Deep Autoencoder Neural Networks for Short-Term Traffic Congestion Prediction of Transportation Networks

SEN ZHANG, YONG YAO, JIE HU, YONG ZHAO, SHAOBO LI, JIANJUN HU (2019)

MARTÍN I. LÓPEZ PAVEZ

"La **predicción** de la **congestión** es fundamental para implementar sistemas de transporte inteligentes que mejoren la **eficiencia** y la **capacidad** de las **redes de transporte**"

Datos de congestión a gran escala

Datos de congestión a gran escala

↓

Análisis de Imágenes

Datos de congestión a gran escala

↓

Análisis de Imágenes

↓

Predice congestión del tráfico

Presentación del Estudio

Abstract

Introducción

Trabajos Relacionados

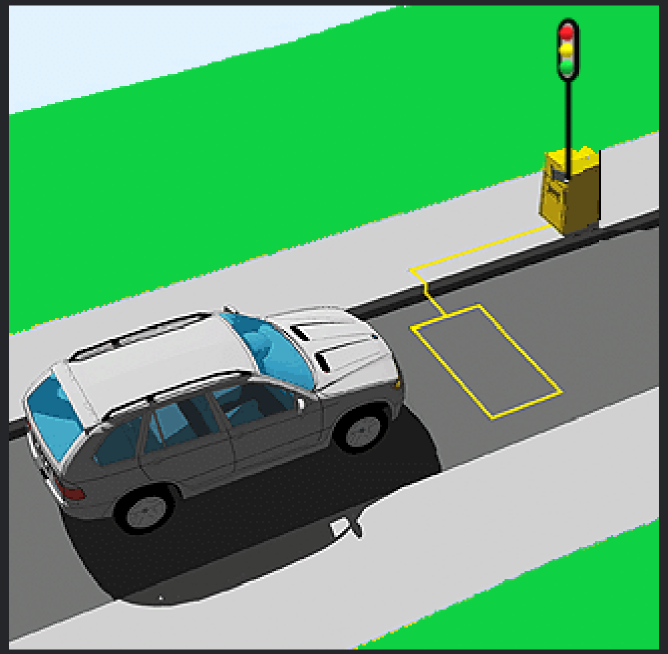
Metodología

Experimentos y Análisis de Resultados

Discusión

Conclusiones

Que información se tiene



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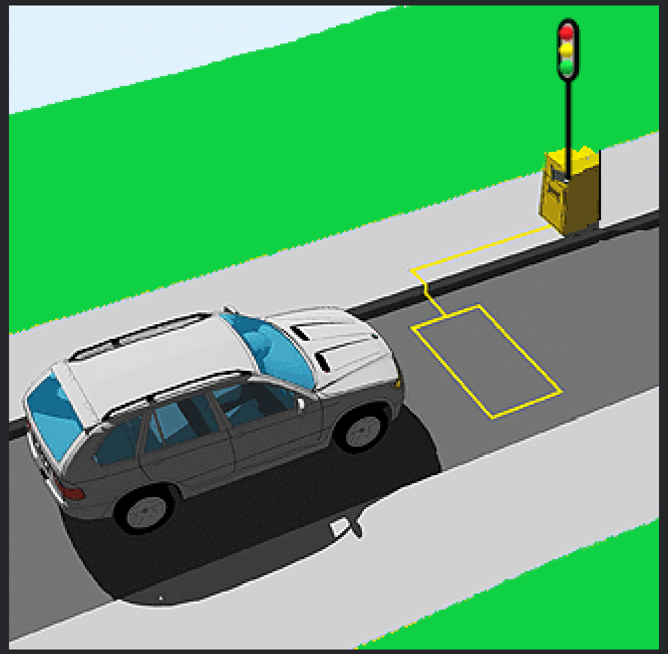

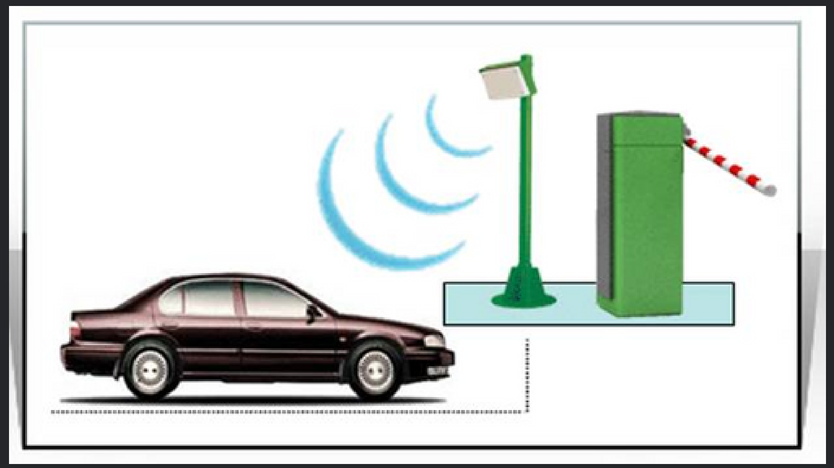

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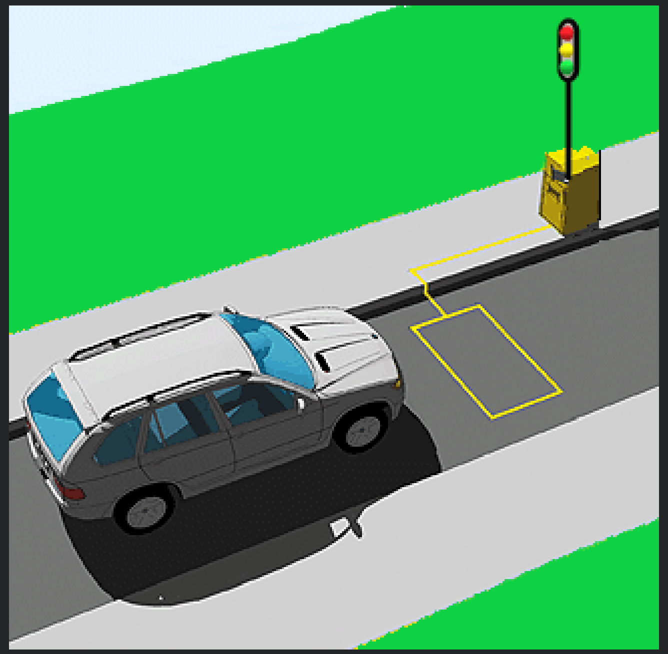

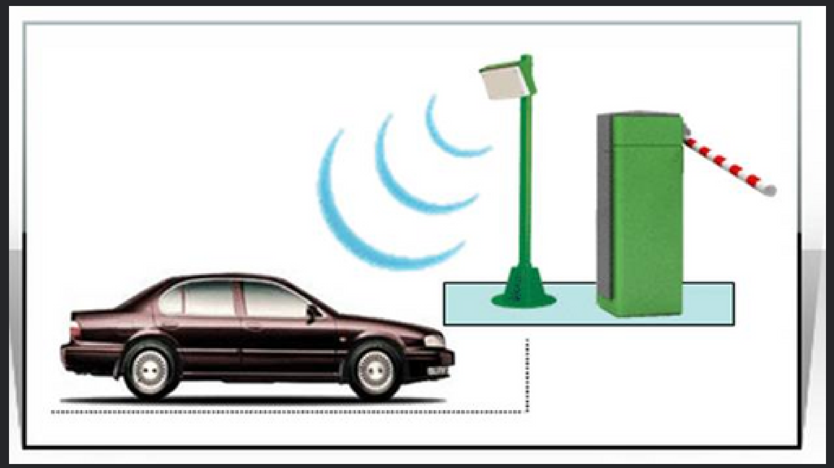

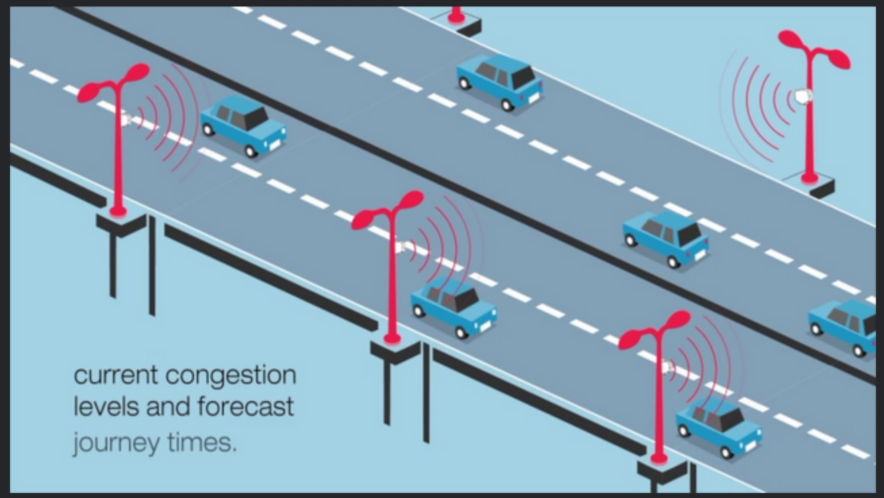

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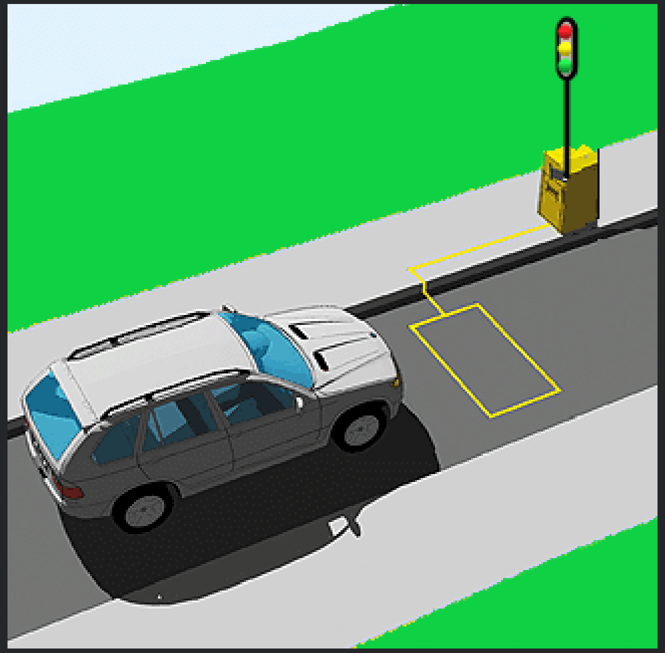

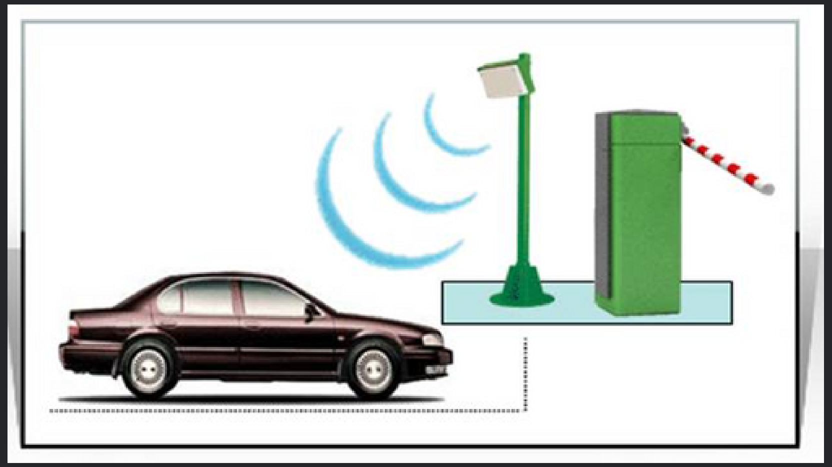

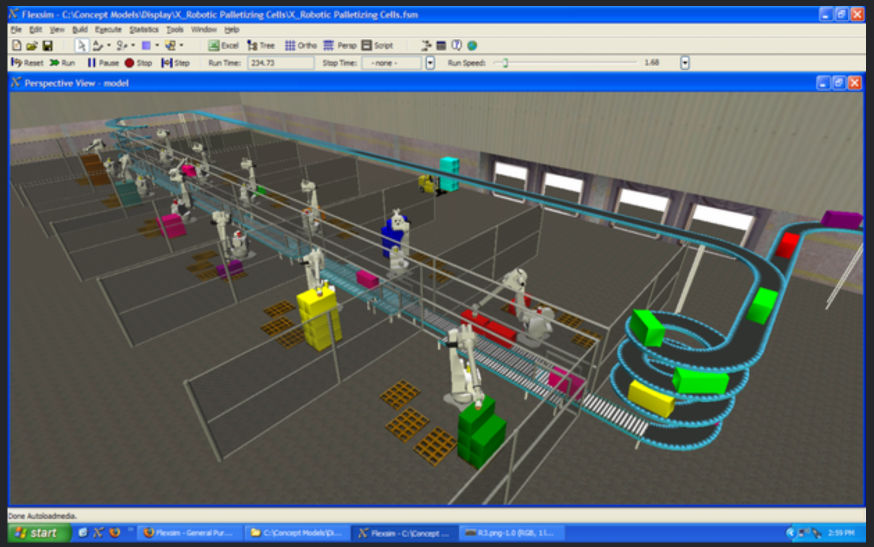

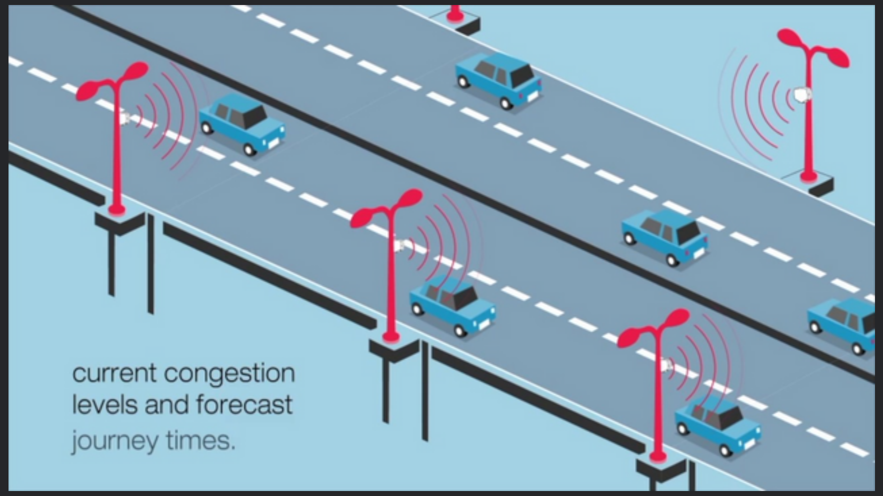

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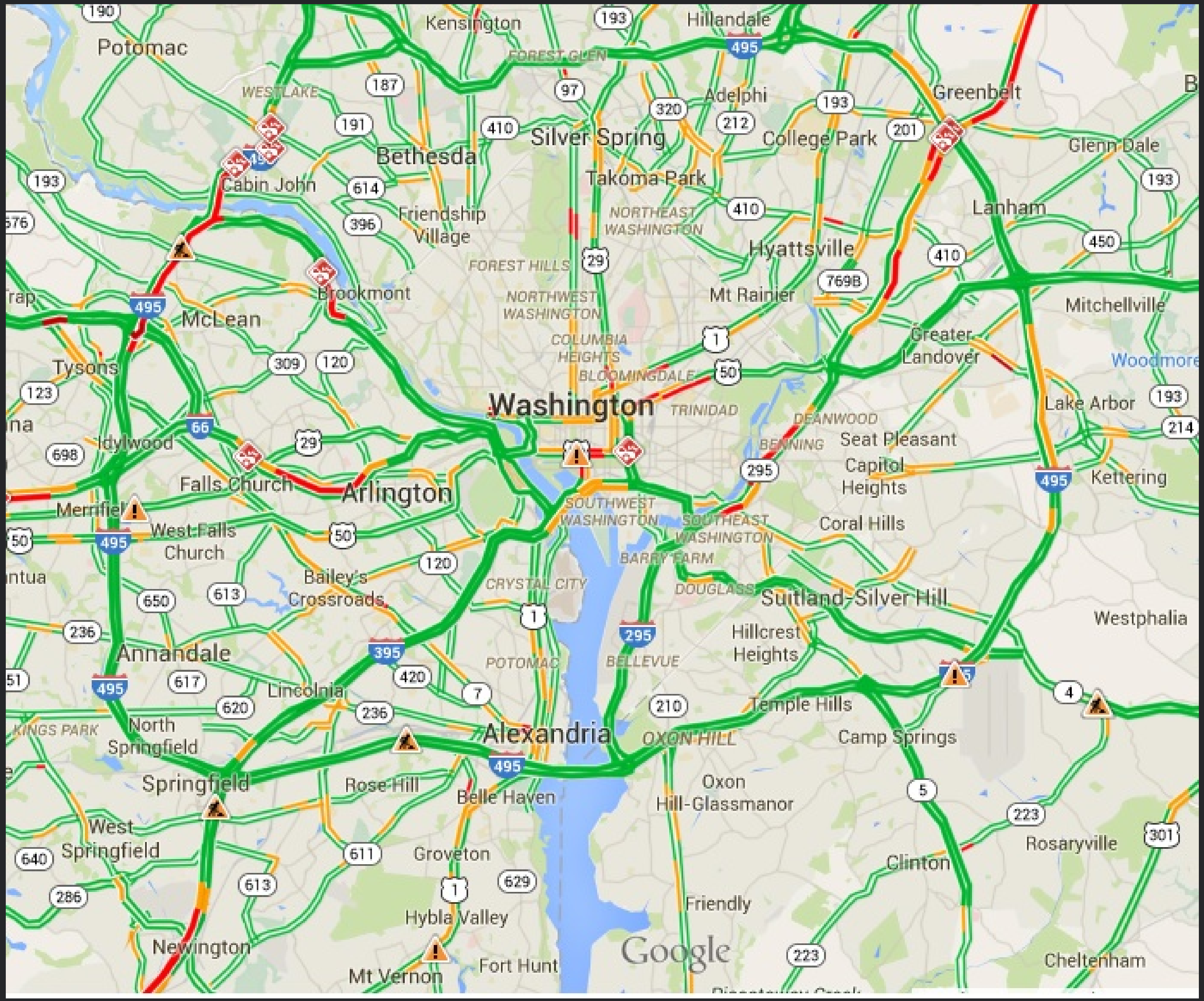

Beneficios

Cobertura

Condiciones en tiempo real

Accesibilidad

Otro estudios

ARIMA (series te tiempo, flujos)
SARIMA
KARIMA
ARIMAX
CTM-SARIMA

→ Acercamientos Paramétricos

Otro estudios

ARIMA (series te tiempo, flujos)
SARIMA
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→ Acercamientos Paramétricos

! Sujetos a estructuras predeterminadas de modelos

Otro estudios

SVM
Redes Neuronales Artificiales
KNN (velocidades y flujos)
SVM
SVR
Online-SVM

→ Acercamientos No Paramétricos

Otro estudios

SVM
Redes Neuronales Artificiales
KNN (velocidades y flujos)
SVM
SVR
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Acercamientos
No Paramétricos

!

Requieren un conocimiento de dominio previo significativo y un trabajo de preprocesamiento extenso

Otro estudios

BIG DATA →

RNN
LSTM (flujos, velocidades y congestión)
CNN
DBN
SRCN

Otro estudios

BIG DATA →

RNN
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Aprender correlaciones profundas inherentes a los datos con poco o ningún conocimiento previo

"Sin embargo, se siguen enfocando en predicción de variables de tráfico en pequeñas redes"

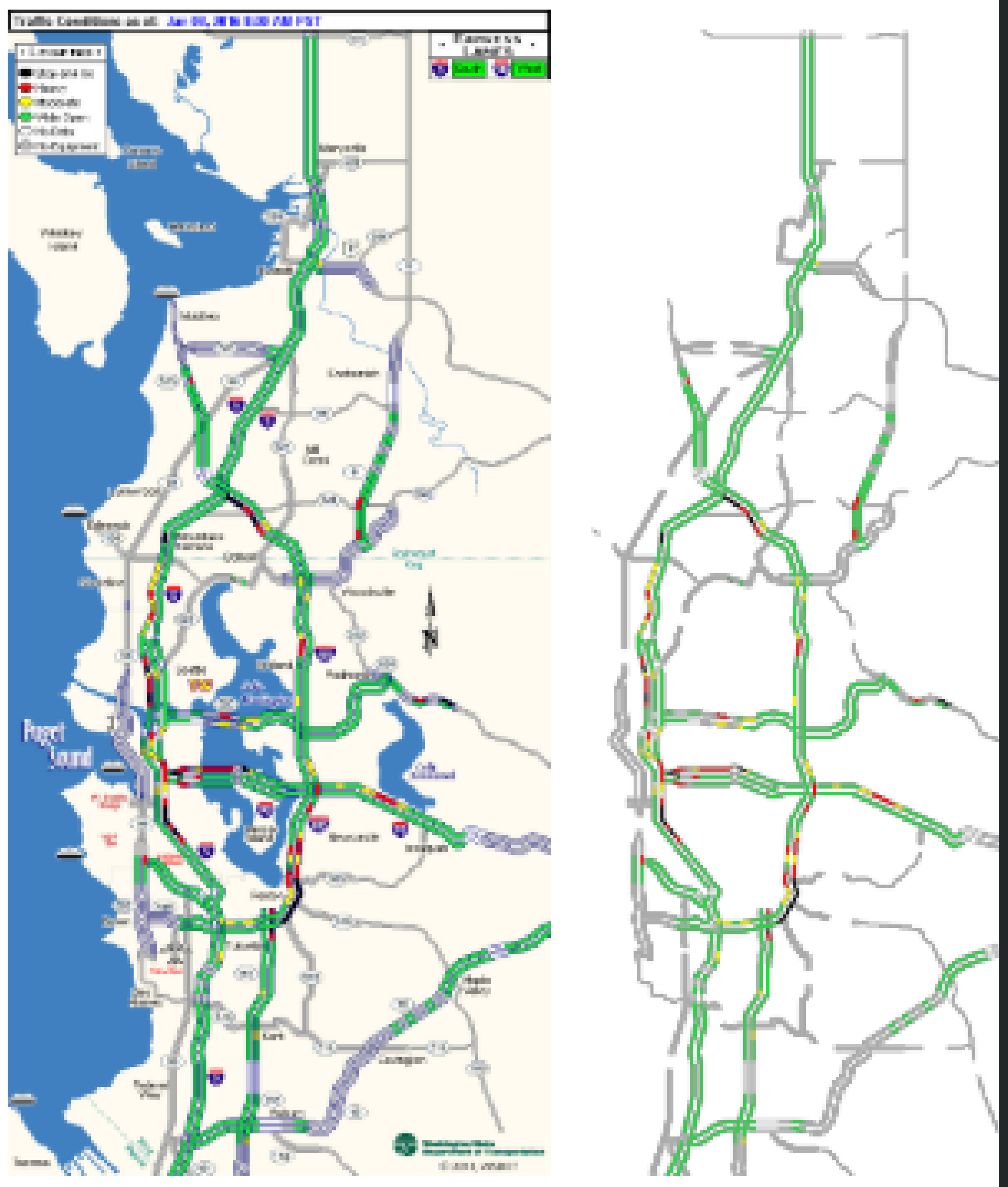
Metodología

1. Recopilación de imágenes

(a)

Metodología

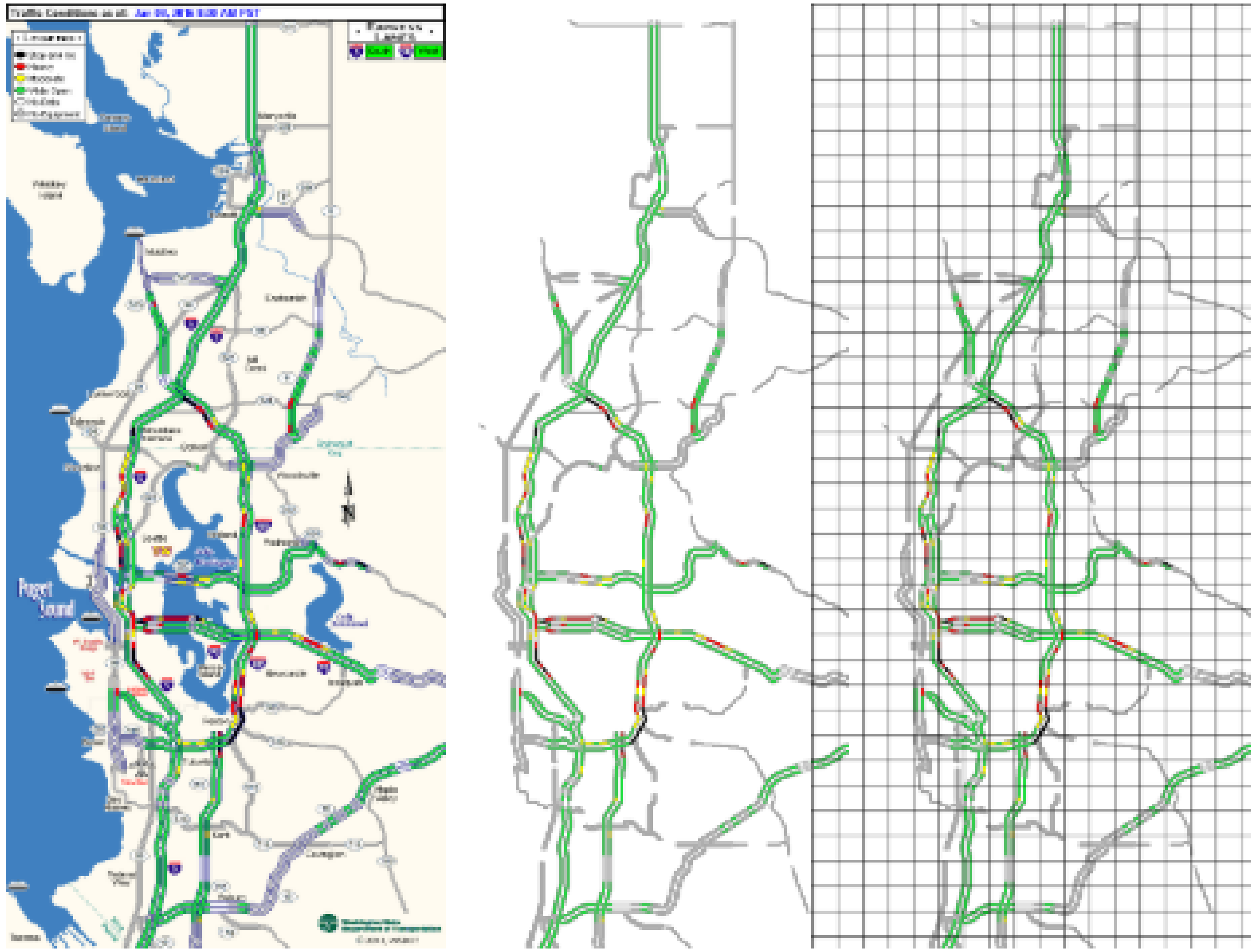
1. Recopilación de imágenes
2. Limpieza de las imágenes



(a) (b)

Metodología

1. Recopilación de imágenes
2. Limpieza de las imágenes
3. División de imágenes en celdas, y a su vez, estas en grillas



(a) (b) (c)

Metodología

1. Recopilación de imágenes
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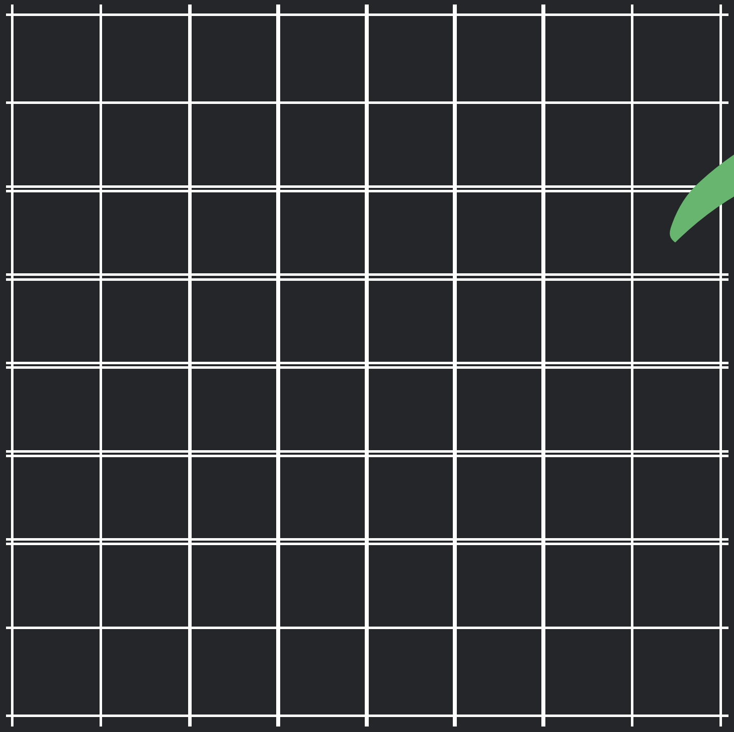
4. Cálculo del nivel de cogestión por grilla



$$\bar{c}^{t}_{i,j} = \frac{\sum_{k=1}^{64} c^{k}_{t,i,j}}{\sum_{k=1}^{64}[c^{k}_{t,i,j} > 0]}$$

(d)

Metodología

1. Recopilación de imágenes
2. Limpiza de las imágenes
3. División de imágenes en celdas, y a su vez, estas en grillas
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5. Obtención de una matriz representativa

$$R_t = \begin{bmatrix} \vec{c}^{\,t}_{1,1} & \vec{c}^{\,t}_{1,2} & \cdots & \vec{c}^{\,t}_{1,C} \\ \vec{c}^{\,t}_{2,1} & \vec{c}^{\,t}_{2,2} & \cdots & \vec{c}^{\,t}_{2,C} \\ \vdots & \vdots & \cdots & \vdots \\ \vec{c}^{\,t}_{R,1} & \vec{c}^{\,t}_{R,2} & \cdots & \vec{c}^{\,t}_{R,C} \end{bmatrix}$$

Problema a Resolver

Series de Tiempo

$$(R_{t-n}, \ldots, R_{t-2}, R_{t-1}, R_t, R_{t+1}, R_{t+2}, \ldots, R_{t+h})$$

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Deep Congestion Prediction Network

DPCN - Autoencoder

1. Primera parte
    a. Encoder -> Data histórica (4 capas)
    b. Decoder -> Representación futura (4 capas)

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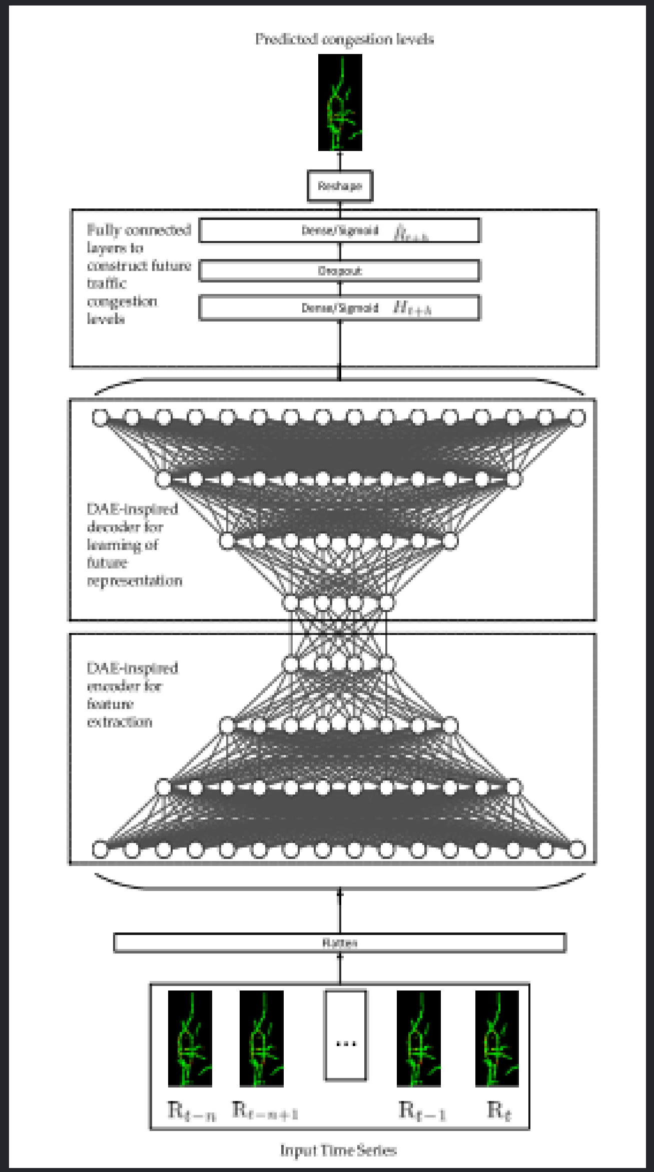
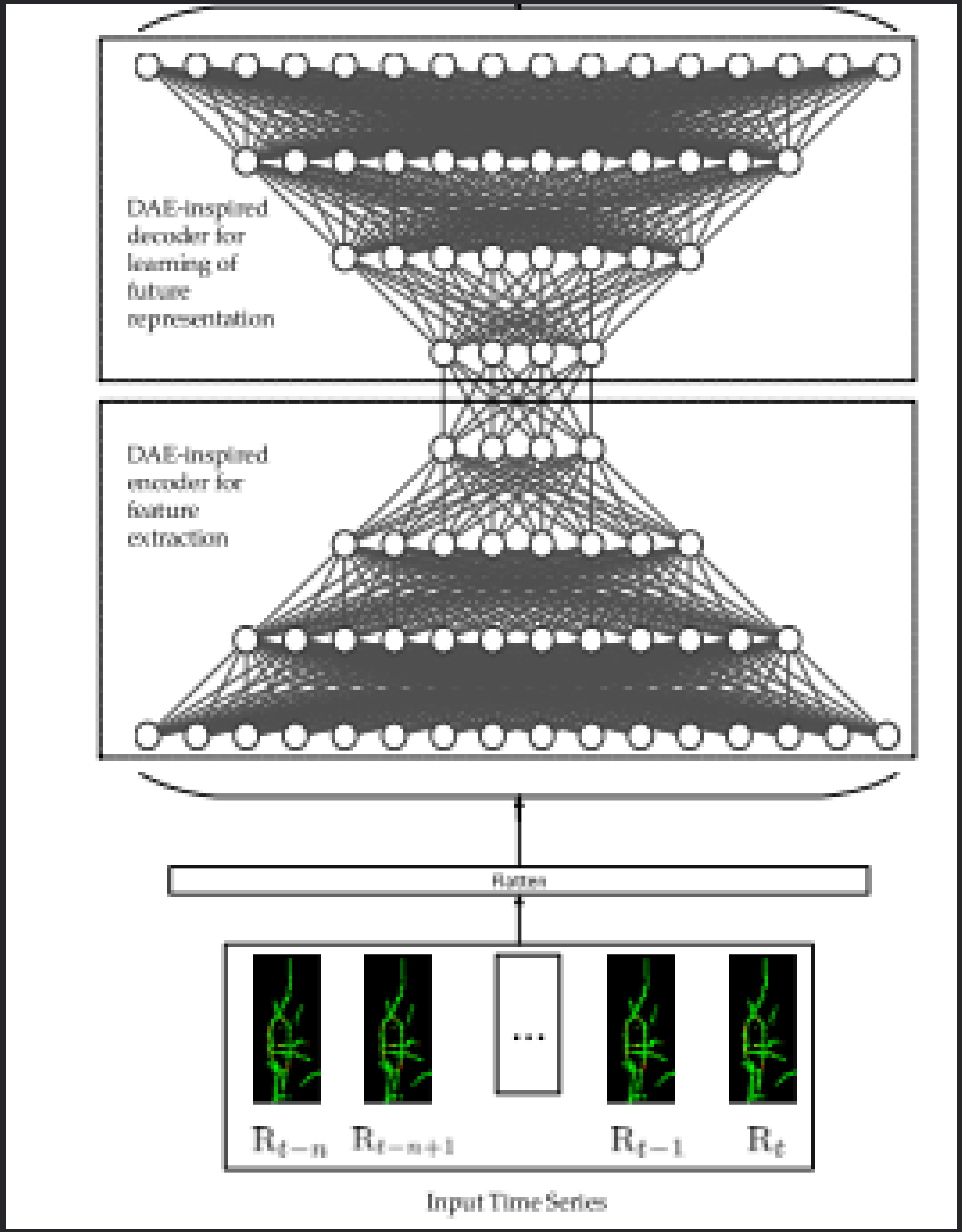
4. Capa de reorganización


Predicted congestion levels
Reshape
Fully connected layers to construct future traffic congestion levels
Dense/Sigmoid $\hat{R}_{t+h}$
Dropout
Dense/Sigmoid H_{t+h}
DAE-inspired decoder for learning of future representation
DAE-inspired encoder for feature extraction
Flatten
...
R_{t-n} R_{t-n+1} R_{t-1} R_t
Input Time Series


DAE-inspired decoder for learning of future representation
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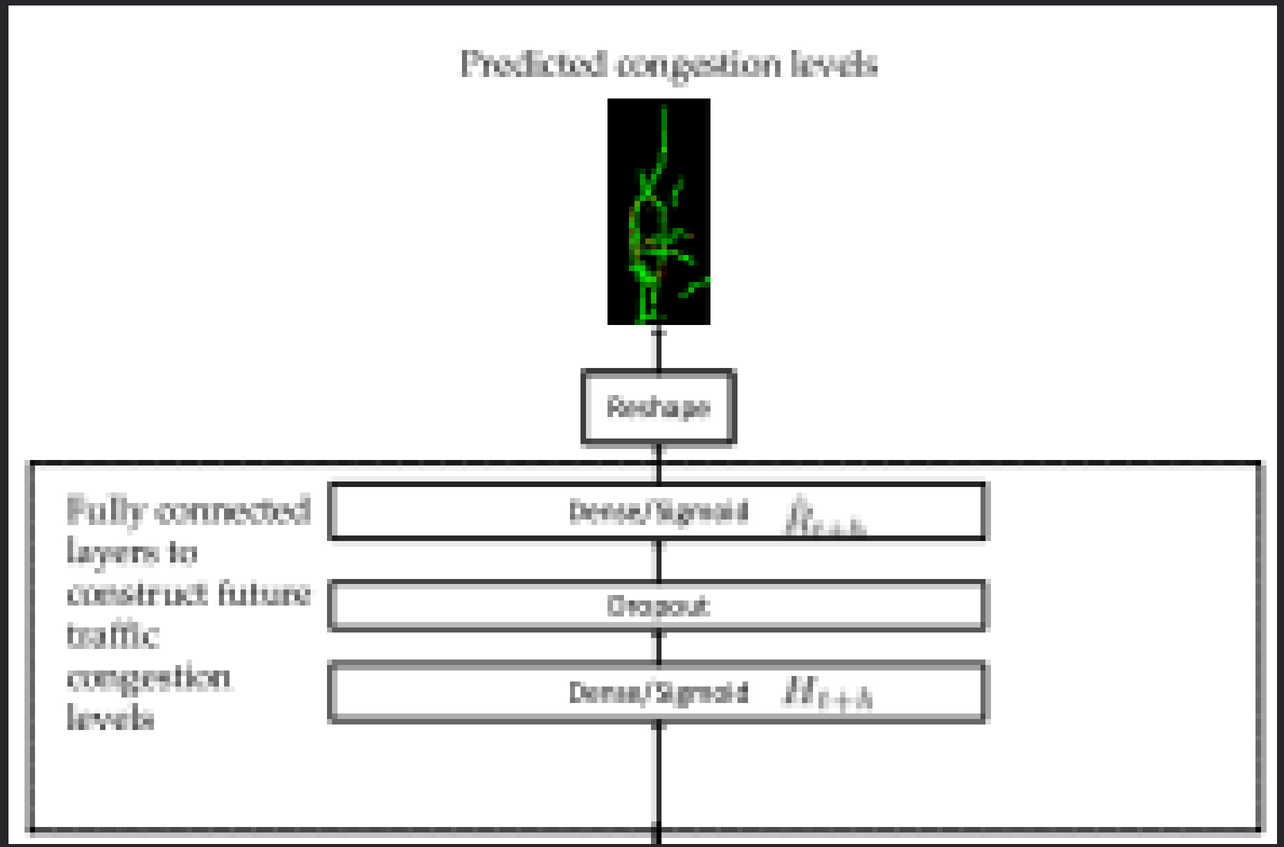
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- 07:00 a 10:00 am
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- 283 días (19 muestras cada uno)
- Intervalos de 10 minutos
- Datos de 2016 -> Set de entrenamiento
- Datos de 2017 -> Set de testeo via back-testing
- SATCS

Comparación de Modelos

- Cmparación con modelos:
  - SRCN (predicción de velocidades)
    - Uso de capas CNN y LSTM

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- Cmparación con modelos:
  - SRCN (predicción de velocidades)
    - Uso de capas CNN y LSTM
  - ConvLSTM (predicción de tráfico)
    - Multiples capas ConvLSTM

Comparación de Modelos

- Horizontes Temporales: 10, 30, 60
- Métricas: Mean Absolute Error (MAE) yWeighted Mean Squared Error (wMSE)

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$$MAE = \frac{1}{W \times H} \sum_{i=1}^{W} \sum_{j=1}^{H} |c_{ij}^t - \hat{c}_{ij}^t|$$

$$wMSE = \frac{1}{W \times H} \sum_{i=1}^{W} \sum_{j=1}^{H} w_{ij}^t \times (c_{ij}^t - \hat{c}_{ij}^t)^2$$

Resultados

Table 1. Comparison of prediction metrics by different configurations of DCPN. Minimum wMSE values marked in bold.

#	Prediction Horizon Averaged Metric Model Config	10 min wMSE	MAE	30 min wMSE	MAE	60 min wMSE	MAE
1st	512_384_256_128	0.058873	**0.010635**	**0.054298**	**0.010028**	0.045638	0.009572
2nd	640_512_384_256	**0.058357**	0.010737	0.054314	0.010125	**0.045414**	**0.009245**
3rd	768_640_512_384	0.061818	0.012796	0.058384	0.012838	0.049112	0.011893
4th	896_768_640_512	0.069279	0.016329	0.064761	0.016280	0.055138	0.016076
5th	1024_896_768_640	0.069227	0.016338	0.064663	0.016229	0.054909	0.015983

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5th	1024_896_768_640	0.069227	0.016338	0.064663	0.016229	0.054909	0.015983

Table 2. Significance of difference between the top 2 configurations of DCPN using Welch's t-test.

Prediction Horizon Averaged Metric Test Results	10 min wMSE	MAE	30 min wMSE	MAE	60 min wMSE	MAE
t stat	0.073076	−0.220181	−0.002431	−0.186772	0.038266	0.734073
p-value	0.941928	0.826291	0.998067	0.852313	0.969571	0.465075

Resultados

Table 3. Comparison of prediction metrics using time lags of 120 and 110 minutes. Minimum wMSE values marked in bold.

Prediction Horizon Averaged Metric Time Lag (minutes)	10 min wMSE	MAE	30 min wMSE	MAE	60 min wMSE	MAE
110	**0.058730**	0.010705	**0.054224**	0.010130	**0.045305**	0.009293
120	0.058873	0.010635	0.054298	0.010028	0.045638	0.009572

Resultados

- Back-Testing para el testeo
  - Series de tiempo
- Error de predicción
  - 2-Ene a 8-Feb (2017)
- 10 minutos de predicción

Resultados

- Back-Testing para el testeo
  - Series de tiempo
- Error de predicción
  - 2-Ene a 8-Feb (2017)
- 10 minutos de predicción
- **DPCN**
  - MAE mejor en 32 días
  - wMSE mejor en 33 días

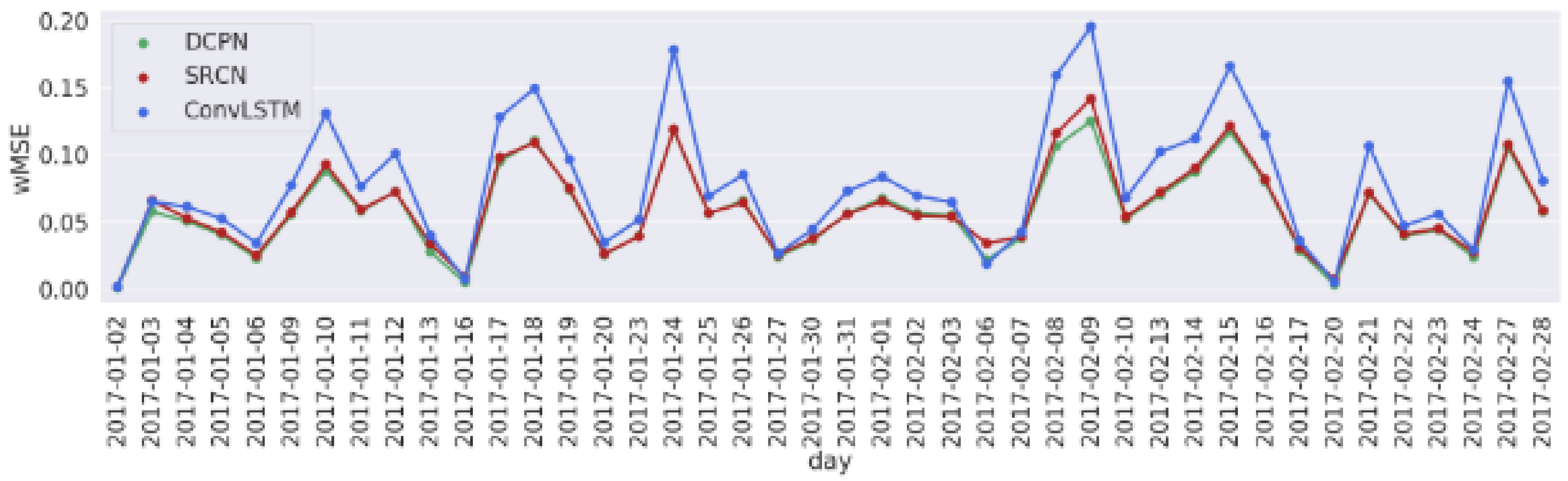

Figure 4. Daily total wMSE errors with a prediction horizon of 10 min on 42 days evaluated with back-testing.

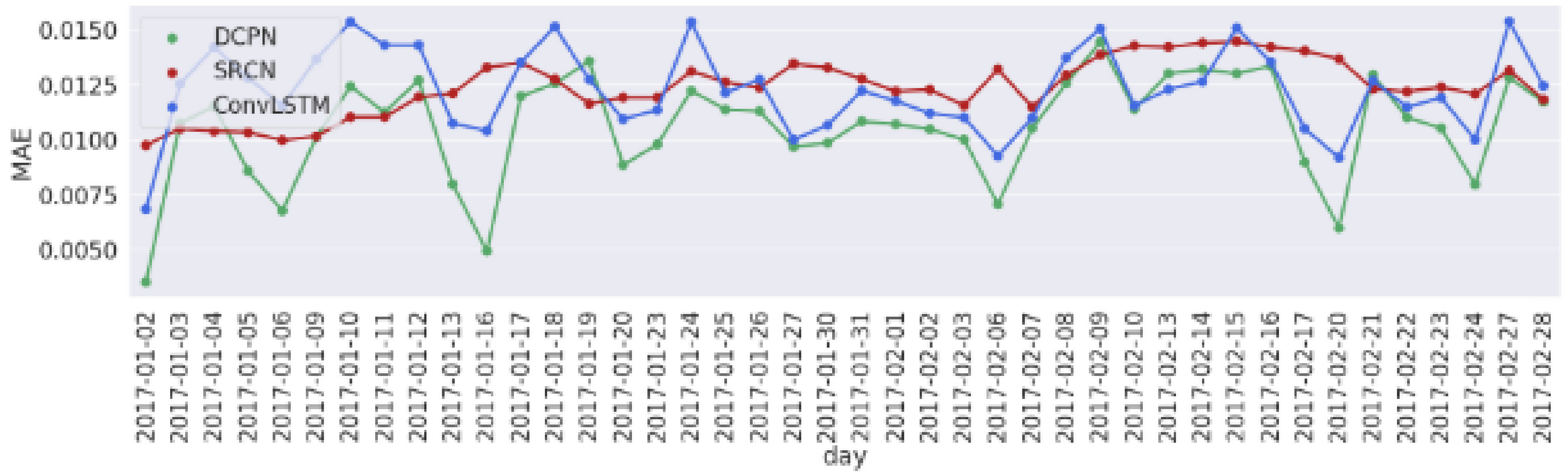

Figure 5. Daily total MAE errors with a prediction horizon of 10 min on 42 days evaluated with back-testing.

Resultados

Table 5. MAE and wMSE by day of the whole network at different prediction horizons of 10, 30, and 60 min through back-testing. Best performance values for each day are marked with a bold typeface.

	10 min						30 min						60 min					
	MAE			wMSE			MAE			wMSE			MAE			wMSE		
Day	SRCN	ConvLSTM	DCPN	SRCN	ConvLSTM	DCPN	SRCN	ConvLSTM	DCPN	SRCN	ConvLSTM	DCPN	SRCN	ConvLSTM	DCPN	SRCN	ConvLSTM	DCPN
2017-01-02	0.0097	0.0068	**0.0035**	0.0017	0.0016	**0.0010**	0.0083	0.0069	**0.0034**	0.0014	0.0016	**0.0009**	0.0104	0.0072	**0.0067**	0.0037	**0.0023**	0.0025
2017-01-03	**0.0105**	0.0125	0.0107	0.0660	0.0651	**0.0576**	0.0115	0.0124	**0.0109**	0.0550	0.0590	**0.0543**	0.0103	0.0120	**0.0088**	0.0490	0.0500	**0.0483**
2017-01-04	**0.0104**	0.0142	0.0115	0.0527	0.0613	**0.0504**	**0.0103**	0.0123	0.0104	**0.0460**	0.0640	0.0471	0.0093	0.0137	**0.0088**	0.0387	0.0476	**0.0382**
2017-01-05	0.0103	0.0128	**0.0086**	0.0422	0.0525	**0.0404**	0.0112	0.0127	**0.0089**	0.0388	0.0491	**0.0381**	0.0110	0.0149	**0.0086**	0.0329	0.0405	**0.0315**
2017-01-06	0.0100	0.0116	**0.0068**	0.0251	0.0341	**0.0228**	0.0103	0.0111	**0.0071**	0.0274	0.0385	**0.0234**	0.0111	0.0131	**0.0077**	0.0264	0.0258	**0.0214**
2017-01-09	0.0102	0.0137	**0.0101**	0.0571	0.0773	**0.0557**	0.0110	0.0122	**0.0085**	0.0577	0.0787	**0.0531**	0.0120	0.0128	**0.0093**	0.0516	0.0538	**0.0447**
2017-01-10	**0.0110**	0.0154	0.0124	0.0927	0.1307	**0.0881**	0.0158	0.0141	**0.0118**	0.1051	0.1302	**0.0814**	0.0127	0.0146	**0.0115**	0.0917	0.1057	**0.0676**
2017-01-11	**0.0110**	0.0143	0.0112	0.0593	0.0765	**0.0582**	0.0167	0.0121	**0.0108**	0.0704	0.0795	**0.0508**	**0.0108**	0.0138	0.0111	0.0468	0.0534	**0.0395**
2017-01-12	**0.0119**	0.0143	0.0127	**0.0722**	0.1010	0.0725	0.0130	0.0146	**0.0124**	0.0900	0.1122	**0.0724**	**0.0115**	0.0131	0.0117	0.0812	0.0879	**0.0683**
2017-01-13	0.0121	0.0107	**0.0080**	0.0337	0.0399	**0.0277**	0.0100	0.0113	**0.0087**	0.0364	0.0375	**0.0259**	0.0103	0.0140	**0.0081**	0.0385	0.0391	**0.0285**
2017-01-16	0.0133	0.0104	**0.0049**	0.0089	0.0075	**0.0050**	0.0107	0.0093	**0.0058**	0.0089	0.0064	**0.0048**	0.0097	0.0122	**0.0044**	0.0067	0.0087	**0.0036**
2017-01-17	0.0135	0.0135	**0.0120**	0.0981	0.1282	**0.0951**	0.0124	0.0132	**0.0118**	0.1118	0.1262	**0.0912**	0.0110	0.0128	**0.0106**	0.0907	0.0983	**0.0752**
2017-01-18	0.0127	0.0151	**0.0126**	**0.1089**	0.1495	0.1106	0.0132	0.0162	**0.0122**	0.1318	0.1621	**0.1024**	0.0134	0.0142	**0.0107**	0.1169	0.1243	**0.0866**
2017-01-19	**0.0116**	0.0127	0.0136	0.0750	0.0965	**0.0738**	**0.0110**	0.0132	0.0112	0.0807	0.0943	**0.0665**	0.0112	0.0124	**0.0094**	0.0679	0.0755	**0.0533**
2017-01-20	0.0119	0.0109	**0.0088**	0.0263	0.0346	**0.0255**	**0.0079**	0.0124	0.0083	0.0292	0.0308	**0.0257**	**0.0072**	0.0108	0.0085	0.0208	0.0242	**0.0179**
2017-01-23	0.0119	0.0114	**0.0098**	**0.0391**	0.0517	0.0396	**0.0094**	0.0120	0.0098	0.0455	0.0519	**0.0373**	**0.0079**	0.0108	0.0088	0.0314	0.0337	**0.0264**
2017-01-24	0.0131	0.0153	**0.0122**	0.1191	0.1780	**0.1182**	**0.0131**	0.0146	0.0136	0.1330	0.1735	**0.1118**	**0.0114**	0.0141	0.0117	0.1261	0.1262	**0.0850**
2017-01-25	0.0126	0.0121	**0.0114**	0.0568	0.0693	**0.0563**	**0.0097**	0.0124	0.0123	0.0614	0.0691	**0.0546**	**0.0082**	0.0115	0.0092	0.0480	0.0512	**0.0397**
2017-01-26	0.0124	0.0127	**0.0113**	**0.0642**	0.0851	0.0658	**0.0100**	0.0122	0.0108	0.0697	0.0884	**0.0605**	0.0093	0.0118	**0.0090**	0.0578	0.0595	**0.0433**
2017-01-27	0.0135	0.0100	**0.0097**	0.0255	0.0264	**0.0240**	**0.0079**	0.0099	0.0082	0.0243	0.0300	**0.0219**	0.0079	0.0105	**0.0075**	0.0242	0.0253	**0.0187**
2017-01-30	0.0133	0.0107	**0.0099**	0.0377	0.0445	**0.0363**	**0.0085**	0.0105	0.0094	0.0312	0.0399	**0.0310**	0.0079	0.0103	**0.0073**	0.0262	0.0281	**0.0224**
2017-01-31	0.0128	0.0122	**0.0108**	**0.0560**	0.0731	0.0565	**0.0093**	0.0111	0.0107	0.0598	0.0693	**0.0493**	**0.0073**	0.0097	0.0085	0.0450	0.0527	**0.0403**
2017-02-01	0.0122	0.0118	**0.0107**	**0.0654**	0.0838	0.0675	**0.0105**	0.0116	**0.0105**	0.0723	0.0901	**0.0619**	**0.0086**	0.0109	0.0099	0.0618	0.0685	**0.0500**
2017-02-02	0.0123	0.0112	**0.0105**	**0.0547**	0.0694	0.0564	**0.0095**	0.0112	0.0105	0.0582	0.0662	**0.0518**	**0.0085**	0.0113	0.0093	0.0484	0.0502	**0.0408**
2017-02-03	0.0116	0.0110	**0.0100**	**0.0539**	0.0645	0.0548	**0.0095**	0.0107	0.0100	0.0550	0.0618	**0.0469**	0.0084	0.0103	**0.0079**	0.0401	0.0408	**0.0331**
2017-02-06	0.0132	0.0093	**0.0071**	0.0340	**0.0185**	0.0217	0.0123	**0.0095**	0.0097	0.0212	0.0189	**0.0108**	0.0127	0.0134	**0.0061**	0.0225	0.0308	**0.0208**
2017-02-07	0.0115	0.0110	**0.0105**	0.0390	0.0424	**0.0380**	0.0096	0.0102	**0.0079**	0.0361	0.0391	**0.0324**	0.0096	0.0106	**0.0074**	0.0299	0.0307	**0.0245**
2017-02-08	0.0129	0.0137	**0.0126**	0.1159	0.1591	**0.1064**	**0.0121**	0.0142	0.0125	0.1313	0.1812	**0.1046**	**0.0113**	0.0133	0.0122	0.1333	0.1674	**0.0943**
2017-02-09	**0.0139**	0.0150	0.0144	0.1417	0.1955	**0.1251**	0.0136	0.0157	**0.0133**	0.1562	0.2183	**0.1221**	0.0130	0.0139	**0.0123**	0.1464	0.1698	**0.1097**
2017-02-10	0.0143	0.0116	**0.0114**	0.0538	0.0679	**0.0522**	**0.0103**	0.0120	0.0105	0.0576	0.0718	**0.0488**	**0.0090**	0.0111	0.0101	0.0472	0.0546	**0.0411**
2017-02-13	0.0142	**0.0123**	0.0130	0.0722	0.1023	**0.0702**	**0.0110**	0.0124	0.0122	0.0809	0.0949	**0.0612**	**0.0095**	0.0118	0.0117	0.0694	0.0795	**0.0532**
2017-02-14	0.0144	**0.0126**	0.0132	0.0901	0.1123	**0.0873**	**0.0122**	0.0133	0.0134	0.1054	0.1381	**0.0891**	**0.0112**	0.0120	0.0115	0.1011	0.1137	**0.0815**
2017-02-15	0.0145	0.0151	**0.0130**	0.1214	0.1660	**0.1173**	0.0142	0.0152	**0.0124**	0.1366	0.1676	**0.1099**	0.0125	0.0141	**0.0120**	0.1213	0.1428	**0.0943**
2017-02-16	0.0142	0.0135	**0.0134**	0.0817	0.1144	**0.0802**	0.0118	0.0135	**0.0116**	0.0888	0.1150	**0.0733**	**0.0100**	0.0124	0.0112	0.0783	0.0895	**0.0643**
2017-02-17	0.0140	0.0105	**0.0090**	0.0306	0.0360	**0.0288**	**0.0074**	0.0101	0.0083	0.0308	0.0340	**0.0265**	**0.0072**	0.0100	0.0089	0.0289	0.0301	**0.0244**
2017-02-20	0.0137	0.0092	**0.0060**	0.0074	0.0052	**0.0034**	0.0101	0.0091	**0.0049**	0.0065	0.0070	**0.0041**	0.0112	0.0116	**0.0060**	0.0083	0.0096	**0.0048**
2017-02-21	**0.0123**	0.0127	0.0129	0.0716	0.1065	**0.0707**	**0.0101**	0.0125	0.0111	0.0769	0.1067	**0.0640**	**0.0090**	0.0109	0.0108	0.0630	0.0785	**0.0515**
2017-02-22	0.0122	0.0115	**0.0110**	0.0410	0.0472	**0.0396**	**0.0094**	0.0113	0.0096	0.0435	0.0519	**0.0341**	**0.0078**	0.0107	0.0089	0.0307	0.0363	**0.0274**
2017-02-23	0.0124	0.0119	**0.0105**	0.0451	0.0558	**0.0443**	0.0097	0.0114	**0.0094**	0.0435	0.0513	**0.0365**	**0.0075**	0.0102	0.0082	0.0306	0.0348	**0.0269**
2017-02-24	0.0121	0.0100	**0.0080**	0.0274	0.0291	**0.0236**	**0.0081**	0.0097	0.0085	0.0249	0.0308	**0.0218**	**0.0075**	0.0096	0.0113	**0.0195**	0.0235	0.0206
2017-02-27	0.0132	0.0154	**0.0128**	0.1078	0.1547	**0.1051**	0.0127	0.0166	**0.0120**	0.1142	0.1672	**0.0937**	**0.0110**	0.0134	0.0119	0.0910	0.1231	**0.0753**
2017-02-28	0.0118	0.0125	**0.0117**	0.0586	0.0804	**0.0576**	**0.0096**	0.0120	0.0113	0.0606	0.0800	**0.0522**	**0.0082**	0.0111	0.0118	0.0485	0.0604	**0.0427**

Resultados

MAE		
Tiempo	SRCN	DPCN
30 minutos	22	20
60 minutos	21	21
wMSE		
Tiempo	-	DPCN
30 mintuos	-	41
60 minutos	-	40

- Promedios mas bajos para MAE y wMSE para 10, 30 y 60 minutos

Table 5. MAE and wMSE by day of the whole network at different prediction horizons of 10, 30, and 60 min through back-testing. Best performance values for each day are marked with a bold typeface.

	10 min						30 min						60 min					
	MAE			wMSE			MAE			wMSE			MAE			wMSE		
Day	SRCN	ConvLSTM	DCPN	SRCN	ConvLSTM	DCPN	SRCN	ConvLSTM	DCPN	SRCN	ConvLSTM	DCPN	SRCN	ConvLSTM	DCPN	SRCN	ConvLSTM	DCPN
2017-01-02	0.0097	0.0068	**0.0035**	0.0017	0.0016	**0.0010**	0.0083	0.0069	**0.0034**	0.0014	0.0016	**0.0009**	0.0104	0.0072	**0.0067**	0.0037	**0.0023**	0.0025
2017-01-03	**0.0105**	0.0125	0.0107	0.0660	0.0651	**0.0576**	0.0115	0.0124	**0.0109**	0.0550	0.0590	**0.0543**	0.0103	0.0120	**0.0088**	0.0490	0.0500	**0.0483**
2017-01-04	**0.0104**	0.0142	0.0115	0.0527	0.0613	**0.0504**	**0.0103**	0.0123	0.0104	**0.0460**	0.0640	0.0471	0.0093	0.0137	**0.0088**	0.0387	0.0476	**0.0382**
2017-01-05	0.0103	0.0128	**0.0086**	0.0422	0.0525	**0.0404**	0.0112	0.0127	**0.0089**	0.0388	0.0491	**0.0381**	0.0110	0.0149	**0.0086**	0.0329	0.0405	**0.0315**
2017-01-06	0.0100	0.0116	**0.0068**	0.0251	0.0341	**0.0228**	0.0103	0.0111	**0.0071**	0.0274	0.0385	**0.0234**	0.0111	0.0131	**0.0077**	0.0264	0.0258	**0.0214**
2017-01-09	0.0102	0.0137	**0.0101**	0.0571	0.0773	**0.0557**	0.0110	0.0122	**0.0085**	0.0577	0.0787	**0.0531**	0.0120	0.0128	**0.0093**	0.0516	0.0538	**0.0447**
2017-01-10	**0.0110**	0.0154	0.0124	0.0927	0.1307	**0.0881**	0.0158	0.0141	**0.0118**	0.1051	0.1302	**0.0814**	0.0127	0.0146	**0.0115**	0.0917	0.1057	**0.0676**
2017-01-11	**0.0110**	0.0143	0.0112	0.0593	0.0765	**0.0582**	0.0167	0.0121	**0.0108**	0.0704	0.0795	**0.0508**	**0.0108**	0.0138	0.0111	0.0468	0.0534	**0.0395**
2017-01-12	**0.0119**	0.0143	0.0127	**0.0722**	0.1010	0.0725	0.0130	0.0146	**0.0124**	0.0900	0.1122	**0.0724**	**0.0115**	0.0131	0.0117	0.0812	0.0879	**0.0683**
2017-01-13	0.0121	0.0107	**0.0080**	0.0337	0.0399	**0.0277**	0.0100	0.0113	**0.0087**	0.0364	0.0375	**0.0259**	0.0103	0.0140	**0.0081**	0.0385	0.0391	**0.0285**
2017-01-16	0.0133	0.0104	**0.0049**	0.0089	0.0075	**0.0050**	0.0107	0.0093	**0.0058**	0.0089	0.0064	**0.0048**	0.0097	0.0122	**0.0044**	0.0067	0.0087	**0.0036**
2017-01-17	0.0135	0.0135	**0.0120**	0.0981	0.1282	**0.0951**	0.0124	0.0132	**0.0118**	0.1118	0.1262	**0.0912**	0.0110	0.0128	**0.0106**	0.0907	0.0983	**0.0752**
2017-01-18	0.0127	0.0151	**0.0126**	**0.1089**	0.1495	0.1106	0.0132	0.0162	**0.0122**	0.1318	0.1621	**0.1024**	0.0134	0.0142	**0.0107**	0.1169	0.1243	**0.0866**
2017-01-19	**0.0116**	0.0127	0.0136	0.0750	0.0965	**0.0738**	**0.0110**	0.0132	0.0112	0.0807	0.0943	**0.0665**	0.0112	0.0124	**0.0094**	0.0679	0.0755	**0.0533**
2017-01-20	0.0119	0.0109	**0.0088**	0.0263	0.0346	**0.0255**	**0.0079**	0.0124	0.0083	0.0292	0.0308	**0.0257**	**0.0072**	0.0108	0.0085	0.0208	0.0242	**0.0179**
2017-01-23	0.0119	0.0114	**0.0098**	**0.0391**	0.0517	0.0396	**0.0094**	0.0120	0.0098	0.0455	0.0519	**0.0373**	**0.0079**	0.0108	0.0088	0.0314	0.0337	**0.0264**
2017-01-24	0.0131	0.0153	**0.0122**	0.1191	0.1780	**0.1182**	**0.0131**	0.0146	0.0136	0.1330	0.1735	**0.1118**	**0.0114**	0.0141	0.0117	0.1261	0.1262	**0.0850**
2017-01-25	0.0126	0.0121	**0.0114**	0.0568	0.0693	**0.0563**	**0.0097**	0.0124	0.0123	0.0614	0.0691	**0.0546**	**0.0082**	0.0115	0.0092	0.0480	0.0512	**0.0397**
2017-01-26	0.0124	0.0127	**0.0113**	**0.0642**	0.0851	0.0658	**0.0100**	0.0122	0.0108	0.0697	0.0884	**0.0605**	0.0093	0.0118	**0.0090**	0.0578	0.0595	**0.0433**
2017-01-27	0.0135	0.0100	**0.0097**	0.0255	0.0264	**0.0240**	**0.0079**	0.0099	0.0082	0.0243	0.0300	**0.0219**	0.0079	0.0105	**0.0075**	0.0242	0.0253	**0.0187**
2017-01-30	0.0133	0.0107	**0.0099**	0.0377	0.0445	**0.0363**	**0.0085**	0.0105	0.0094	0.0312	0.0399	**0.0310**	0.0079	0.0103	**0.0073**	0.0262	0.0281	**0.0224**
2017-01-31	0.0128	0.0122	**0.0108**	**0.0560**	0.0731	0.0565	**0.0093**	0.0111	0.0107	0.0598	0.0693	**0.0493**	**0.0073**	0.0097	0.0085	0.0450	0.0527	**0.0403**
2017-02-01	0.0122	0.0118	**0.0107**	**0.0654**	0.0838	0.0675	**0.0105**	0.0116	**0.0105**	0.0723	0.0901	**0.0619**	**0.0086**	0.0109	0.0099	0.0618	0.0685	**0.0500**
2017-02-02	0.0123	0.0112	**0.0105**	**0.0547**	0.0694	0.0564	**0.0095**	0.0112	0.0105	0.0582	0.0662	**0.0518**	**0.0085**	0.0113	0.0093	0.0484	0.0502	**0.0408**
2017-02-03	0.0116	0.0110	**0.0100**	**0.0539**	0.0645	0.0548	**0.0095**	0.0107	0.0100	0.0550	0.0618	**0.0469**	0.0084	0.0103	**0.0079**	0.0401	0.0408	**0.0331**
2017-02-06	0.0132	0.0093	**0.0071**	0.0340	**0.0185**	0.0217	0.0123	**0.0095**	0.0097	0.0212	0.0189	**0.0108**	0.0127	0.0134	**0.0061**	0.0225	0.0308	**0.0208**
2017-02-07	0.0115	0.0110	**0.0105**	0.0390	0.0424	**0.0380**	0.0096	0.0102	**0.0079**	0.0361	0.0391	**0.0324**	0.0096	0.0106	**0.0074**	0.0299	0.0307	**0.0245**
2017-02-08	0.0129	0.0137	**0.0126**	0.1159	0.1591	**0.1064**	**0.0121**	0.0142	0.0125	0.1313	0.1812	**0.1046**	**0.0113**	0.0133	0.0122	0.1333	0.1674	**0.0943**
2017-02-09	**0.0139**	0.0150	0.0144	0.1417	0.1955	**0.1251**	0.0136	0.0157	**0.0133**	0.1562	0.2183	**0.1221**	0.0130	0.0139	**0.0123**	0.1464	0.1698	**0.1097**
2017-02-10	0.0143	0.0116	**0.0114**	0.0538	0.0679	**0.0522**	**0.0103**	0.0120	0.0105	0.0576	0.0718	**0.0488**	**0.0090**	0.0111	0.0101	0.0472	0.0546	**0.0411**
2017-02-13	0.0142	**0.0123**	0.0130	0.0722	0.1023	**0.0702**	**0.0110**	0.0124	0.0122	0.0809	0.0949	**0.0612**	**0.0095**	0.0118	0.0117	0.0694	0.0795	**0.0532**
2017-02-14	0.0144	**0.0126**	0.0132	0.0901	0.1123	**0.0873**	**0.0122**	0.0133	0.0134	0.1054	0.1381	**0.0891**	**0.0112**	0.0120	0.0115	0.1011	0.1137	**0.0815**
2017-02-15	0.0145	0.0151	**0.0130**	0.1214	0.1660	**0.1173**	0.0142	0.0152	**0.0124**	0.1366	0.1676	**0.1099**	0.0125	0.0141	**0.0120**	0.1213	0.1428	**0.0943**
2017-02-16	0.0142	0.0135	**0.0134**	0.0817	0.1144	**0.0802**	0.0118	0.0135	**0.0116**	0.0888	0.1150	**0.0733**	**0.0100**	0.0124	0.0112	0.0783	0.0895	**0.0643**
2017-02-17	0.0140	0.0105	**0.0090**	0.0306	0.0360	**0.0288**	**0.0074**	0.0101	0.0083	0.0308	0.0340	**0.0265**	**0.0072**	0.0100	0.0089	0.0289	0.0301	**0.0244**
2017-02-20	0.0137	0.0092	**0.0060**	0.0074	0.0052	**0.0034**	0.0101	0.0091	**0.0049**	0.0065	0.0070	**0.0041**	0.0112	0.0116	**0.0060**	0.0083	0.0096	**0.0048**
2017-02-21	**0.0123**	0.0127	0.0129	0.0716	0.1065	**0.0707**	**0.0101**	0.0125	0.0111	0.0769	0.1067	**0.0640**	**0.0090**	0.0109	0.0108	0.0630	0.0785	**0.0515**
2017-02-22	0.0122	0.0115	**0.0110**	0.0410	0.0472	**0.0396**	**0.0094**	0.0113	0.0096	0.0435	0.0519	**0.0341**	**0.0078**	0.0107	0.0089	0.0307	0.0363	**0.0274**
2017-02-23	0.0124	0.0119	**0.0105**	0.0451	0.0558	**0.0443**	0.0097	0.0114	**0.0094**	0.0435	0.0513	**0.0365**	**0.0075**	0.0102	0.0082	0.0306	0.0348	**0.0269**
2017-02-24	0.0121	0.0100	**0.0080**	0.0274	0.0291	**0.0236**	**0.0081**	0.0097	0.0085	0.0249	0.0308	**0.0218**	**0.0075**	0.0096	0.0113	**0.0195**	0.0235	0.0206
2017-02-27	0.0132	0.0154	**0.0128**	0.1078	0.1547	**0.1051**	0.0127	0.0166	**0.0120**	0.1142	0.1672	**0.0937**	**0.0110**	0.0134	0.0119	0.0910	0.1231	**0.0753**
2017-02-28	0.0118	0.0125	**0.0117**	0.0586	0.0804	**0.0576**	**0.0096**	0.0120	0.0113	0.0606	0.0800	**0.0522**	**0.0082**	0.0111	0.0118	0.0485	0.0604	**0.0427**

Resultados - Eficiencia

Table 6. Computing resources for training with prediction horizons of 10, 30, and 60 min.

10 min metric description	SRCN	ConvLSTM	DCPN
total number of epochs to converge	876	719	823
total training time (s)	30,646.517	70,125.471	21,450.032
30 min metric description	**SRCN**	**ConvLSTM**	**DCPN**
total number of epochs to converge	757	631	845
total training time (s)	26,572.629	61,677.397	22,235.832
60 min metric description	**SRCN**	**ConvLSTM**	**DCPN**
total number of epochs to converge	769	690	795
total training time (s)	27,585.755	66,646.381	20,299.434

Resultados

17 enero 2017 - Horizonte de predicción de 10 minutos

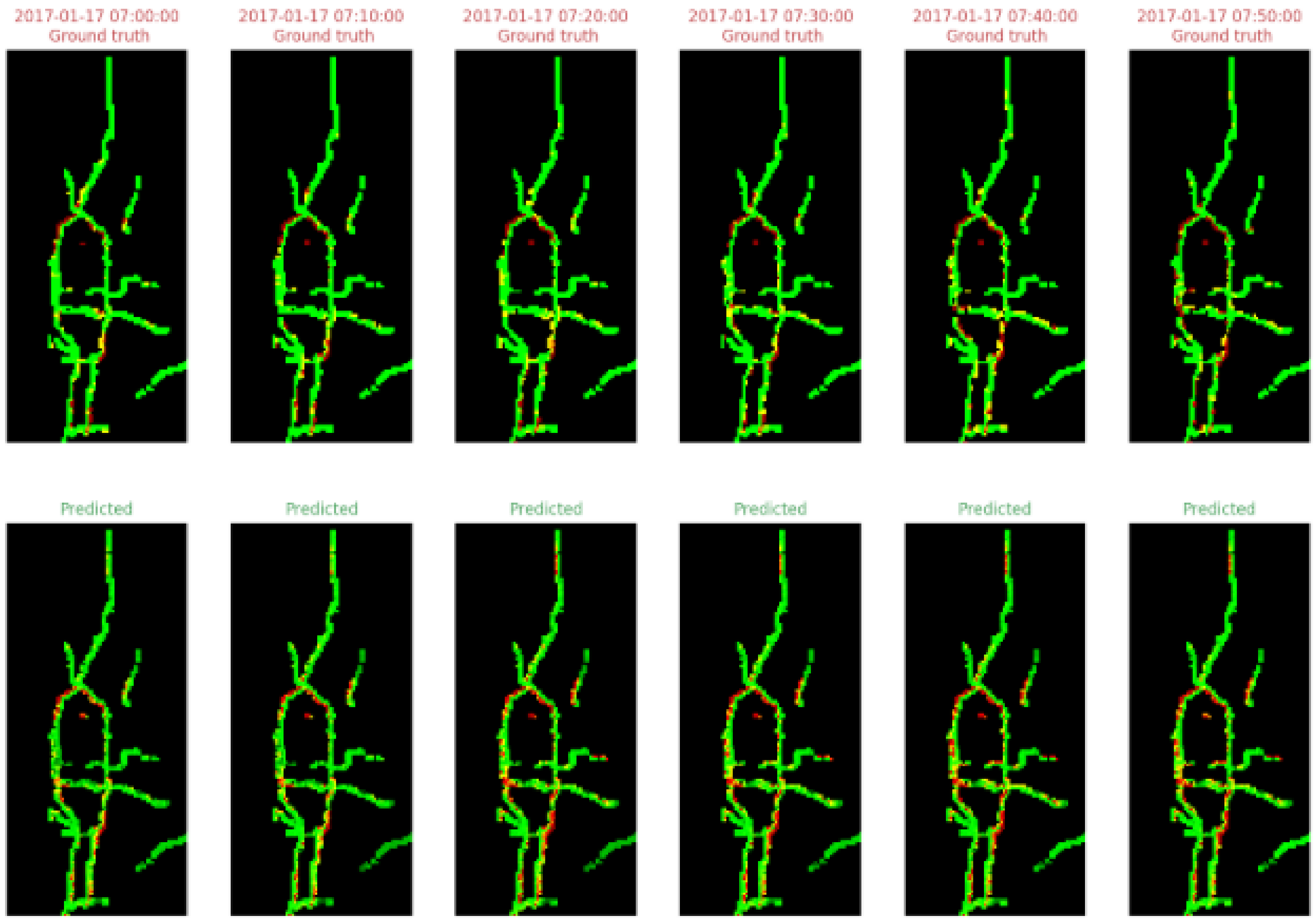

Figure 6. Ground truth congestion levels (first row) vs. predicted congestion levels (second row) on 17 January 2017 with a prediction horizon of 10 min.

Conclusiones

- Herramienta de predicción de congestión a través de imágenes
    - Accesible

Conclusiones

- Herramienta de predicción de congestión a través de imágenes
    - Accesible
- Construcción de modelo DPCN

Conclusiones

- Herramienta de predicción de congestión a través de imágenes
    - Accesible
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- DPCN es mas efectivo

Conclusiones

- Herramienta de predicción de congestión a través de imágenes
  - Accesible
- Construcción de modelo DPCN
- DPCN es mas efectivo
- DPCN es mas eficiente

Investigaciones Futuras

- Incluir mas información

Investigaciones Futuras

- Incluir mas información
- Utilizar imágenes de otros sistemas

Investigaciones Futuras

- Incluir mas información
- Utilizar imágenes de otros sistemas
- Cuantificar cuanta información se pierde

Investigaciones Futuras

- Incluir mas información
- Utilizar imágenes de otros sistemas
- Cuantificar cuanta información se pierde
- Mejorar la eficiencia dejando de considerar valores 0

Opiniones Personales

- Valor de la herramienta

Opiniones Personales

- Valor de la herramienta
- Dudas respecto a la bidireccionalidad

Opiniones Personales

- Valor de la herramienta
- Dudas respecto a la bidireccionalidad
- Enfoque en transsporte urbano

Opiniones Personales

- Valor de la herramienta
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- Enfoque en transssporte urbano
- Relación con investigación

Deep Autoencoder Neural Networks for Short-Term Traffic Congestion Prediction of Transportation Networks

SEN ZHANG, YONG YAO, JIE HU, YONG ZHAO, SHAOBO LI, JIANJUN HU (2019)

MARTÍN I. LÓPEZ PAVEZ

Anexos

Herramientas del estudio

Acercamiento al procesamiento de imagenes sobre niveles de congestion

Modelo eficiente de predicción de congestión de la red

Resultados eficientes y efectivos

Resultados

Table 4. Configuration of parameters for DCPN.

Layer	Name	Channels	Shape
0	Inputs	1	(11, 149, 69)
1	Flattern	1	113,091
2	Dense (ReLU)	1	512
3	Dense (ReLU)	1	384
4	Dense (ReLU)	1	256
5	Dense (ReLU)	1	128
6	Dense (ReLU)	1	128
7	Dense (ReLU)	1	256
8	Dense (ReLU)	1	384
9	Dense (ReLU)	1	512
10	Dense (Sigmoid)	1	149×69
11	Dropout (0.1)	——	——
12	Dense (Sigmoid)	1	149×69
13	Reshape	1	(149, 69)

Pasos realizados

- Limpieza de imágenes, a traves del procesamiento de imágenes
- Asignación de números por pixel usando HSL