New ICT infrastructure and reference architecture to support Operations in future PI Logistics NETworks

D2.14 Intelligent Optimization of PI-Containers and PI-Means in PI-Nodes (Final)

Document Summary Information

Grant Agreement No		**Acronym**	
Full Title	**IC** **NET**		**O**

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
	Guillotine Rectangular Packing Problems
	Strip Packing Problem
NOLI Model	

Executive Summary

-
-
-
-
-

(LL3)

(LL3)

iii) (LL4)

iv) (LL4)

(LL3/LL4)

bundling

1 Introduction

.

!

"#" $%&&'()!*+!,(-./*%0!.-(0/*10!

-
-
-
-

2 Heuristics - PI-Node Optimization

width *length*

width *length*

i *S* w_i h_i d_i
b *W H* .

w_i h_i
d_i)

!

2#" 3(*45- &!6-+/1/7/*1!!

b,

$$\sum_{i=1}^{b} w_i \leq W$$

$$\sum_{i=1}^{b} h_i \leq H$$

$$\sum_{i=1}^{b} d_i \leq D$$

$$\sum_{i=1}^{b} w_i\, h_i\, d_i \leq WHD$$

$$WHD - \sum_{i=1}^{b} w_i\, h_i\, d_i$$

2#2 $*5%7/*1!8 -79*6*5*:)!

different dimensions

First Fit Decreasing *Best Fit*

2.2.1 3D Best Fit Algorithm

bin
x *y*
z ***pivot*** *x*
y *z* *3D bin*

2.2.2 3D First Fit Decreasing Algorithm

second

third

3 Learning based PI-Optimization

;#" </& -=$-(/-0!>*(-?'07/1:!

;#2 @'?A:(*%16!B!$7'7-!*+!<9-!C(7!

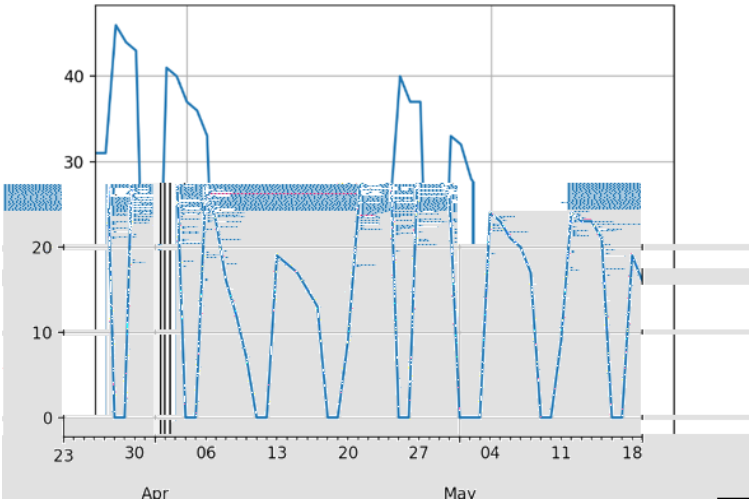


Figure 1 – Product Quantity in Storage

3.2.1 Introduction to LSTM (Long Short-Term Memory)

;#; D%(!8 -79*6*5* :)!

n

4 Application in LLs Perspective

E#" F/./1:!F'4!;!G*'50!

-
-
-

E#2 F/./1:!F'4!;!H'7'!

	DAY	STOCK	STOCK	STOCK	STOCK	SKU
	count	mean	min	max	std	COUNT
STORE						
A	38.5948851	33.953754	0.68685199	56.5175478	12.9223681	48095
B	38.4471396	50.8024221	0.71729754	88.4664147	20.1113731	55079
C	38.7545982	40.4017437	0.63057038	64.389396	14.1121618	47954
D	39.3461568	31.6502373	0.27462652	51.5378535	11.7727301	26462

Table 1 - Sonae Data

E#; 8 -79*60!

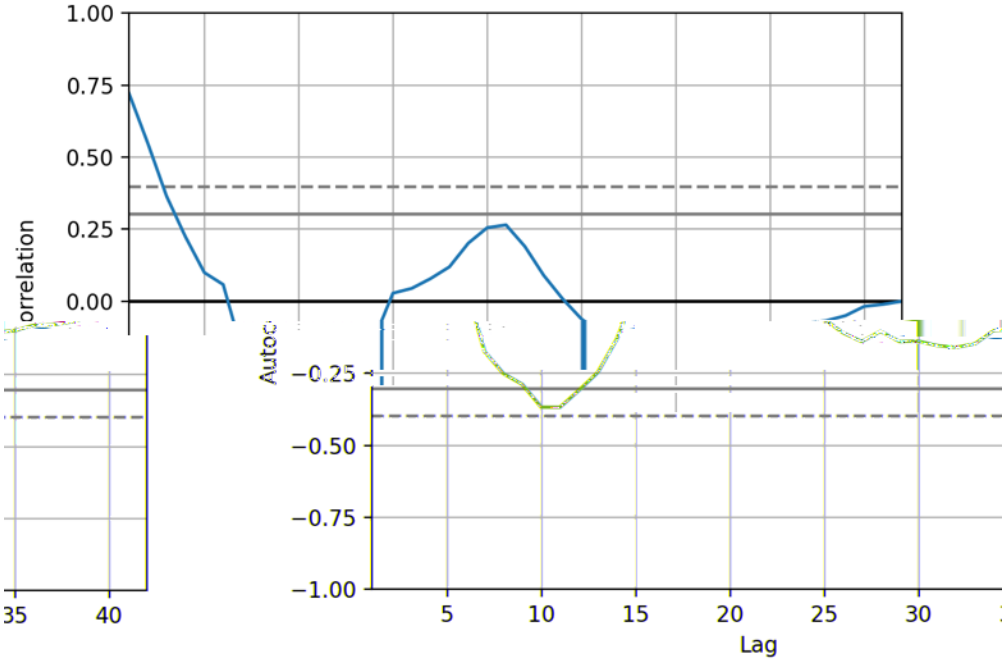


Figure 2 - Autocorrelation
Note: Lag 5 = 1 week / Lag 10 = 2 weeks and so on

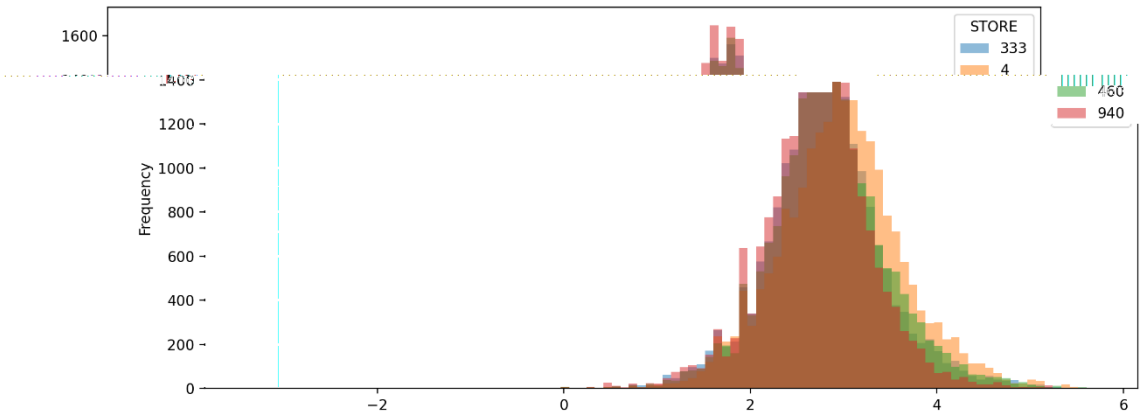


Figure 3 - Heterogeneity in the sum of the values of the timeseries for the Porto dataset

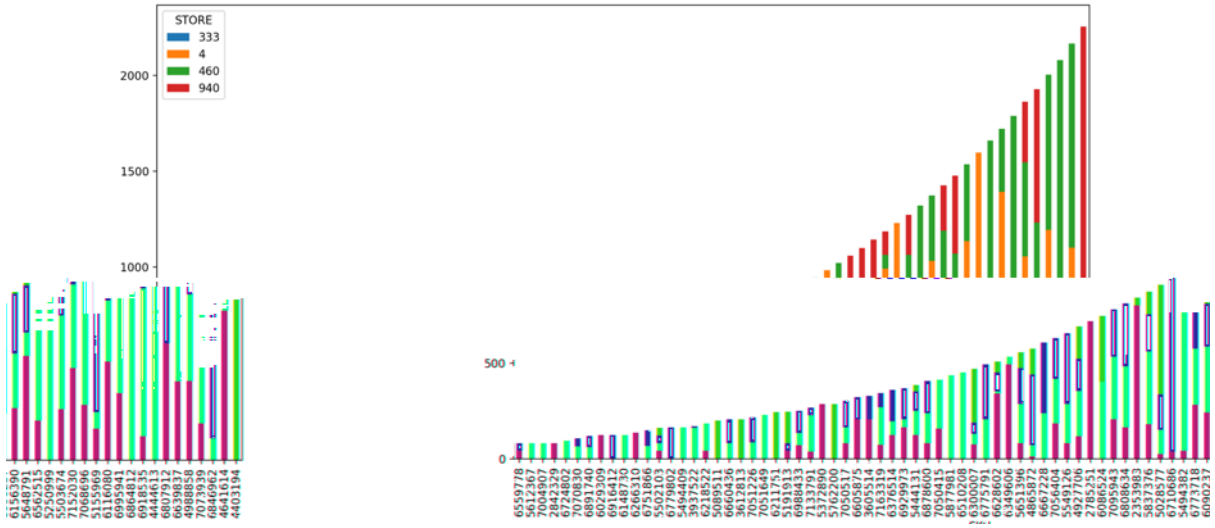


Figure 4 - Products per Store

```
X_std = (X - X.min(axis=0)) / (X.max(axis=0) - X.min(axis=0))
X_scaled = X_std * (max - min) + min
```

Note: where min, max = feature_range.

4.3.1 LSTM training

j

4.3.2 ARIMA training

4.3.3 Comparison (LSTM & ARIMA models)

b)

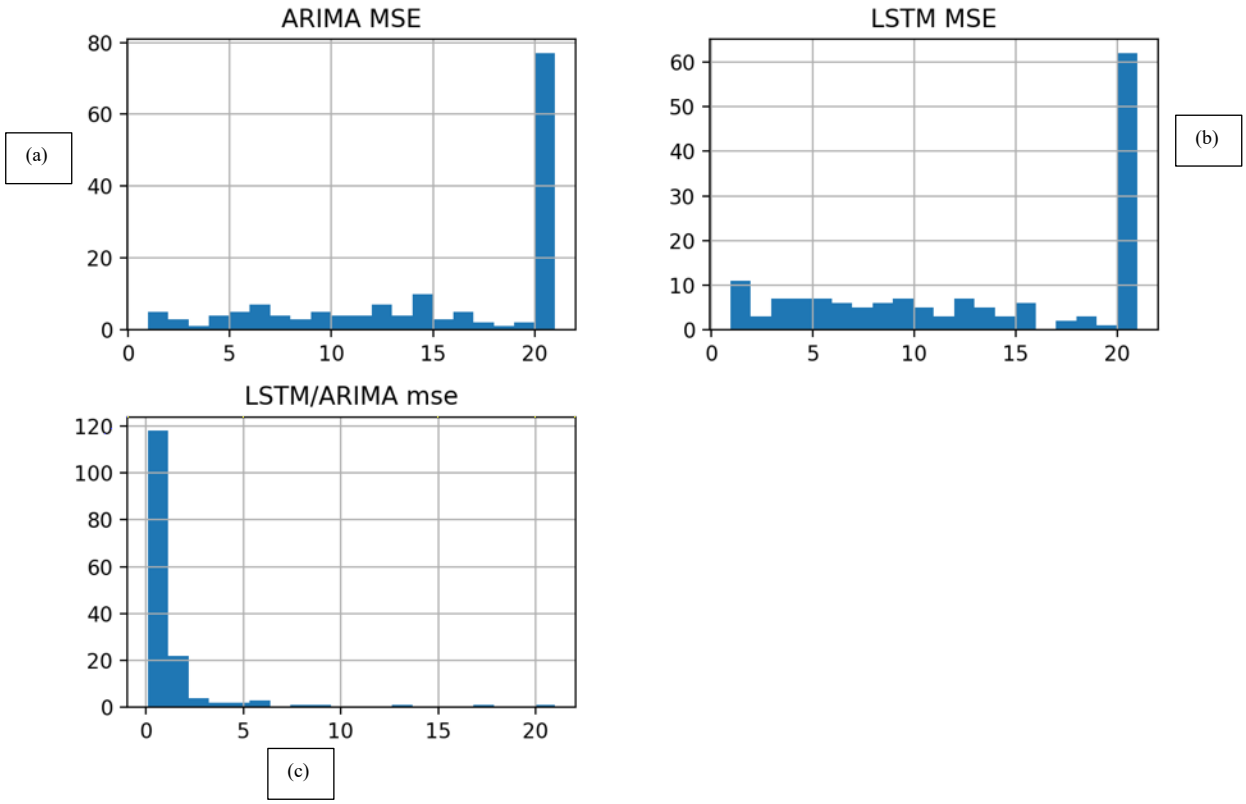


Figure 5 – Mean Square Error

(a) ARIMA Model: approx. 70 time series > 20
(b) LSTM Model: Mean Quare Error: 60 times series > 20
(c) Ratio between LSTM & ARIMA models: There are more than 100 time series with a value < 1, meaning LSTM is lower than ARIMA

E#E F/./1:!F'4!E!G*'50!

!

E#I F/./1:!F'4!E!H'7'!

Field	Description
maj	Indicates the date of movement
tmv	Indicates the type of movement. There are 5 types: arrival(EE), departure(SS), free space(LS), internal putting(DE), internal pushing(DS). In some cases, there are no records so not applicable (NA)
pbru	Indicates the weight moved
allee	Length of the warehouse
prof	Depth of the warehouse
niv	Level of the warehouse
ref	Unique id of the products
npalfm	Unique id of a palette
qte	Number of units of a palette moved.

Table 2 - Stockbooking Data Template

Table 3

Field	Min	Max	Mean	Std. Dev	Median	Mode	Unique	Valid
maj	2015-01-06	2020-04-01	--	--	2017-08-28	2018-10-12	--	7191271
tmv	--	--	--	--	--	EE	6	7191271
pbru	0.000	1029.600	197.390	157.762	178.360	220.320	--	7191271
allee	1.000	999.000	253.922	243.926	176.000	160.000	--	7191271
prof	1.000	999.000	135.987	151.787	72.000	201.000	--	7191271
niv	1.000	10101.000	8.773	22.758	3.000	1.000	--	7191271
ref	140039.000	43932990.000	12120466.273	2184508.043	12263964.000	12310574.000	--	7191271

npalfm	--	--	--	--	--	--	--	7191271
qte	0.000	448.000	50.656	43.296	42.000	63.000	--	7191271

Table 3 - Stockbooking Dataset Statistics

Field	Outliers	Extreme	Action	Impute Missing	% Complete	Valid Records	Null Value	Empty String	White Space	Blank Value
maj	0	0	None	Never	99.999	7191271	58	0	0	0
tmv	--	--	--	Never	99.999	7191271	0	58	58	0
pbru	133796	420	None	Never	99.999	7191271	58	0	0	0
allee	1	0	None	Never	99.999	7191271	58	0	0	0
prof	58059	3503	None	Never	99.999	7191271	58	0	0	0
niv	1284	29	None	Never	99.999	7191271	58	0	0	0
ref	99657	54090	None	Never	99.999	7191271	58	0	0	0
npalfm	--	--	--	Never	99.999	7191271	0	58	58	0
qte	89855	26708	None	Never	99.999	7191271	58	0	0	0

Table 4 - Data Quality

!

E#J 8 -79*60!

4.6.1 SOM Training

5 Results & Discussion

I#" F/./1:!F'4!;!

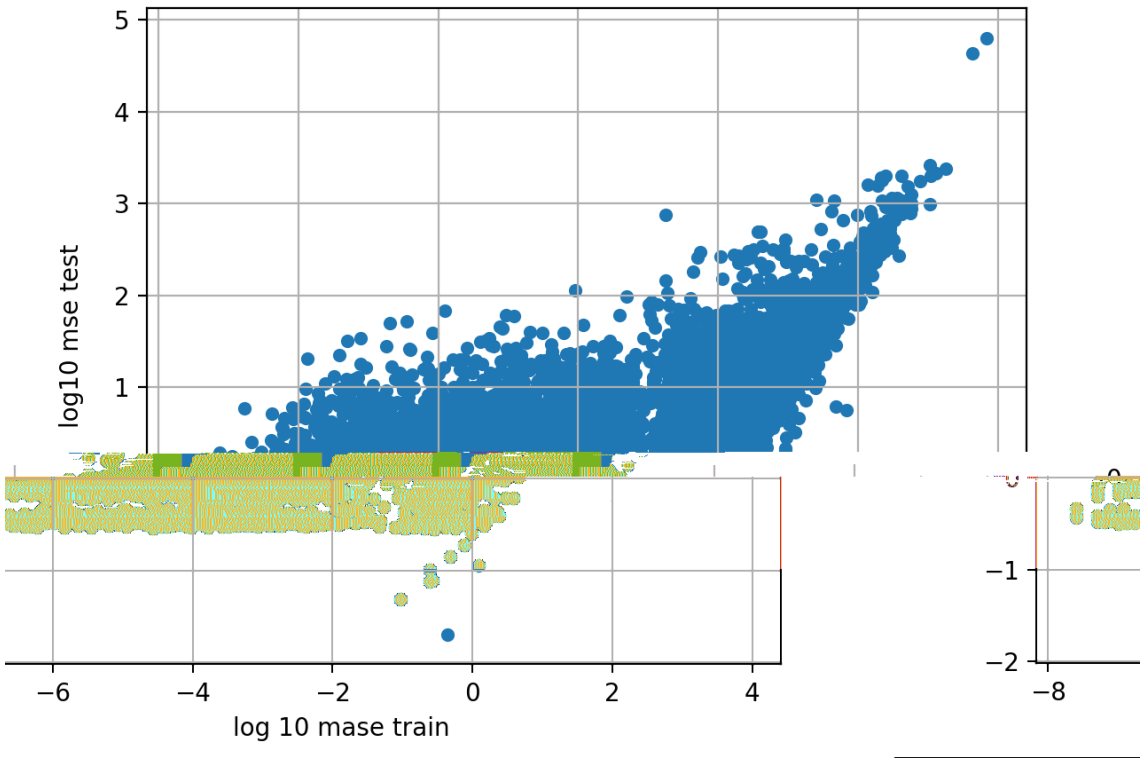


Figure 6 - Mean Square Error Scatterplot for the distribution of prediction of each time series

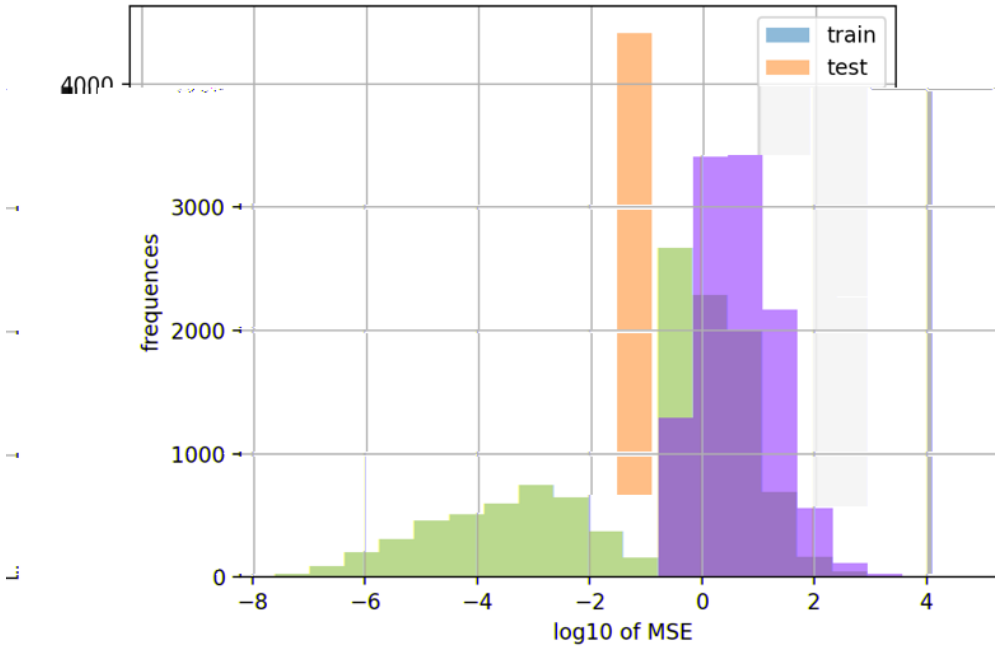


Figure 7 - Mean Squared Error - Training vs Test

I#2 F/./1:!F'4!E!!

Figure 8 – SOM Heat Maps
Left Map (a): A heat map based on weekly quanity in departure
Right Map (b): A heat map based over the daily distribution of units in departure

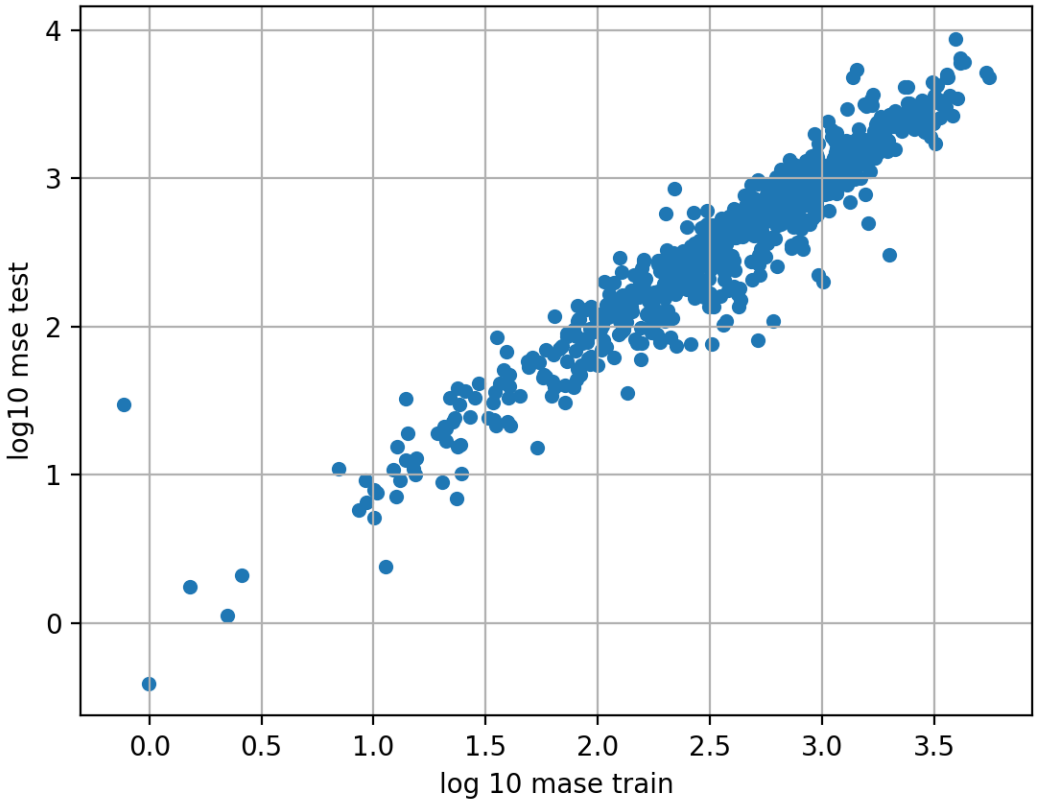


Figure 9 - Scatter Plot: Mean Square Error Training vs Test

6 Optimisation PI WebServices & Integration with other PI Services

1 2

3

J#" K -4!$-(./?-!LM7-10/*1!

[1] Representational State Transfer
[2] Swagger
[3] IBM Cloud

6.1.1 Restructuring the Optimisation ReST API

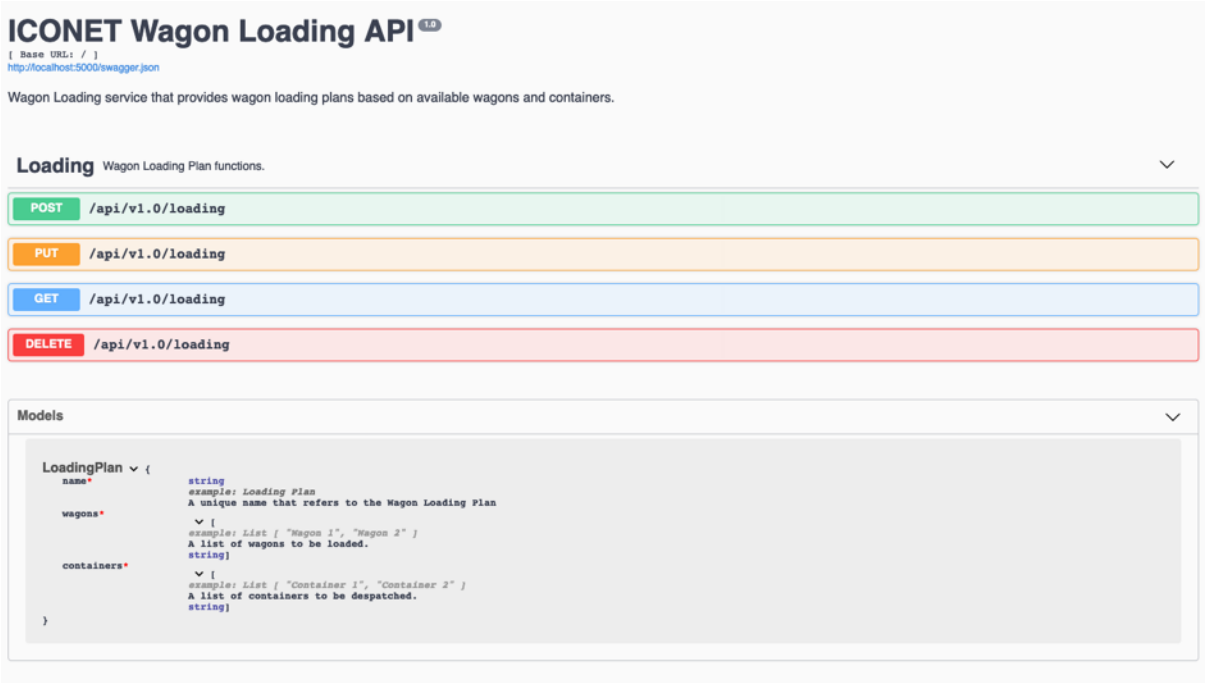


Figure 10 - The original Optimisation Service API

Input:

```
{
  "wagons": [
    {
      "id": "W1",
      "width": 2.43,
      "length": 12.19,
      "weight": 1000
    }
  ],
  "containers": [
    {
      "id": "f8777772-d15a-467a-9a3a-cd372b5e29d2",
      "width": 0.26,
      "height": 0.6,
      "type": "carbon",
      "weight": 10,
      "premium": 1,
      "origin": "Budapest",
      "destination": "London",
      "trans_time": "2020-01-29 07:06:54.950140"
    }
  ]
}
```

Output:

```
{
  "result": [
    {
      "capacity": [
        1000,
        2.43,
        12.19
      ],
      "containers": [
        {
          "id": "f8777772-d15a-467a-9a3a-cd372b5e29d2",
          "width": 0.26,
          "height": 0.6,
          "type": "carbon",
          "weight": 10,
          "premium": 1,
          "origin": "Budapest",
          "destination": "London",
          "trans_time": "2020-01-29 07:06:54.950140"
        }
      ]
    }
  ]
}
```

Figure 11 - Loading function API inputs and output

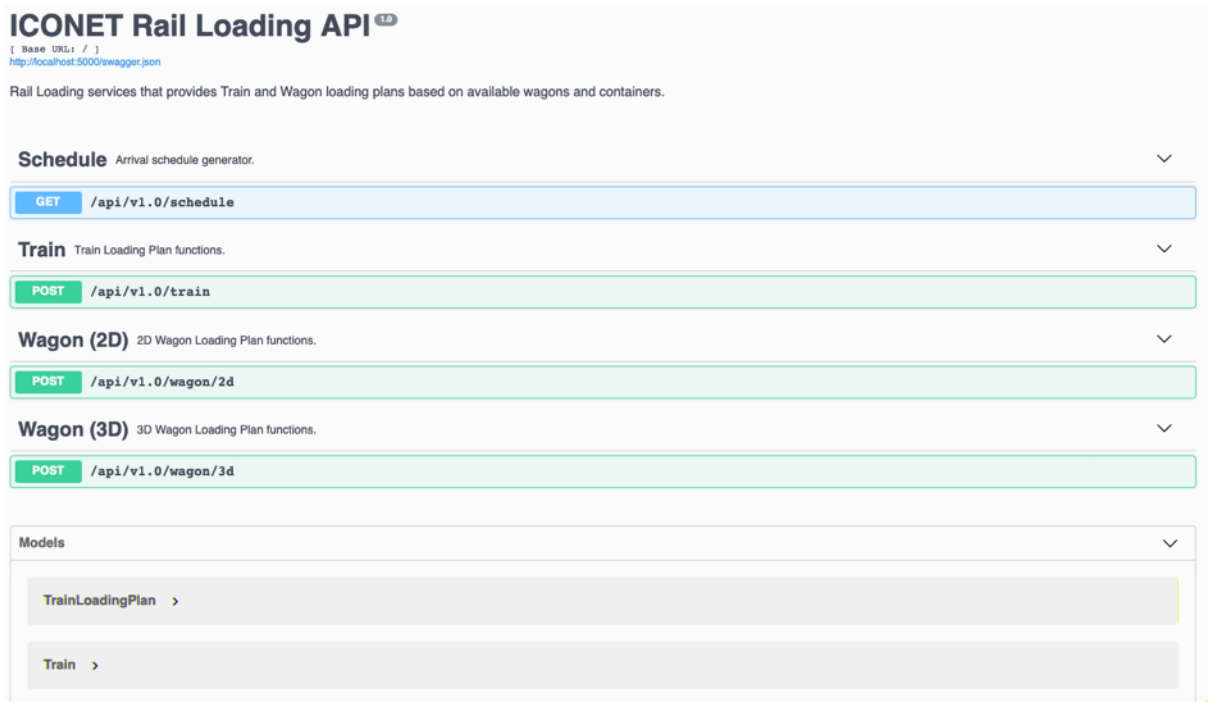
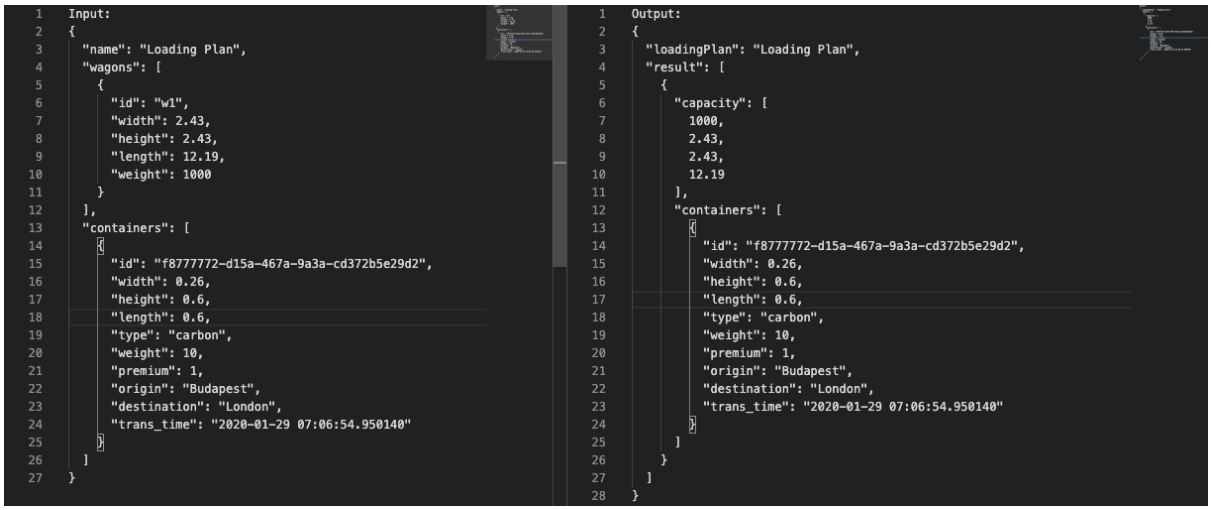


Figure 12 - The ICONET Rail Loading Swagger interface

6.1.2 Rail wagon loading in Three Dimensions

4

5



```
Input:
{
  "name": "Loading Plan",
  "wagons": [
    {
      "id": "w1",
      "width": 2.43,
      "height": 2.43,
      "length": 12.19,
      "weight": 1000
    }
  ],
  "containers": [
    {
      "id": "f8777772-d15a-467a-9a3a-cd372b5e29d2",
      "width": 0.26,
      "height": 0.6,
      "length": 0.6,
      "type": "carbon",
      "weight": 10,
      "premium": 1,
      "origin": "Budapest",
      "destination": "London",
      "trans_time": "2020-01-29 07:06:54.950140"
    }
  ]
}
```

```
Output:
{
  "loadingPlan": "Loading Plan",
  "result": [
    {
      "capacity": [
        1000,
        2.43,
        2.43,
        12.19
      ],
      "containers": [
        {
          "id": "f8777772-d15a-467a-9a3a-cd372b5e29d2",
          "width": 0.26,
          "height": 0.6,
          "length": 0.6,
          "type": "carbon",
          "weight": 10,
          "premium": 1,
          "origin": "Budapest",
          "destination": "London",
          "trans_time": "2020-01-29 07:06:54.950140"
        }
      ]
    }
  ]
}
```


Figure 13 - Wagon (3D) JSON input and output

[4] Py3dbp

[5] Optimizing Three-Dimensional Bin Packing through Simulation

6.1.3 Train loading

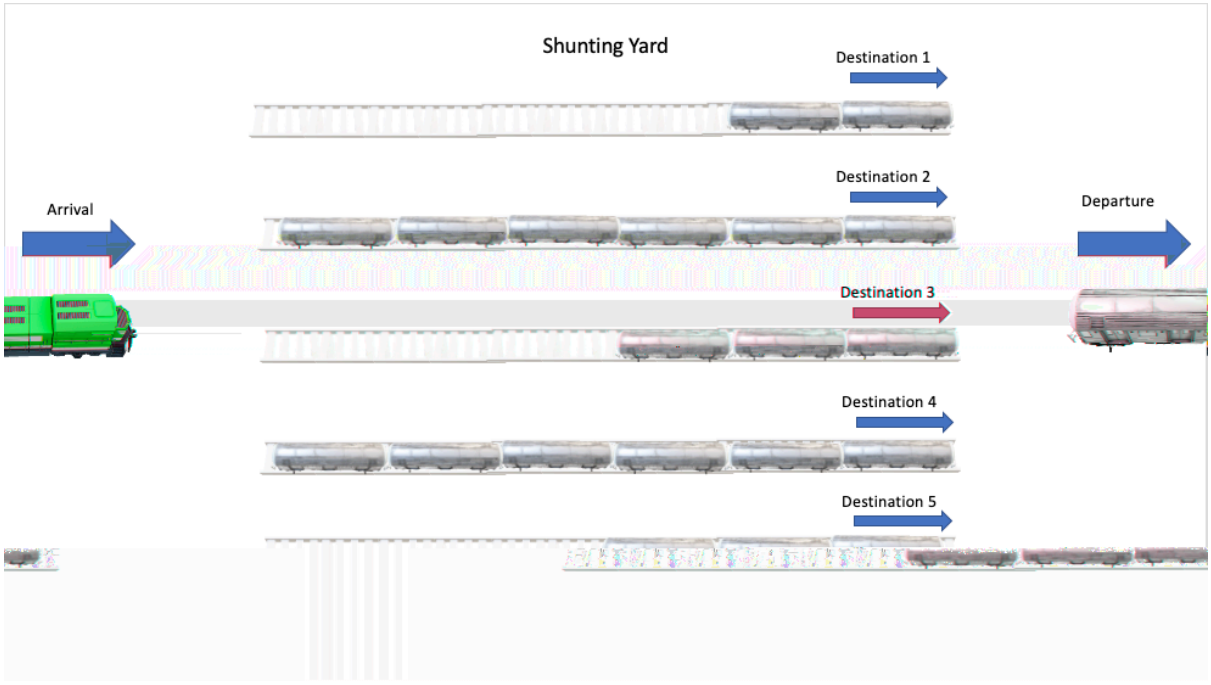


Figure 14 - Wagon (3D) JSON input and output

-
-
-
-

J#2 N17-:('7/*1!O/79!*79-(!$-(./?-0!

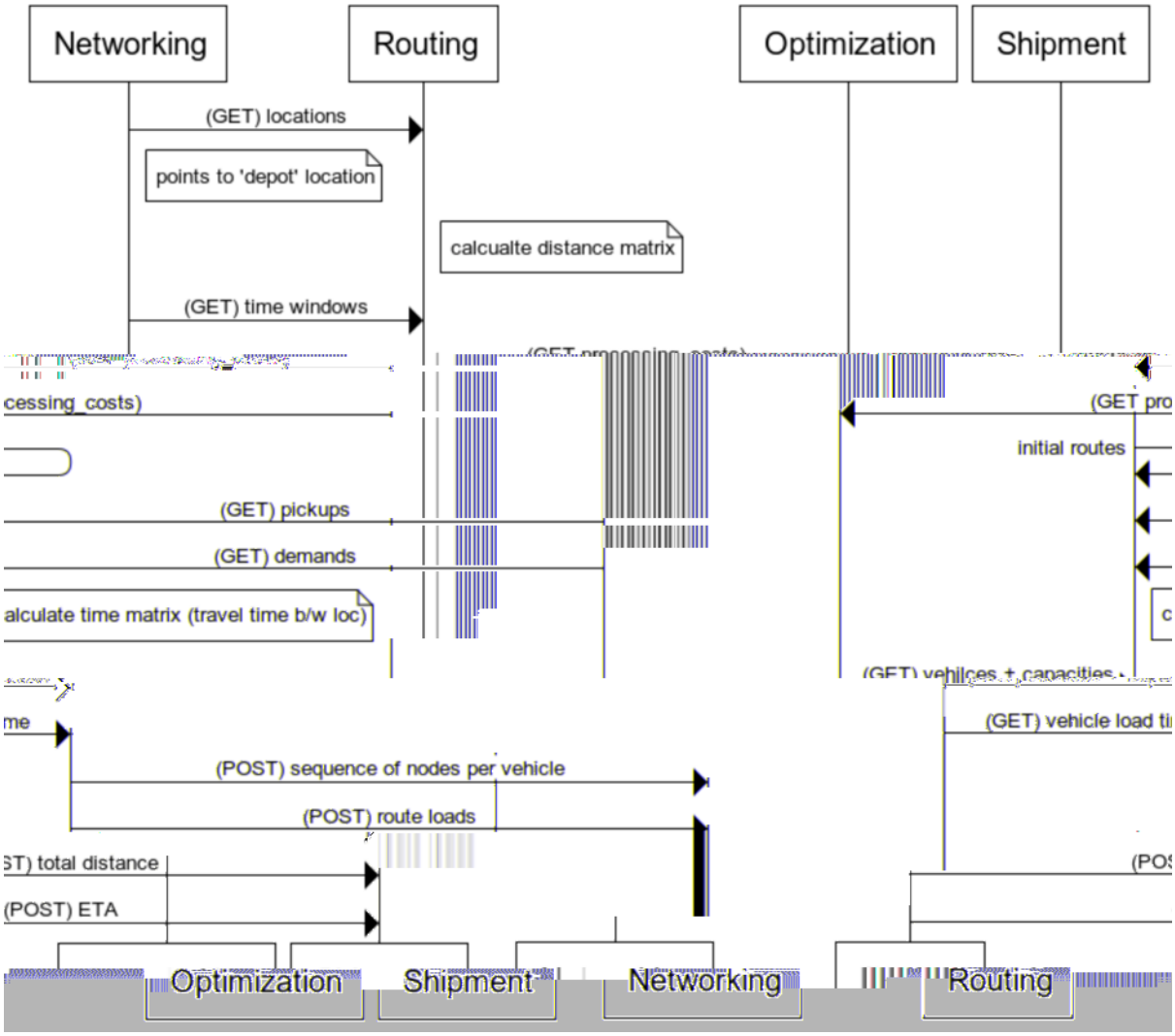


Figure 15 - Interaction between optimization and other services

!

J#; ℕ17-:('7/*1!O/79!D,7/&/P'7/*1!'16!Q*%7/1:!

$$cost = link\_cost + processing\_cost$$

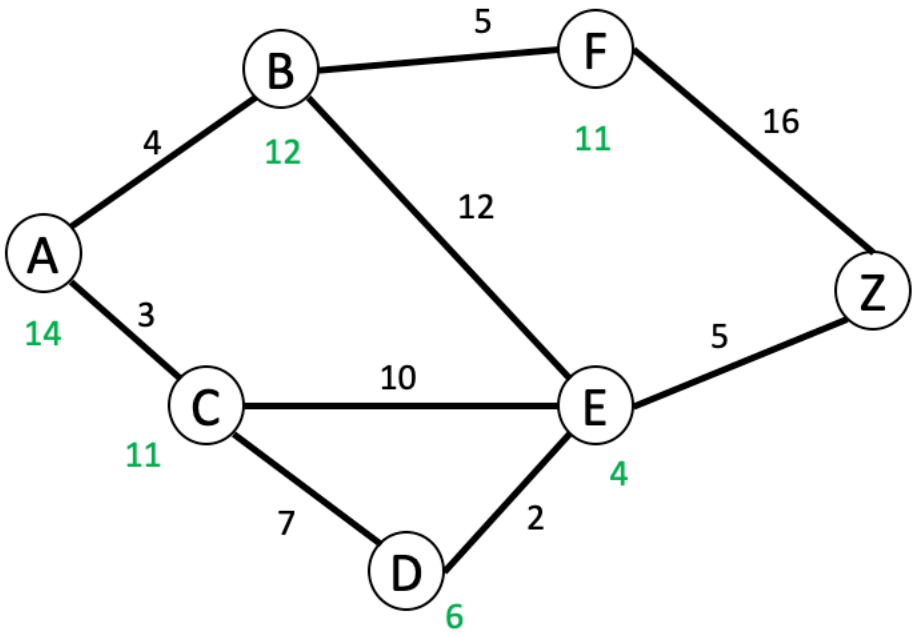


Figure 16 - Example network

7 Conclusion

8 Bibliography

Using Self-Organizing Maps to Cluster Products for Storage Assignment in a Distribution Center. *Sixth IASTED International Conference Modelling, Simulation, and Optimization.*

International Journal of Production Research

Proceedings of the UK Workshop on Computational Intelligence.

Sustainability

IEEE Transactions on Intelligent Transportation Systems.

Econometrica

Neural Computation

International Workshop on Service Orientation in Holonic and Multi-Agent Manufacturing

Water Resources Research

Logistics Research 3.2-3

IFAC-PapersOnLine

PLoS one

nternational journal of production research.

9 Annex I – Pseudocode

```
if (binWidth is smaller than binHeight
and binDepth) then
{
      packByWidth=true
      packByHeight=false;
}
else if (binDepth is smaller than
binHeight and binWidth) then
```

```
{
      packByWidth=false
      packByHeight=false  //both  false
      implies pack by depth
}
else  if  (binHeight  is  smaller  than
binWidth and binDepth) then
{
      packByWidth=false
      packByHeight=true
}

notPacked=Items

[a]do
{
  toPack=notPacked
  notPacked={} //clear notPacked

  Create  a  new  bin  called  currentBin
  and check whether the item toPack[0]
  is  able  to  fit  in  this  bin  at
  position (x,y,z)=(0,0,0).
  if  toPack[0]  does  not  fit  then
  rotate  it  (over  the  six  rotation
  types)  until  it  fits  and  pack  it
  into this bin at postion (0,0,0).
  [b]for i=1 to (size of toPack-1) do
  {
   currentItem=toPack[i]
   fitted=false

   [c]for p=0 to 2 do
   {
    k=0
   [d] while  (k  <  number  of  items  in
currentBin) and (not fitted)
    {
     binItem=k^th item in currentBin
      if (packByWidth) then
            pivot=p
      else if (packByHeight) then
        switch (p)
        {
            compute pivot p for height
        }
      else  //pack by depth
        switch (p)
        {
            compute pivot p for depth
        }

 switch (pivot)
  {
    case 0 : Choose (pivotX, pivovY,
pivotZ ) as the back lower
             right corner of binItem
             break;
      case 1 : Choose (pivotX, pivovY,
   pivotZ ) as the front lower
```

```
                left corner of binItem
                 break
        case 2 : Choose (pivotX, pivovY,
pivotZ ) as the back Upper
                 left corner of binItem
                break
    }

        if (currentItem can be packed
        in currentBin at
            position(pivotX,    pivotY
        ,pivotZ ) ) then
        {
         Pack currentItem into
        currentBin at position
         (pivotX, pivotY ,pivotZ).
         fitted=true
        }
         else
       { // try rotating item
        do
         Rotate currenItem
        while (currentItem cannot be
        packed in currentBin at

        position(pivotX,pivotY) )
                and (not all
        rotations for currentItem
        checked)

        if (currentItem can be packed
        in currentBin at
            position(pivotX, pivotY ,
        pivotZ) ) then
        {
          Pack currentItem into
        currentBin at position
          (pivotX, pivotY ,pivotZ).
          fitted=true

        }else
            Restore   currentItem   to
        its original rotation type
      }

        if (not fitted) then
          Add currentItem to the list
notPacked

       }
      }
    }

    while notPacked becomes empty.
          Item in list notPacked is
```

10 Annex II – Overview of LSTM (long short-term memory)

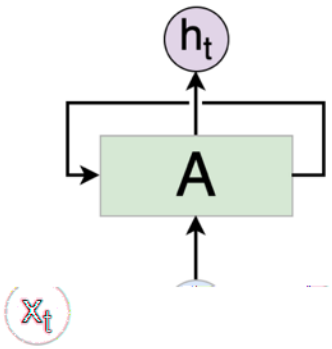


Figure 1 - Neural Network Chunk

A x_t h_t

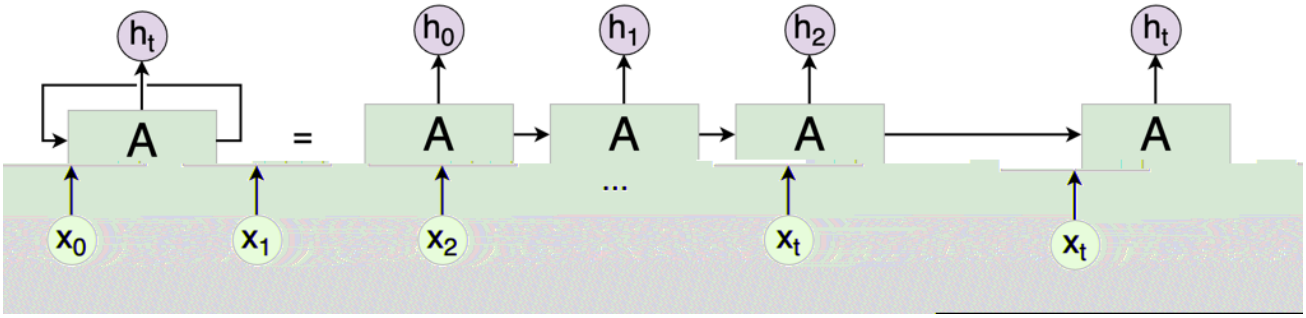


Figure 2 - Neural Network Loop

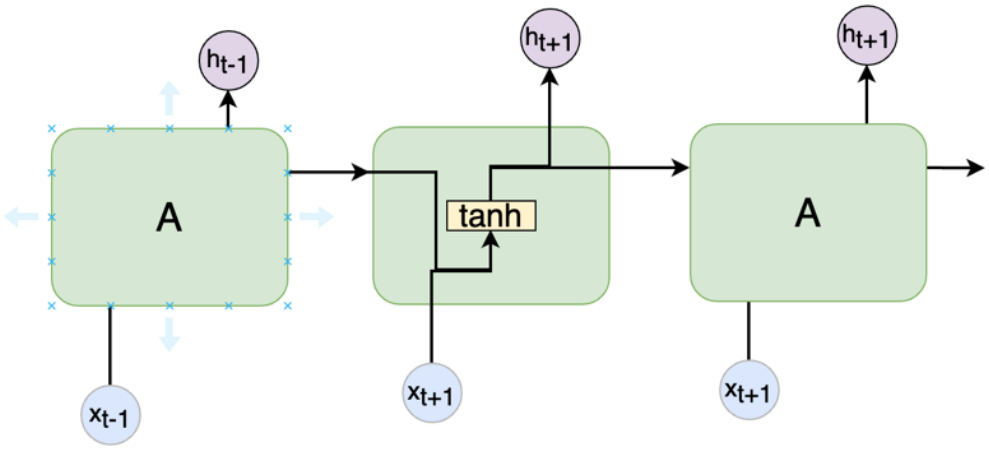


Figure 3 - Tanh Layer

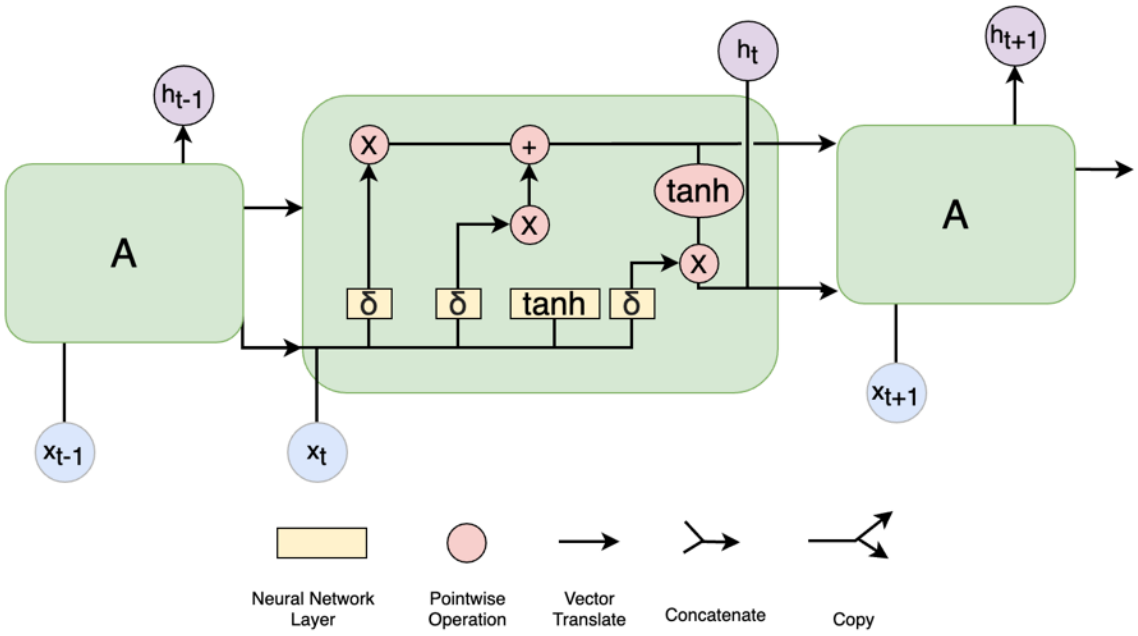


Figure 4 - Detailed LSTM

11 Annex III – Overview of SOM (Self Organising Maps)

vector quantisation

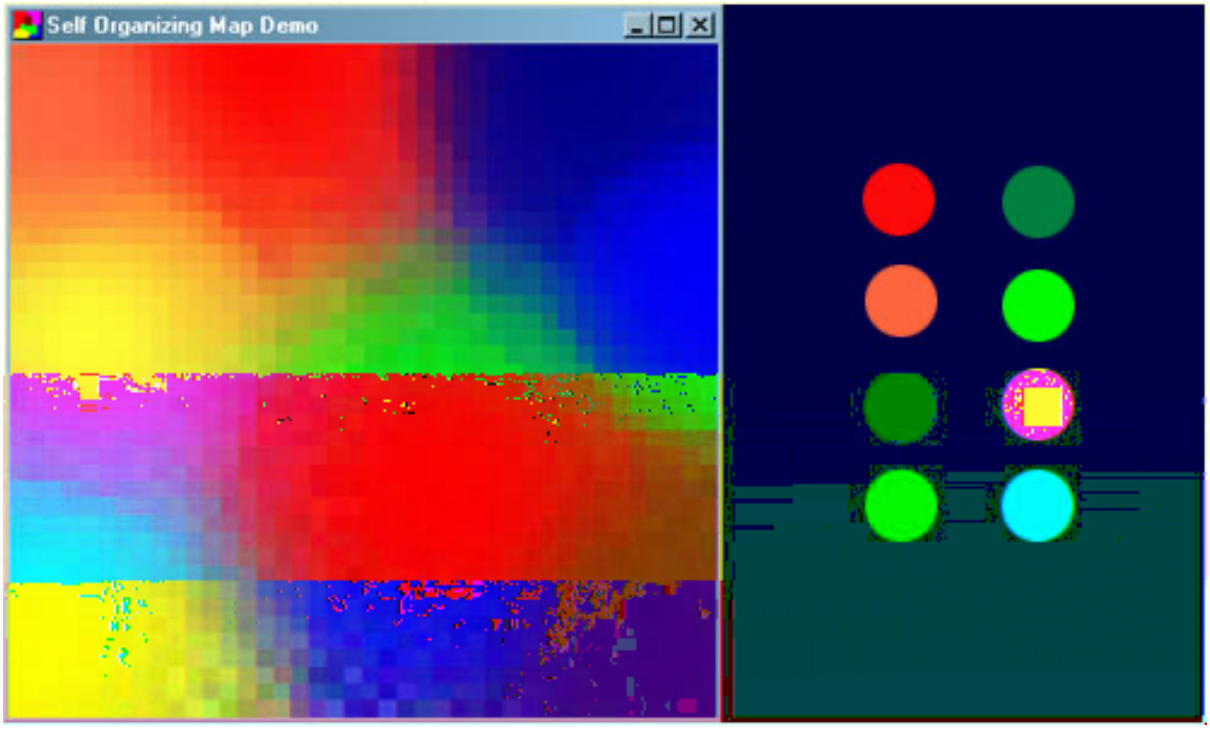


Figure 1 - Screenshot of the demo program (left) and the colours it has classified (right)

without supervision.

11.1.1.1 Network Architecture

Figure 2 - A simple Kohonen network

$V \quad n$

1 2 3 n

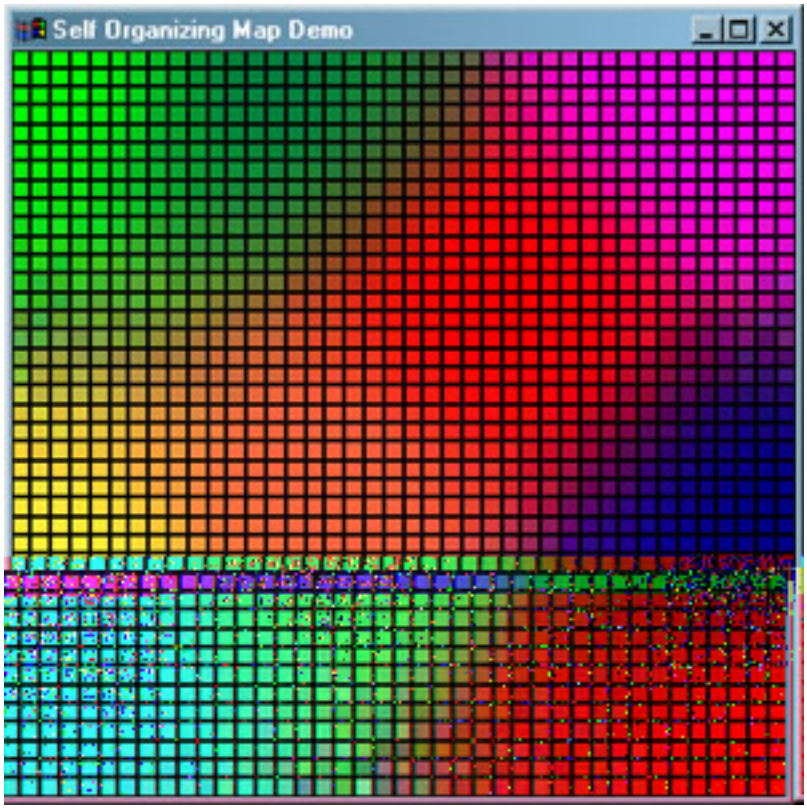


Figure 3 - Each cell represents a node in the lattice (size 40 x 40)

11.1.1.2 Learning Algorithm Overview