

Enhancing Flood Routing Simulation of Dam Safety Remote Monitoring System by Machine Learning Technique

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[ASEAN IVO : ASEAN ICT Virtual Organization]

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[NICT : National Institute of Information and Communications Technology]

Agenda

- Background
- Dam Safety Management and Water Governance System
 - Dam Safety Remote Monitoring System (DS-RMS)
 - Flood Routing Simulation
- Machine Learning Model for Inflow Forecasting
- Results
- Conclusion

Background



Large electricity generating dams maintained by EGAT.

- Electricity Generating Authority of Thailand (EGAT) has generating capacity 37% or 15,757 MW of total managed capacity as of 2018.
- Renewable energy, mostly from hydro power plants, is accounted for 19% of generating capacity or 2,999 MW.
- EGAT, NECTEC, and Kasetsart University collaborate on Dam Safety Remote Monitoring System (DS-RMS) project to enhance dam monitoring system and reassure down stream public of dam safety condition

Dam Safety Remote Monitoring System (DS-RMS)

Hardware component



RTU module installed in RTU box

Software component



DS-RMS system diagram.

DS-RMS Dataflow

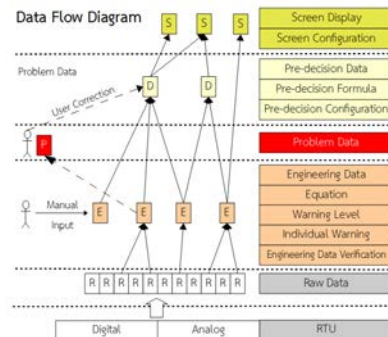
Data Collection



Remote Terminal Unit (RTU)

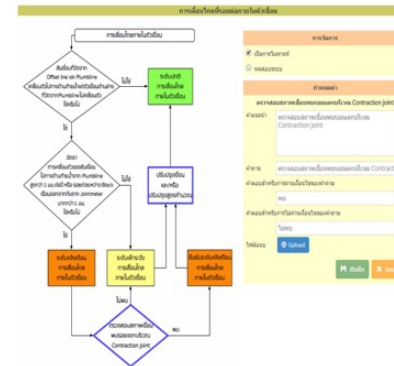
NECTEC RTUs which comply industry standards.

Data Processing



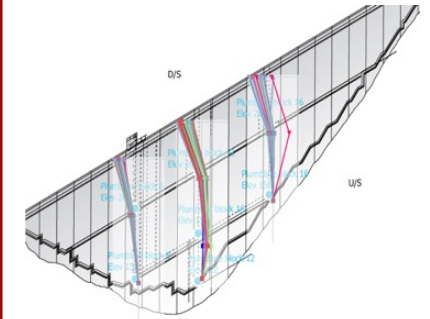
Automate data processing to save time.

Workflow Process



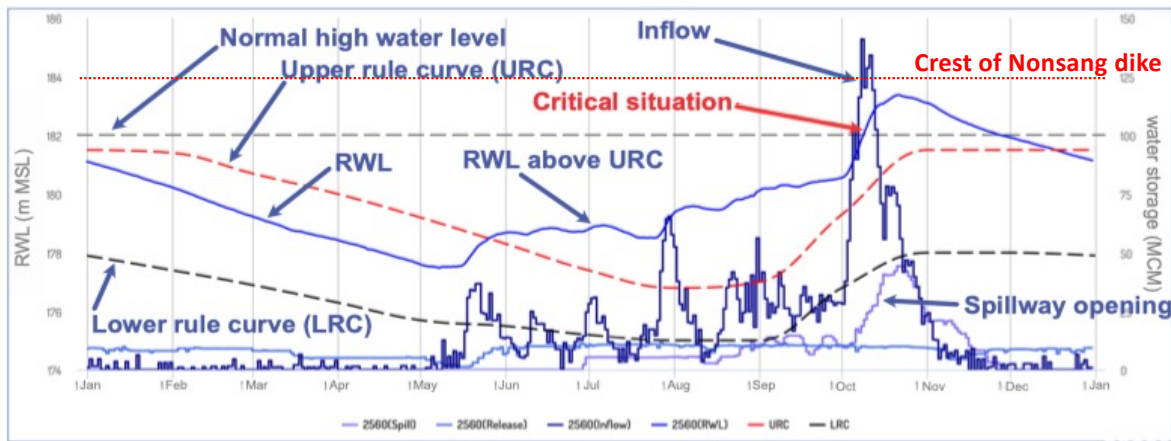
Expert System provides 24/7 monitoring, evaluation and warning.

Visualization



Multi-dimension data display eases dam safety analysis.

Flood Routing Simulation



Water situation at Ubol Ratana dam in 2017.

- In 2017, several storms arrived in the northeast region of Thailand.
- The spillway operation of **Ubol Ratana Dam** could not adhere to the rule curves because of the flood downstream
- A decision had to be made at that critical situation to balance the flood in the downstream and upstream areas and ensure the safety of the dam.

Flood Routing Simulation

OPENING THE GATE(S)

CONDITION I	CONDITION II	CONDITION III	ACTION	CASE
$RWL_i < 158.1$			$OPEN_i = 0$ with fully generation capacity	Case 1
$158.1 \leq RWL_i < 159.25$	$OPEN_{i-1} = 0$		$OPEN_i = 0.5$ with fully generation capacity	Case 2
	$OPEN_{i-1} > 0$	$RWL_i \leq RWL_{i-1}$	$OPEN_i = OPEN_{i-1}$ with fully generation capacity	Case 3
		$RWL_i > RWL_{i-1}$	$OPEN_i = OPEN_{i-1} + (RWL_i - RWL_{i-1}) * 7$ with fully generation capacity	Case 4
$RWL_i \geq 159.25$			$OPEN_i = \text{Fully open}$ with fully generation capacity	Case 5

CLOSING THE GATE(S)

CONDITION I	CONDITION II	ACTION	CASE
Fully open ($RWL_{max} \geq 159.25$)	$RWL_i > 158.1$	$OPEN_i = OPEN_{i-1}$ with fully generation capacity	Case 6
	$158 < RWL_i \leq 158.1$	$OPEN_i = 0.5$ $OPEN_i = OPEN_{i-1} + (RWL_i - RWL_{i-1}) * 5$ with fully generation capacity	Case 7
	$RWL_i \leq 158$	$OPEN_i = 0$	Case 8
Not Fully open ($RWL_{max} < 159.25$)	$RWL_i > 158$	$OPEN_i = OPEN_{i-1} + (RWL_i - RWL_{i-1}) * 5$ with fully generation capacity	Case 9
	$RWL_i \leq 158$	$OPEN_i = 0$	Case 10

RWL (Reservoir Water Level in mMSL)

OUT (Outflow in CMS)

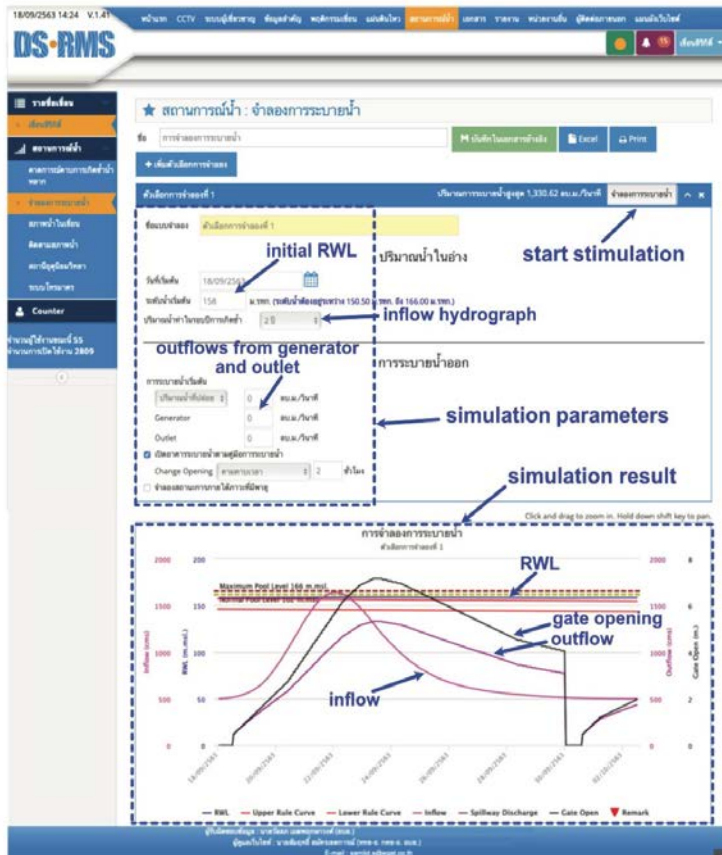
IN (Inflow in CMS)

Supscript _i is used for the parameter of present hour, and _{i-1} for of the previous hour

Spillway operation rules for the Sirikit Dam as described in manual.

- To finely manage the spillway operation, EGAT developed a **spillway operation manual** based on several situations.
- The manual is used as a guideline to control the spillway operation.
- In a real situation, other factors should be considered, such as weather forecast, current inflow, river capacity.
- A meeting with other stakeholders in National Water Resource Committee (NWRC) will be held to devise a plan.

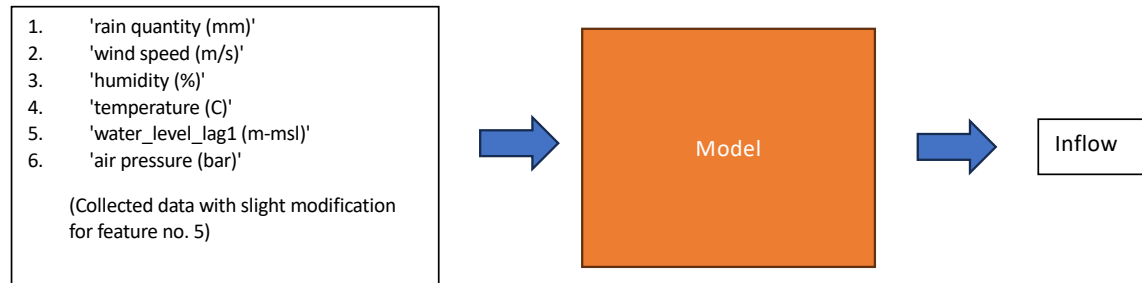
Flood Routing Simulation



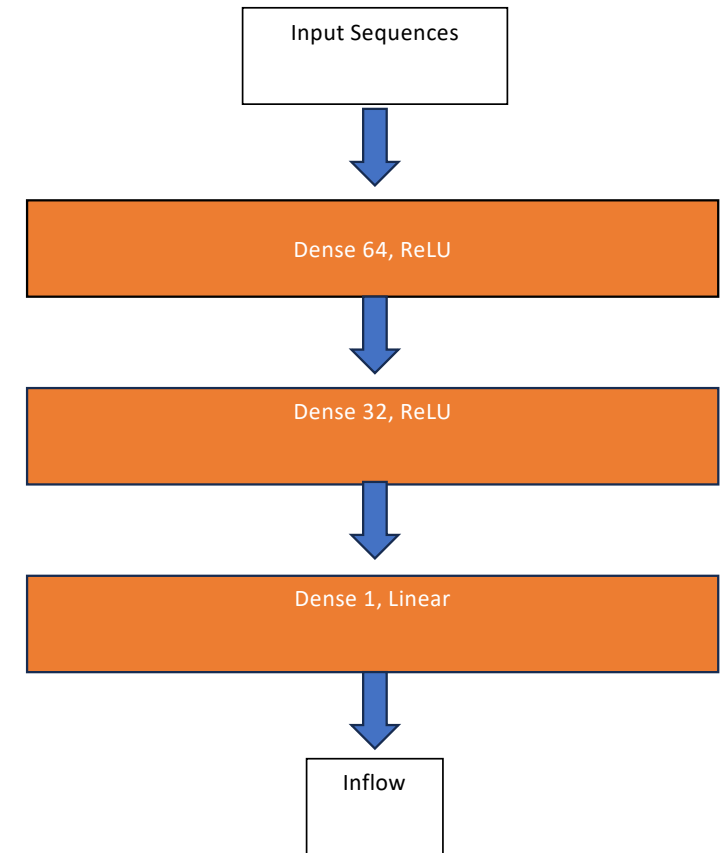
- Web-based reservoir flood simulation software uses simulation parameters to generate simulation result.
- Input simulation parameters include initial RWL, inflow hydrograph, outflows from generator and outlet.
- Simulation result includes RWL, outflow from spillway discharge, gate opening, and outflow.
- Simulated RWL is compared with the critical levels, such as maximum high water level, normal high water level to decide how to operate the actual spillway.

Reservoir flood routing simulation software in DS-RMS screen.

Machine Learning Model for Inflow Forecasting



- The model has three FCNN layers consisting of 64 units with ReLU activation function, 32 units with ReLU activation function, and 1 unit with linear activation function.
- Six environmental parameters were collected by RTUs from 2016 to 2024 (in total 3,000 daily samples) and used as inputs to the model.
- The dataset was split into 70% training data, 10% validation data, and 20% testing data. The number of epochs and batch size were initially set to 100 and 32.
- Huber loss is used for loss evaluation during the training phase. Huber loss combines Mean Squared Error (MSE) and Mean Absolute Error (MAE), making it less sensitive to outliers.



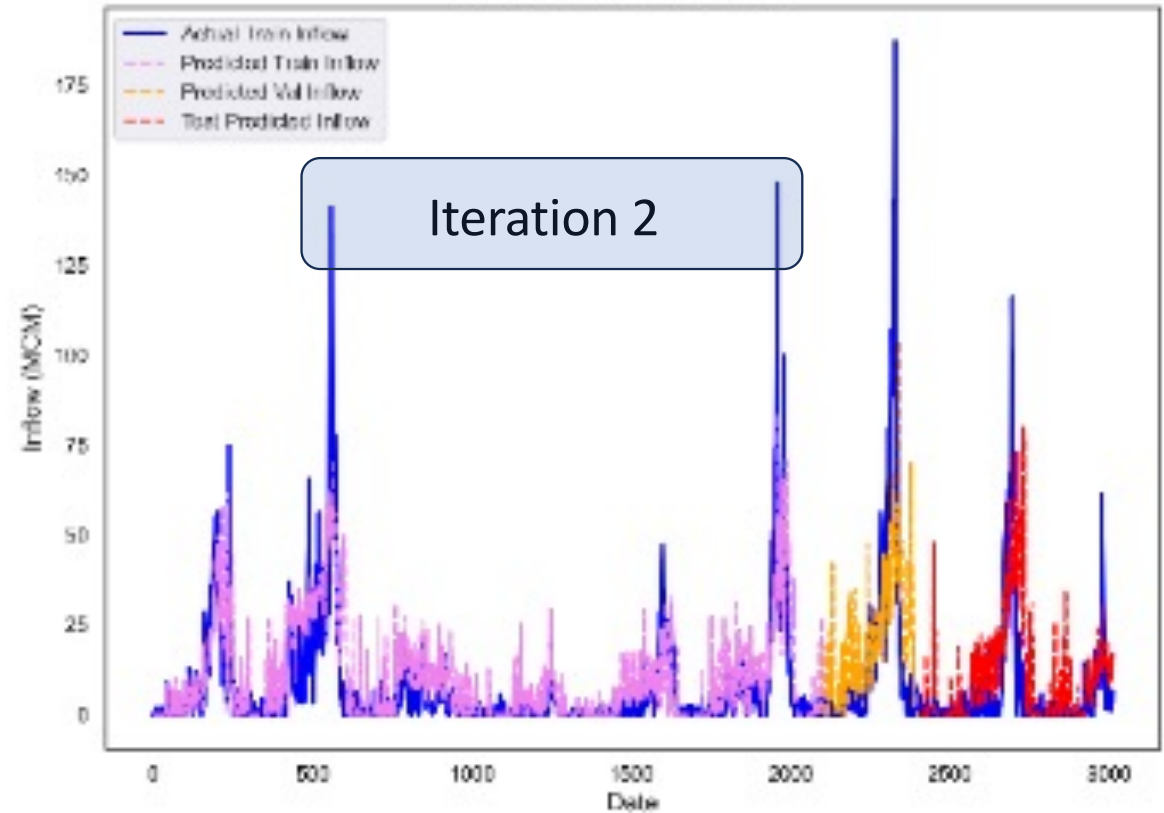
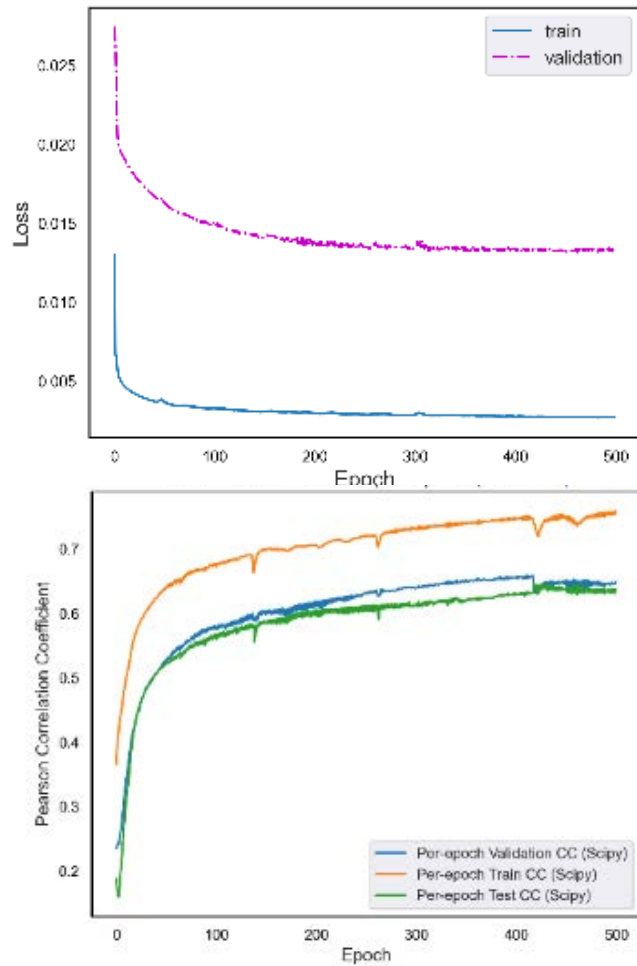
Simulation results

	Iteration 1	Iteration 2	Iteration 3
Training—RMSE	11.02	10.49	11.05
Training—Last CC	0.74995	0.76756	0.75172
Training—Best CC	0.75508	0.76756	0.75517
Validate—RMSE	23.39	23.62	23.23
Validate—Last CC	0.66386	0.65031	0.67160
Validate—Best CC	0.66790	0.67848	0.67272
Testing—RMSE	12.82	13.28	13.90
Testing—Last CC	0.64332	0.63293	0.60452
Testing—Best CC	0.81794	0.82921	0.70910

Table. 1 Evaluation comparison

Fully Connected Neural Network

Simulation results



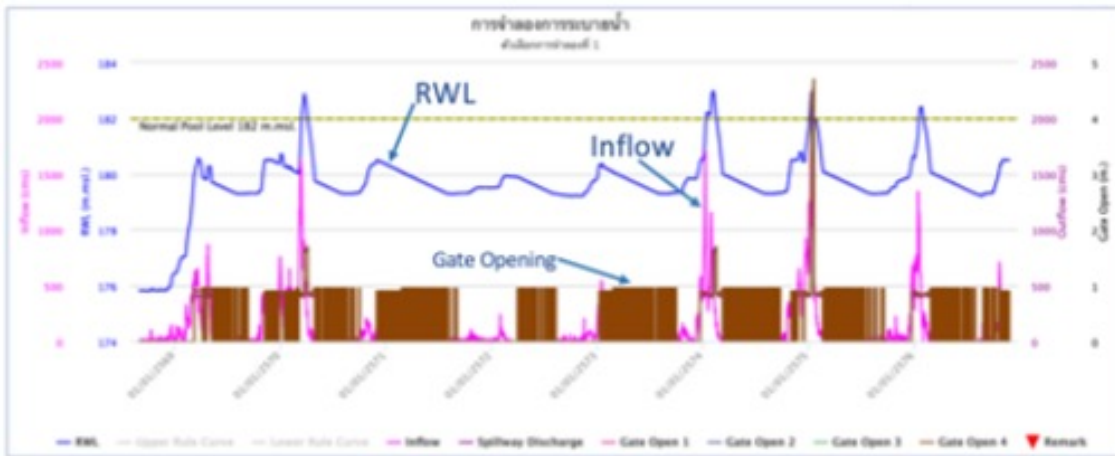
Actual inflow and forecasted inflow.

Loss and correlation coefficient at each epoch.

Simulation results

Integrated flood routing simulation

Flood simulation results from actual inflow.



Flood simulation results from predicted inflow.

Conclusion

- The necessity and implementation of a dam safety remote monitoring system—including flood routing simulation as a main module for balancing dam safety and water governance—have been described.
- The concept of integrating machine learning based inflow forecasting into the flood routing simulation to enhance its adaptability and timeliness has also been presented.
- Preliminary results show improved inflow forecasting performance and demonstrate the effectiveness of the proposed concept in managing reservoir water levels.
- Longer-term and more accurate inflow forecasting—such as by using regional data shared among ASEAN countries via the CyReal testbed—should be further investigated to enable better dam operations across the region..

Thank you for your attention

Q & A

