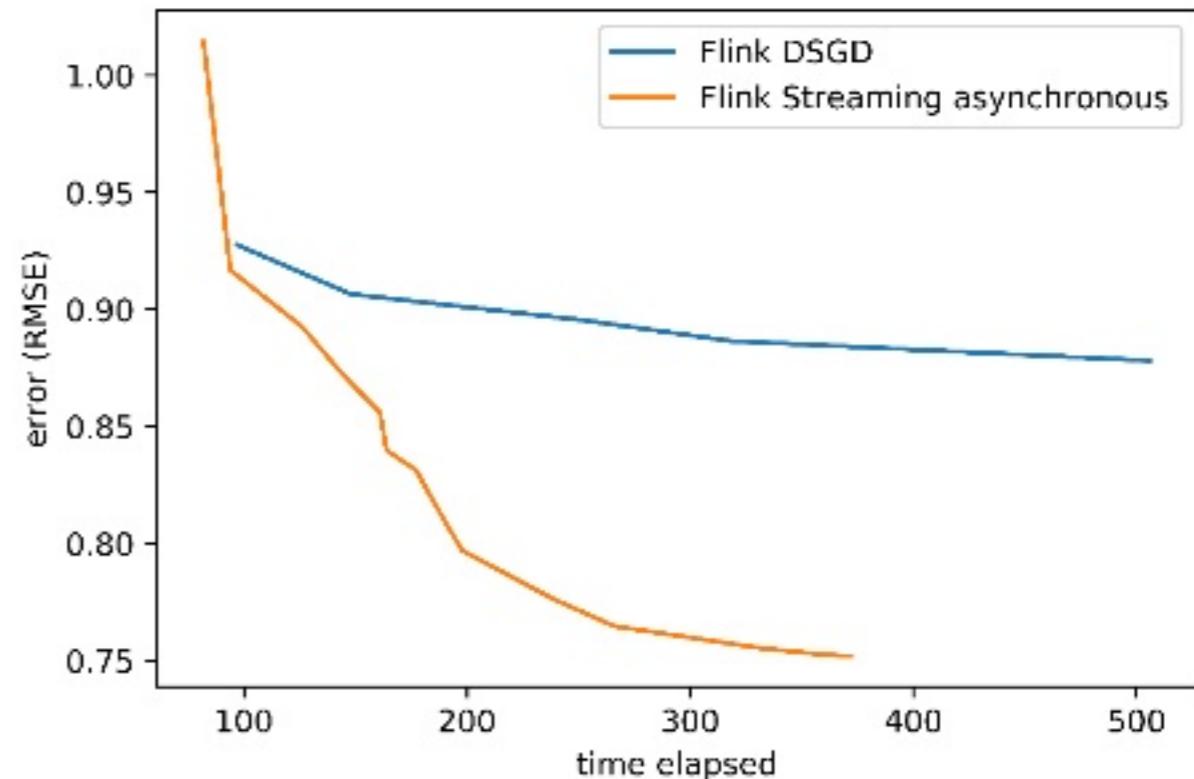
Gemulla et al.: "Large-scale matrix factorization with distributed stochastic gradient descent" 2011.

Crammer et al.: "Online Passive-Aggressive Algorithms" 2006.

Measurements

Flink Batch vs Streaming for Offline

- MovieLens 1M movie rating dataset
- 6000 user, 4000 movies



Flink vs Alpenglow

- Based on public LastFM crawl
- Filtered to avoid spammers
- Lasts 1 year
- Around 45.000 users and 49.000 items

