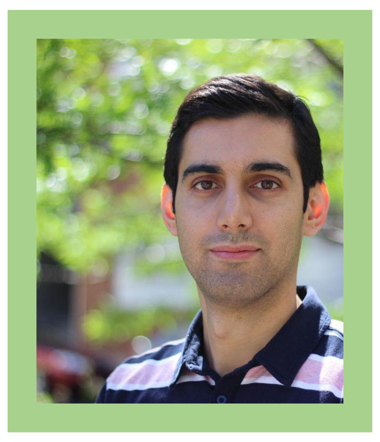

Short-Term Water Demand Forecast Modelling Using Artificial Neural Networks and Genetic Algorithm

Majid Gholami Shirkoohi[1], Mouna Doghri[2], Sophie Duchesne[1], Patrick Drogui[1]

[1] Institut National de la Recherche Scientifique (INRS), Centre-Eau Terre Environnement, Université du Québec, 490, Rue de la Couronne, Québec (QC) G1K 9A9, Canada
[2] Environnement Canada, 1550 Avenue D'Estimauville, Québec, QC G1J 0C3, Canada

Motivation

- Forecasting the urban water demand (UWD) is a crucial issue to ensure a better design, operation, and management of water distribution systems (WDSs).
- The application of Artificial Neural Networks (ANNs) models to predict the UWD is an interesting approach because of their powerful ability to map nonlinear trend of water demand.

Objective

- Comparison of different approaches of ANNs models on making short-term predictions of water consumption using a 15 min time step to define the most relevant model to integrate into a control tool.

Methodology

1) **Single-ANNs**: one time training using all the training and validation data set and then with one trained network, obtaining the performance results on the whole test data set.
2) **Multi-ANNs**: multiple times training meaning that for each time step in the test data set the whole data before that time step will be used as training and validation data set to predict that specific time step.
3) **ANN-GA**: The GA optimization method is utilized to optimize the ANN topology and hyper parameters to gain a network with the best possible performance (Figure 1).

Table 1.
Description of the datasets

Dataset	Training and Validation (year)	Test (year)
City 1 (μ=14,560, σ=3,090 $m^3\ day^{-1}$)	2009-2012	2013
City 2 (μ=887, σ=311 $m^3\ day^{-1}$)	2012-2013 (15 months)	2014 (7 months)

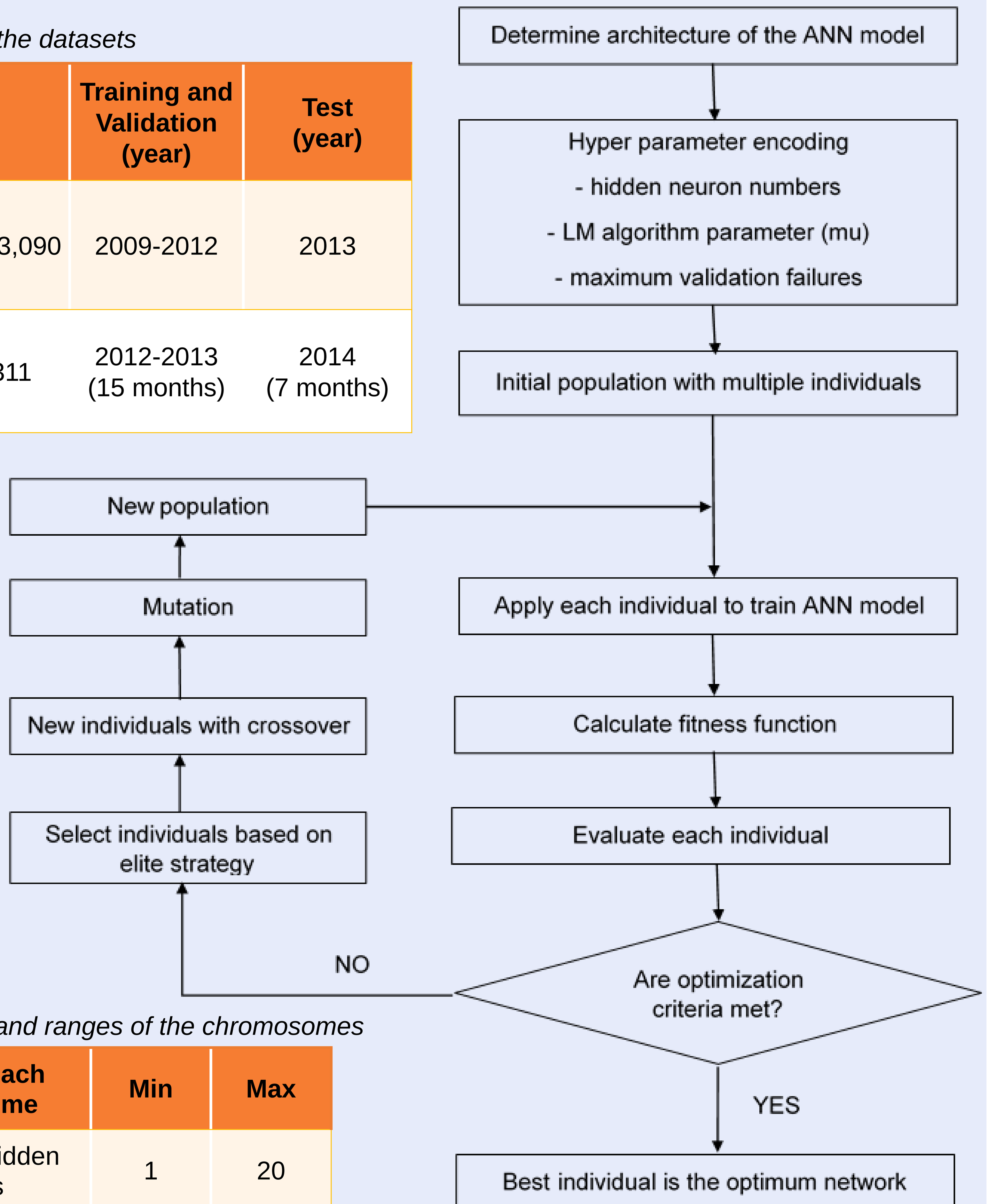

Figure 1. *Flowchart of ANN-GA model*

Table 2.
Genes values and ranges of the chromosomes

Genes of each chromosome	Min	Max
Number of hidden neurons	1	20
Levenberg-Marquardt parameter, mu	0	1
Maximum validation failures	1	20

Results

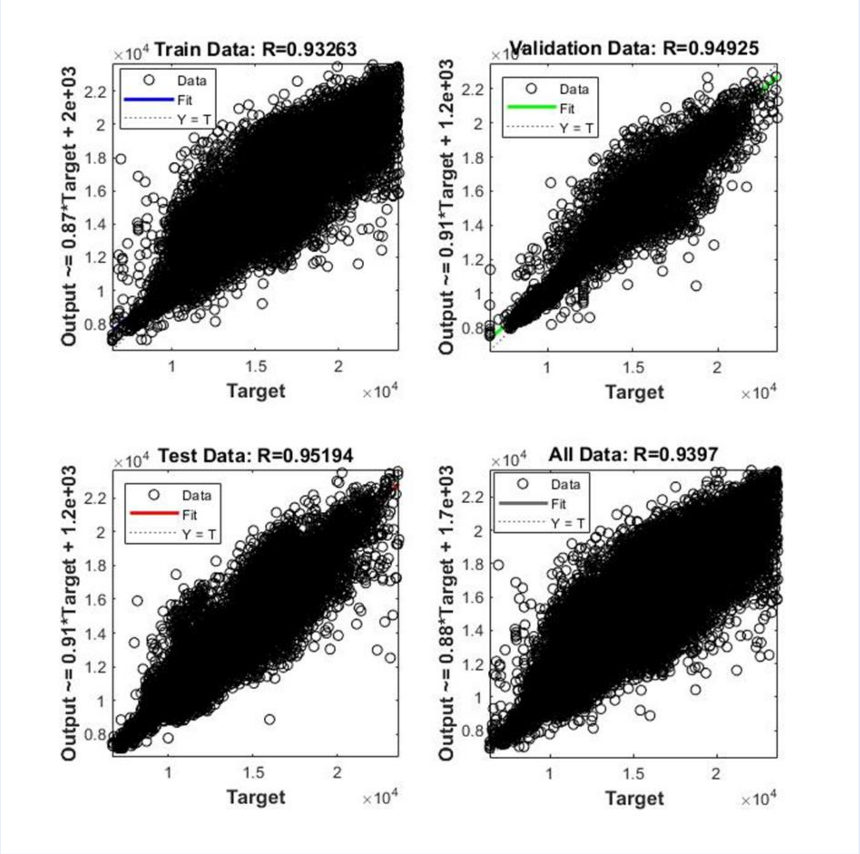

Figure 2. *Single-ANNs model performance result City 1 (m^3/day)*

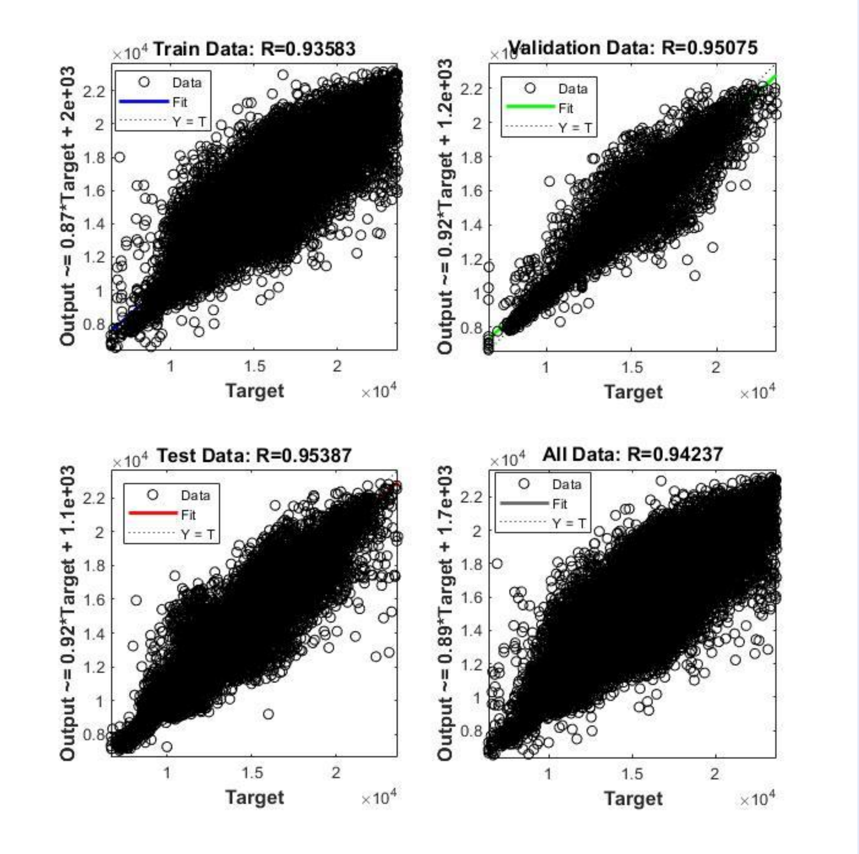

Figure 3. *ANN-GA model performance result City 1 (m^3/day)*

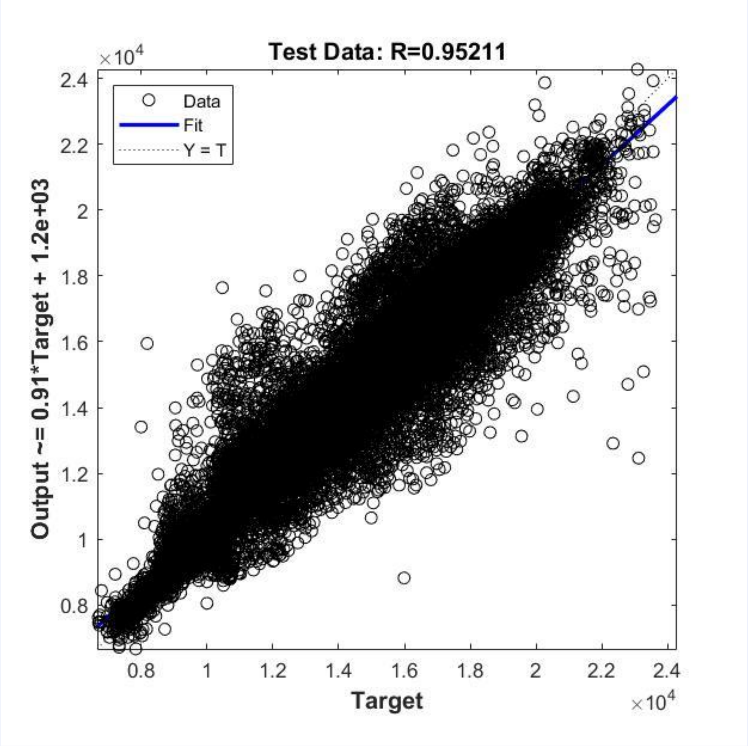

Figure 4. *Multi-ANNs model performance result City 1 (m^3/day)*

Table 3.
Optimized hyper parameters by GA

Genes of each chromosome	Optimized Value City 1	Optimized Value City 2
Number of hidden neurons	18	16
Levenberg-Marquardt parameter, mu	0.4632	0.4307
Maximum validation failures	9	3

Table 4.
The performance of the models for the 15 min time step prediction

Indicator	Model	15min Prediction (City 1)	15min Prediction (City 2)
RRMSE (Relative Root Mean Square Error)	Multi-ANNs	6.4649	18.9971
	Single-ANNs	6.4766	17.7665
	ANN-GA	6.3501	16.2342
MAPE (Mean Absolute Percentage Error)	Multi-ANNs	4.2899	14.4939
	Single-ANNs	4.2836	14.1631
	ANN-GA	4.1520	13.2720
E (Nash-Sutcliffe Efficiency)	Multi-ANNs	0.9064	0.7673
	Single-ANNs	0.9061	0.7965
	ANN-GA	0.9097	0.8301

- ✓ The novel ANN-GA models are the most accurate prediction models for the short-term UWD forecast for both cities.
- ✓ Statistical indicators for City 1 are better than City 2. When the size of the area increases, the consumption increases as well, and its fluctuations are generally mitigated.

Conclusions

- ANN models can successfully achieve accurate UWD prediction for 15 min lead time.
- The novel ANN-GA approach introduced in this work can enhance the performance of the ANN model for the 15 min prediction.
- In both cases studied, the ANN-GA approach showed better performance than the other two ANNs models.

INRS Institut national de la recherche scientifique
Environnement Canada Environment Canada
FONCER TEDGIEER Technologies Environnementales de Décontamination et Gestion Intégrée des Eaux et Effluents Résiduaires
majid.gholami_shirkoohi@ete.inrs.ca