Evaluating Multi-Global Server Architecture for Federated Learning

Asfia Kawnine
Msc Student
Analytics Everywhere Lab
University Of New
Brunswick, Canada

Dr Hung Cao
Assistant Professor
Lab Director
Analytics Everywhere Lab
University Of New
Brunswick, Canada

Atah Nuh Mih
Msc Student
Analytics Everywhere Lab
University Of New
Brunswick, Canada

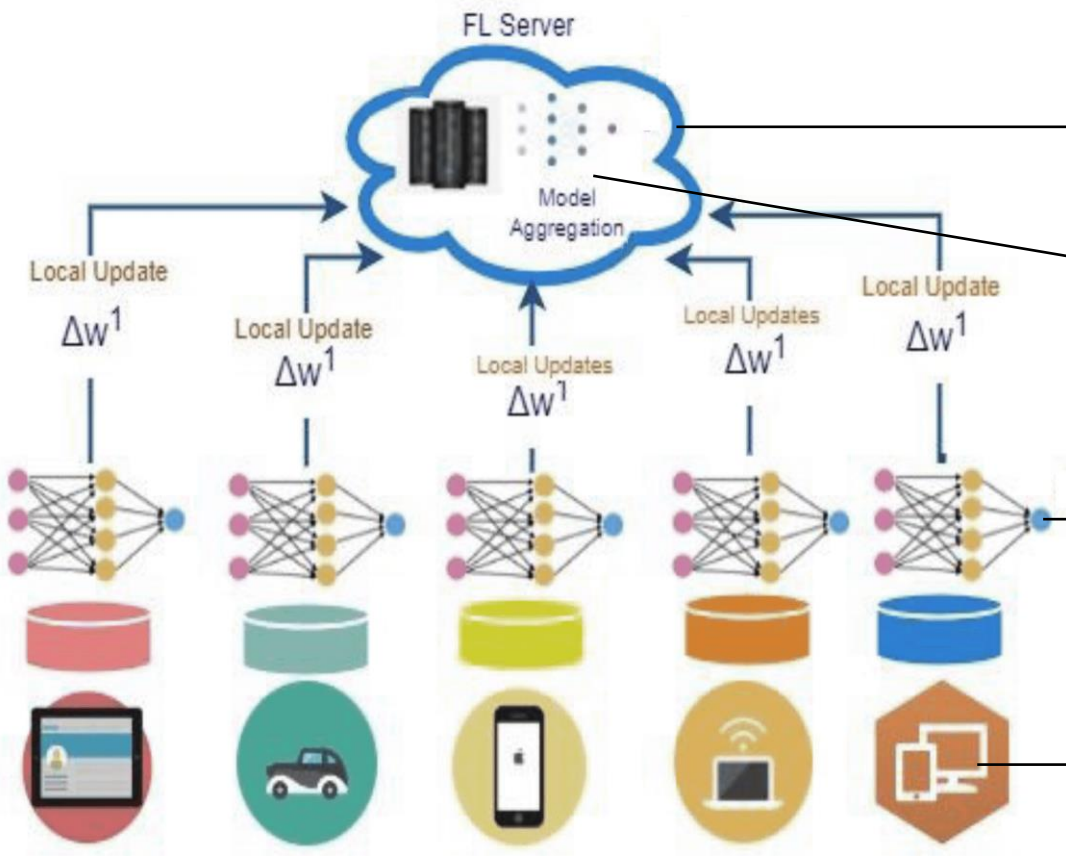
Dr Monica Wachowicz
Adjunct Professor
Associate Dean
Geospatial Science
RMIT University, Australia

Index

- Introduction
- Problem Statement
- Research Hypothesis
- Research Objectives
- Related Works
- Background
- Proposed Methodology
- Dataset Processing
- Experiment
- Results
- Conclusion

Introduction

Federated Learning (FL)



Global Server / Central Server

Aggregating Model

Local Training Model

Local Device / Client Device

Problem Statement

Existing Works

Privacy

Communication efficiency

Heterogeneity

Cost minimization

Architecture

Only one central server

Fault tolerance

Communication issue may cause the system to collapse

Research Hypothesis

Implementing multiple global servers in federated learning

- Can improve training efficiency by exploiting local collaborations and aggregating knowledge.
- Would handle fault tolerance.

Research Objectives

The primary objectives of this research are to:

1) Design a federated learning framework with multiple global server,
2) Evaluate the performance on multiple global server,
3) Ensure communication between the multi-global server and client devices if any challenge occurs.

Related Works

PERFORMANCE

EFFICIENCY

SCALABILITY

PRIVACY

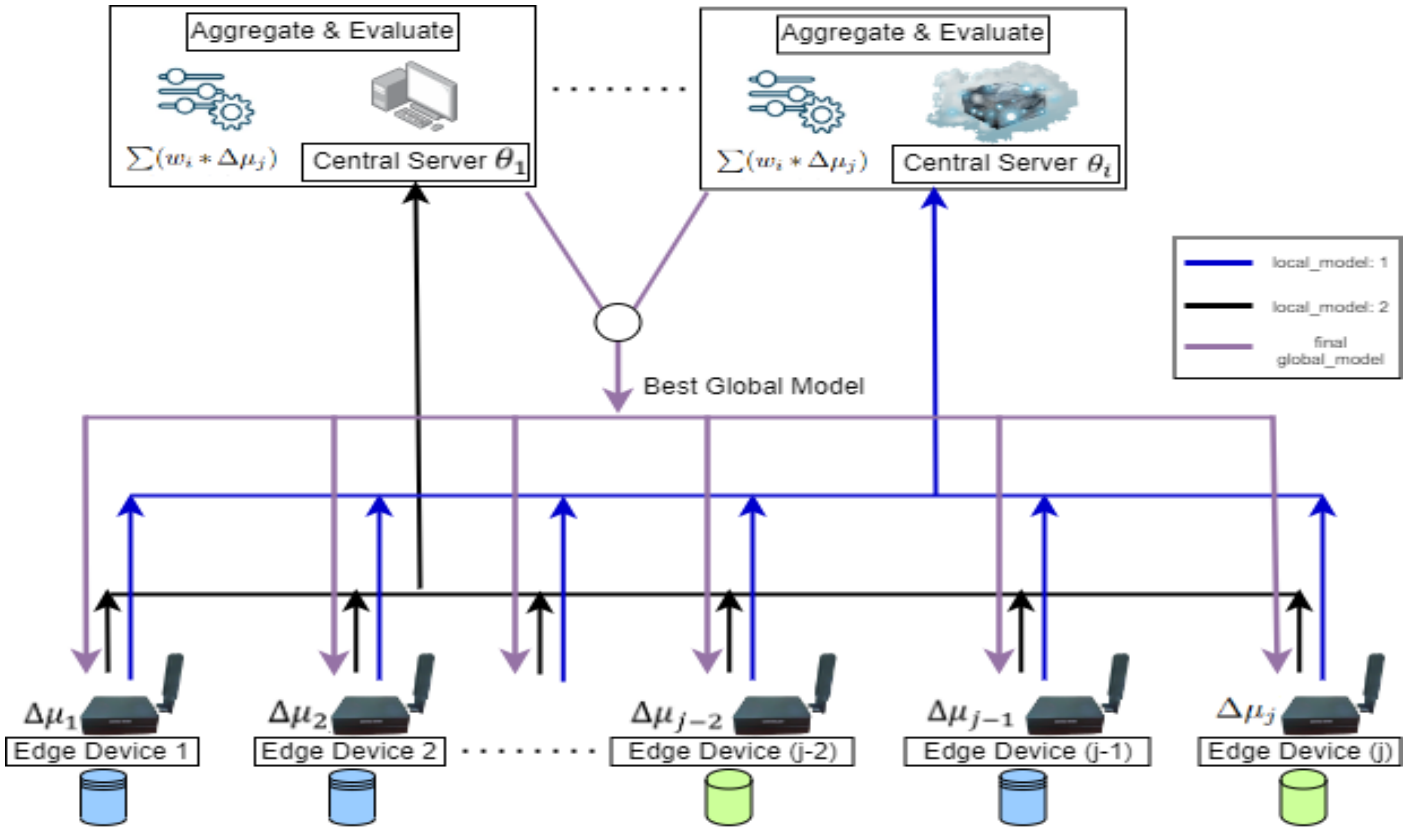
Related Works

- Federated Learning (FL)
  - Decentralized privacy pre-serving approach, introduced by Google (B. McMahan et al 2017)
  - Combination of distributed learning and ensemble learning (S. Niknam et al 2020)
  - Predict how much energy is consumed by households as well as how much solar production is possible (M. Bharadwaj et al 2023)
- Edge Computing and FL
  - Edge devices with limited computational resources can perform FL models (A. Brecko et al 2022)
  - Application: industry, healthcare, finance, transport etc (A. Brecko et al 2022)
  - Smart city sensing is another emerging paradigm where FL and edge computing have great potential. (J. C. Jiang et al 2020)

Background - Aggregation Model

	Mechanism	Advantages	Limitations
FedAvg	Averaging of local model updates from all participating nodes	Simple and easy to implement	Convergence may be slow due to communication bottleneck
FedAvgM	Averaging of local model updates with momentum	Faster convergence than FedAvg	Requires additional hyper-parameters to be tuned
FedAdaGrad	Averaging of local model updates with adaptive learning rate	Fast convergence and can handle non-i.i.d data	Requires additional hyper-parameters to be tuned
FedYogi	Averaging of local model updates with adaptive learning rate	Handles non i.i.d data and noisy gradients well	Requires additional hyper-parameters to be tuned
FedAdam	Averaging of local model updates with adaptive learning rate	Fast convergence, handles non-i.i.d data, and noisy gradients	Requires additional hyper-parameters to be tuned

Proposed Methodology



Multi-Global Server Equation

$$\theta_i(t+1) = \theta_i(t) + \eta * \sum(w_i * \Delta\mu_j)$$

- θ_i represents global model
- $\theta_i(t+1)$ represents the updated global model parameters at time step $(t+1)$
- $\theta_i(t)$ represents the current global model parameters at time step t
- η is the learning rate
- $\sum(\omega_i * \Delta\mu_{j-1})$ represents the weighted sum of the local model parameter updates from different clients
- ω_i represents the weight assigned to the local model update $\Delta\mu_j$ from client i

Dataset - NB Power Stations

EV RECHARGE EVENTS DATA

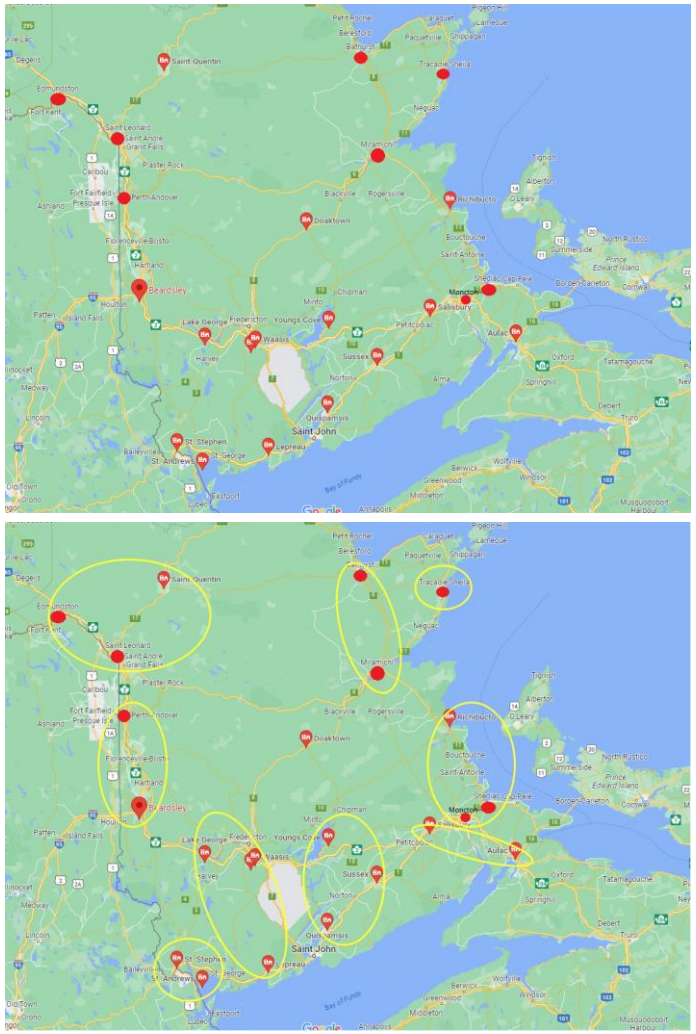
#	Column Name	Non-Null Count	Dtype	Examples
0	Connection ID	11273 non-null	string	ab453504-a3b9-4c99-b238-e7ba374aa2f8
1	Recharge Start Time (local)	11273 non-null	datetime	01/01/2020 11:05
2	Recharge End Time (local)	11273 non-null	datetime	01/01/2020 11:12
3	Account Name	4423 non-null	string	=””
4	Card Identifier	11273 non-null	string	MA01091995436141
5	Recharge duration (hours:minutes)	11273 non-null	datetime	0:06
6	Connector used	11273 non-null	string	J1772
7	Start State of charge (%)	11273 non-null	int	4
8	End State of charge (%)	11273 non-null	int	80
9	End reason	11273 non-null	string	The charging cable was disconnected and put back in the station.
10	Total Amount	11273 non-null	float64	0
11	Currency	0 non-null	float64	
12	Total kWh	11273 non-null	float64	0.77
13	Station	11273 non-null	string	NBA-10008

Dataset - NB Power Stations

EV STATION DETAILS

#	Column Name	Description	Examples
0	Location #	Number indicating station	1
1	Business Location	Short description of business location(e.g city or business name)	Fredericton City Hall
2	Civic Address	The combination of the building number, street name and jurisdiction.	397 Queen St, Fredericton
3	Station Name (separated by Type)	Unique identifier for a charging station	NBA-017 (L2 Station Name)
4	Rate (depending on Type)	Rate per hour for a charging station	1.50/hr
5	GPS Coordinate	Latitude and longitude coordinates of the charging station	45.964141, -66.643130

Dataset - NB Power Stations



- Electrical vehicle (EV) charging events
- Provided by New Brunswick Power Consumption (NB power)
- Contains data from April’19 to June’22

Divided Dataset

Region #	GPS Coordinate	Civic Address
region 1	45.432545, -65.948853	10 Millenium Drive, Quispamsis
	45.723961, -65.526621	201 Main Street, Sussex
	45.9421, -65.831729	10995 Route 10, Youngs Cove
region 2	45.961592, -66.641214	515 King Street, Fredericton
	45.960819, -66.640818	527 King Street, Fredericton
	45.8737, -66.985629	10 Route 635, Lake George
	45.850848, -66.559695	415 Nevers road, Wasis
	45.964141, -66.643130	397 Queen St, Fredericton
	45.172806, -66.464655	7386 Lepreau Village Road, Lepreau
	46.553778, -66.136245	330 Main St., Doaktown
region 3	45.193045, -67.274172	22 Budd Avenue, St. Stephen
	45.081051, -67.058281	24 Reed Street, St. Andrews
region 4	46.131507, -64.743761	275 Macnaughton Ave, Moncton
	46.089925, -64.775189	655 Main St, Moncton
	46.219248, -64.541482	375 Main Street, Shediac
	46.133497, -64.885698	2731 Mountain Road, Moncton
	46.667904, -64.867476	12 Park Drive, Richibucto
region 5	46.051234, -65.062978	2986 Fredericton Road, Salisbury
	45.870585, -64.280992	170 Aulac Road, Aulac
region 6	46.122299, -67.604917	198 Beardsley road, Beardsley
	46.746792, -67.713445	16 F Tribe road, Perth-Andover
region 7	47.524957, -64.911784	3323 de la Rive, Tracadie-Sheila
region 8	47.03071, -65.493625	2433 King George Highway, Miramichi
	47.638942, -65.704406	1450 Vanier Blvd, Bathurst
region 9	47.077067, -67.767413	121 Route 255, St Andre
	47.373115, -68.302961	100 Grey Rock Road, Edmundston
	45.7591, -66.766400	224 Rue Canada, Saint Quentin

Sample Dataset

- Renamed and converted to lowercase
- Converted all the time-date columns to same format
- Removed irreverent symbols (=“”) for the values
- Dropped the personal information, null columns and unrelated columns
- Energy consumption to 3 levels:
  - 0 – low
  - 1 – average
  - 2 – high

	connector_used	duration_min	day_of_week	period	station	gps_lat	gps_long	energy_consumption
15	SAE	21	Saturday	Morning	NBC-10023	45.081051	-67.058281	0
35	SAE	67	Sunday	Morning	NBC-10020	45.193045	-67.274172	1
189	SAE	62	Wednesday	Evening	NBC-10020	45.193045	-67.274172	1
443	CHAdeMO	155	Thursday	Morning	NBC-10020	45.193045	-67.274172	2
586	SAE	16	Saturday	Noon	NBC-10020	45.193045	-67.274172	0
...	...	...	...	...	...	...	...	...
11130	SAE	37	Tuesday	Noon	NBC-10009	46.122299	-67.604917	0
11183	SAE	29	Thursday	Evening	NBC-10009	46.122299	-67.604917	0
11185	SAE	34	Thursday	Evening	NBC-10010	46.746792	-67.713445	0
11194	SAE	0	Friday	Morning	NBC-10009	46.122299	-67.604917	0
11195	J1772	36	Friday	Morning	NBA-10002	46.122299	-67.604917	0

Experiment

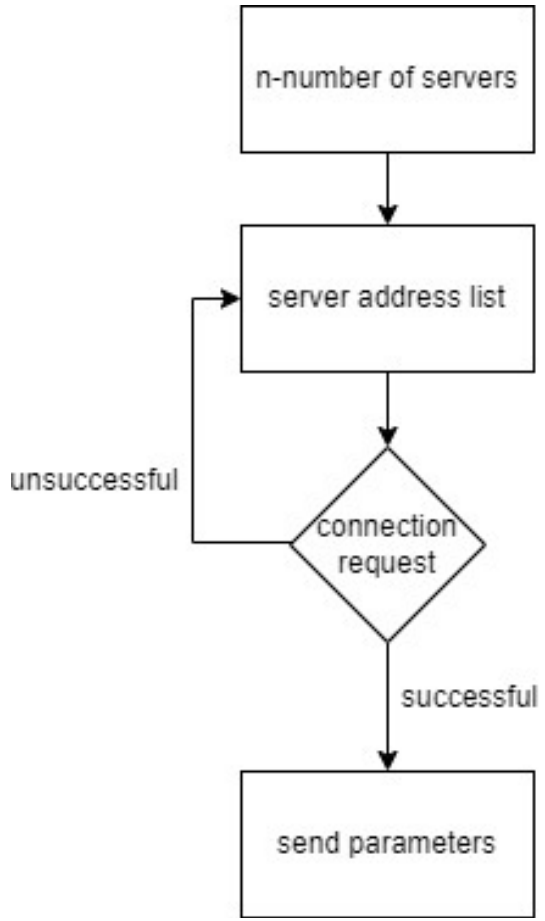
- Global servers: ubuntu cloud server, Intel(R) Core(TM) i7-4790 CPU
- Local/client devices: reComputer-Edge AI Devices
- TabNet:
  - Designed for tabular data
  - A deep tabular data learning architecture that uses sequential attention to choose which features to reason from at each decision step.
- Federated Average (FedAvg)
  - Aggregate the local parameters
  - Weight averaging technique depending on size of dataset

Experiment

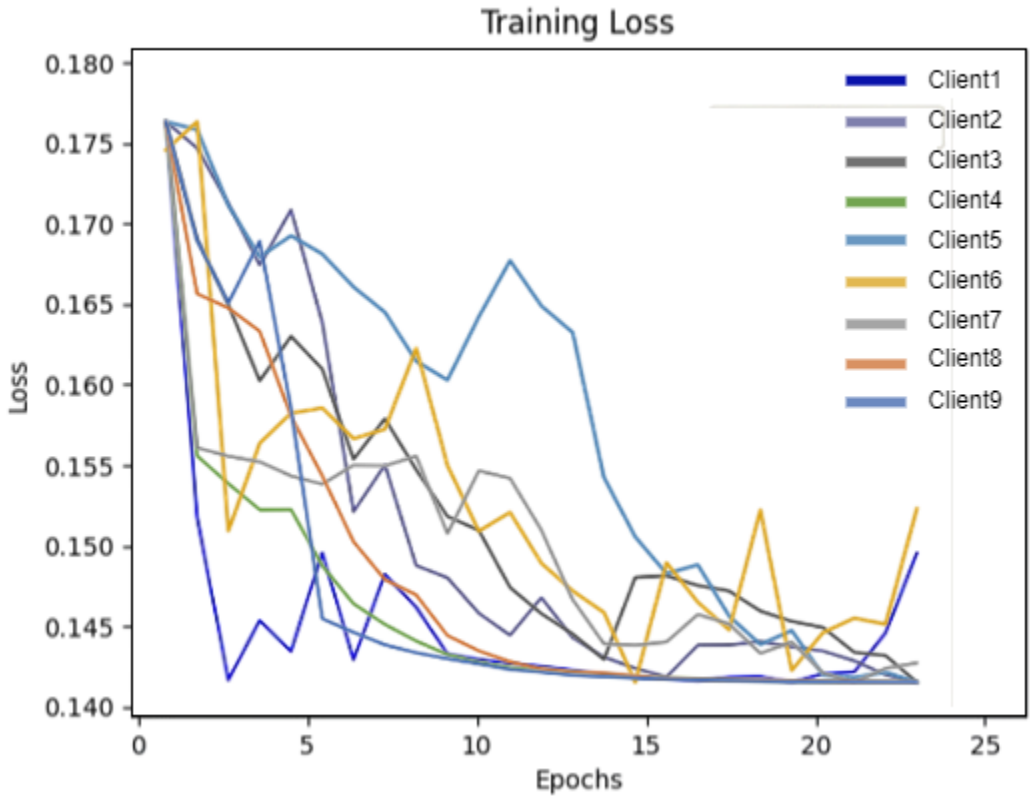
Algorithm 1 Connect to Global Server

Input: List of server addresses S[1..n], Number of servers n
Output: Connection Status

```
Initialize connectionEstablished = False
Initialize selectedServer = None
for i from 1 to n do
    try
        Connect to S[i]
        Set connectionEstablished to True
        Set selectedServer to S[i]
        Break
    catch connectionFailed
        Continue to the next server
    end try
    if connectionEstablished is True then
        Send local parameters to selectedServer
    else
        Print "Failed to connect to all servers."
    end if
end for
```

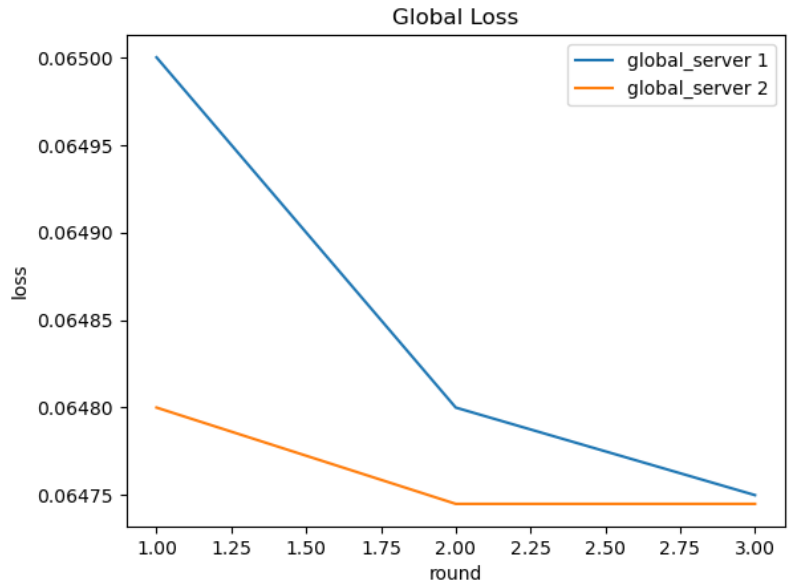


Result – Training Loss (Local)



Result

- Servers:
  - global_server1: corei7
  - global_server2: cloud
- Evaluation Function:
  - While aggregating observe loss reduction
  - Not region specific
- The difference between two server is diminutive
- The aggregating time differs but uncertain



Conclusion

Applications

- Development challenges
- Error tolerant issue

Performance

- Minor difference

Conclusion

Future Work

Evaluate:

- Computational speed
- Handling redundant dataset etc.

Introducing a decision device to evaluate and select global device

Experiment on different dataset


Thank you

ANALYTICS EVERYWHERE LAB

Dr Hung Cao
Assistant Professor
Lab Director
Analytics Everywhere Lab
University Of New
Brunswick, Canada
hcao3@unb.ca

Dr Francis Palma
Assistant Professor
Faculty of Computer Science
University Of New
Brunswick, Canada

Dr Monica Wachowicz
Adjunct Professor
Associate Dean
Geospatial Science
RMIT University, Australia

Dr Trevor Hanson
Professor
Faculty of Civil Engineering
University Of New
Brunswick, Canada

Asfia Kawnine
MSc Student

Atah Nuh Mih
MSc Student

Alireza Rahimi
MSc Student

Simran Dadhich
MSc Student

Arman Nik Khah
MSc Student

Connor Kenneth
McLenaghan
Undergrad Student

...