CSC 2228 Project: Evaluating Methods to Automate Hyperparameter Tuning in Federated Learning

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Agenda

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Motivation, Problem & Solution

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Motivation

01 Rise of Edge Devices

02 Need for ML Solutions for Edge

03 Limited Opportunity for Hyper Parameter Tuning on Edge

Problem

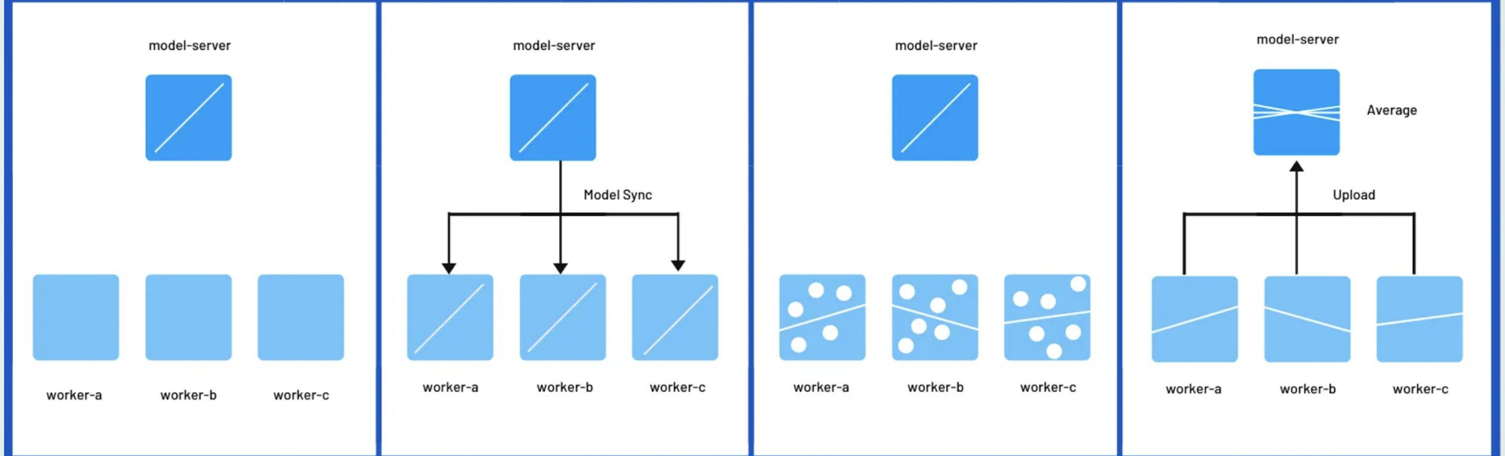
Opportunity for hyperparameter tuning in federated learning is constrained due to the limited number of communication rounds

Solution

Automate hyperparameter tuning! **But how to automate?** We evaluate three strategies for automating or adaptively adjusting hyperparameter tuning for federated learning.

Overview of FL and Client vs Server Optimizers

Step 1	Step 2	Step 3	Step 4
Central server chooses a statistical model to be trained	Central server transmits the initial model to several nodes	Nodes train the model locally with their own data	Central server pools model results and generates one global model without accessing any data



Client Optimizer with it's own Learning Rate

Server Optimizer with it's own Learning Rate

Implementation - Experiments

01

Experiment 1

FedAvg (Server) + SGD (Client) + 3 Client Learning Rate Schedulers

02

Experiment 2

FedAvg (Server) + 1 non adaptive and 3 adaptive client optimizers

03

Experiment 3

FedAvg (Server)+ SGD or Adam (Client) + 3 server learning rate optimizers

Experiment Setup

Model
Simple CNN model
with 3 layers

Datasets
MNIST, FMNIST

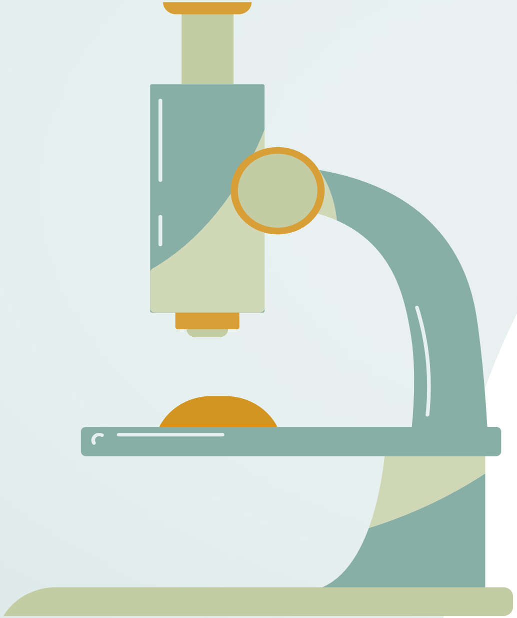
Data Distribution
non-IID

Epochs
30 communication
rounds

Learning Rates
Server Learning Rate = 1
Client Learning Rate =
0.01

Client
100 clients
10 epochs of local training
for each round

Experiment 1
Learning Rate Scheduler



Compare three learning rate schedulers:

- StepLR
  - Reduce the learning rate for some rate every certain epoches
- ReduceLROnPlateau
  - Reduce learning rate when a metric has stopped improving
- CosineAnnealingLR
  - Reduce learning rate every epoches
  - Learning rate is raised back up after a fix number of epochs

Experiment 1 Results

TABLE I. EXPERIMENT 1 RESULTS

Dataset	Experiment 1 Results		
	FL Model Configuration	***Test Accuracy***	***Runtime***
MNIST	FedAvg + SGD + StepLR	88.24%	1035.82s
MNIST	FedAvg + SGD + PlateauLR	88.13%	2549.55s
MNIST	FedAvg + SGD + CosineLR	92.76%	2831.43s
FMNIST	FedAvg + SGD + StepLR	91.85%	2120.20s
FMNIST	FedAvg + SGD + PlateauLR	94.83%	5949.94s
FMNIST	FedAvg + SGD + CosineLR	84.78%	33652.85

Experiment 2: adaptive client optimizer

To further improve local update, adaptive optimizers are introduced on the client's side. Compared with SGD, **adaptive optimizers enable dynamic adaptation based on gradients** instead of predetermined rule.We implemented **(1) Adam**, **(2) Adagrad** and **(3) Adadelta** optimizers as local solvers.

Experiment 2 Results

TABLE II. EXPERIMENT 2 RESULTS

Dataset	Experiment 2 Results		
	FL Model Configuration	***Test Accuracy***	***Runtime***
MNIST	FedAvg + SGD	93.16%	1021.14s
MNIST	FedAvg + Adam	86.23%	1103.74s
MNIST	FedAvg + Adadelta	87.63%	1119.67s
MNIST	FedAvg + Adagrad	78.50%	1068.44s
FMNIST	FedAvg + SGD	94.70%	2184.44s
FMNIST	FedAvg + Adam	88.53%	2373.64s
FMNIST	FedAvg + Adadelta	93.42%	2509.33s
FMNIST	FedAvg + Adagrad	39.02%	2339.49s

Experiment 3: Adaptive server aggregation

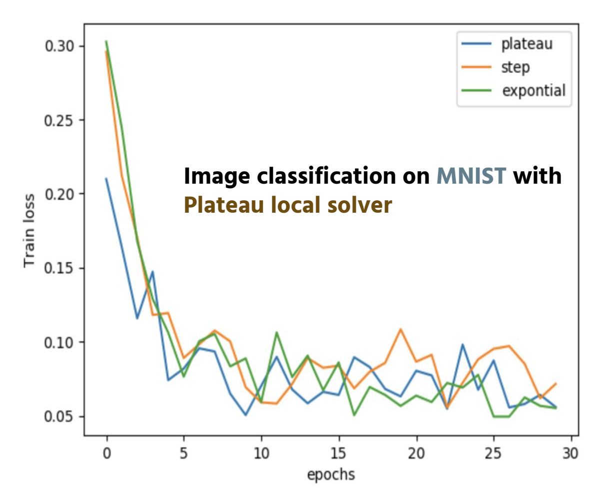
Pseudo-gradient & SGD

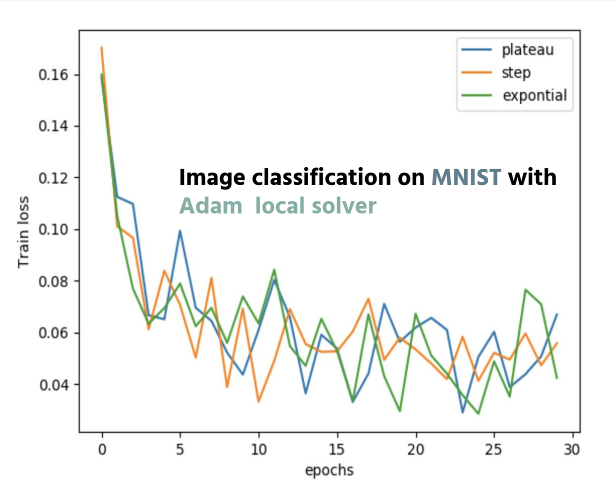
$$x_{t+1} = \frac{1}{|\mathcal{S}|}\sum_{i\in\mathcal{S}} x_i^t = x_t - \frac{1}{|\mathcal{S}|}\sum_{i\in\mathcal{S}} (x_t - x_i^t)$$

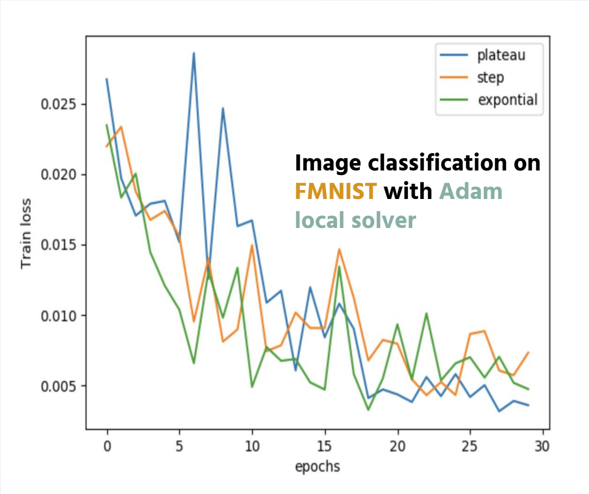
Adaptive global solver

In FedAvg, a vanilla averaging is applied when computing the global model and can be viewed as a pseudo-SGD optimizer. Similarly, to improve the performance, global learning rate decay is expected in the server aggregation step. Particularly, we implemented three global learning rate schedulers: linear decay schedulers, exponential decay scheduler, and loss-based scheduler.

Experiment 3 Results







Results - Key Takeaways

Learning Rate Schedulers

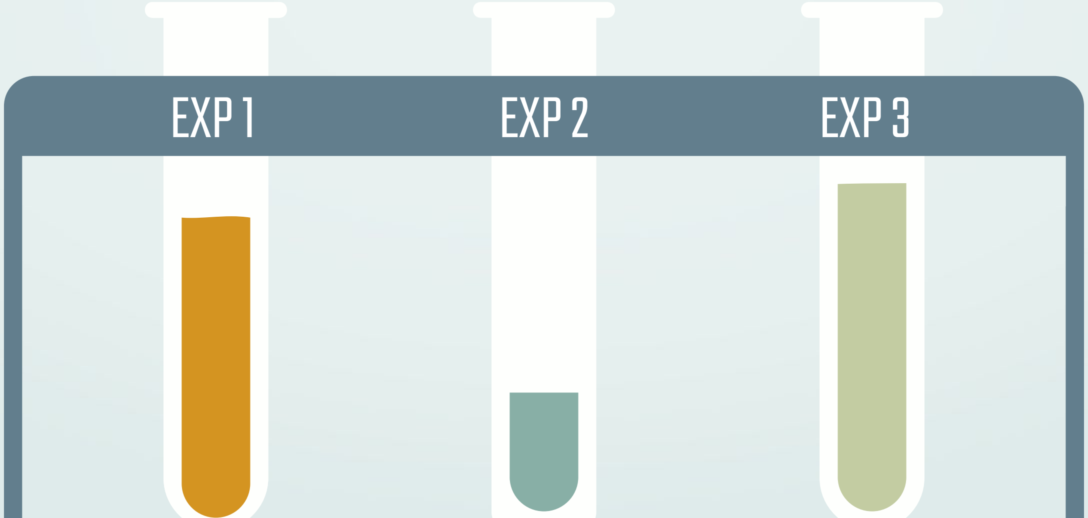
Enable learning rate decay on the client side.

Adaptive Local Solver

Incorporating adaptive optimizers on client side.

Adaptive Server Aggregation

Enable learning rate decay on the server side.



Discussion

1) In federated learning for edge devices, do you think it's more important to tune or optimize the client vs server learning rate and why?
2) Would the increased privacy of federated learning make you more comfortable using ML products on edge devices (eg. smartphone, smart speaker?)

Thanks!

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IN DEPTH

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02

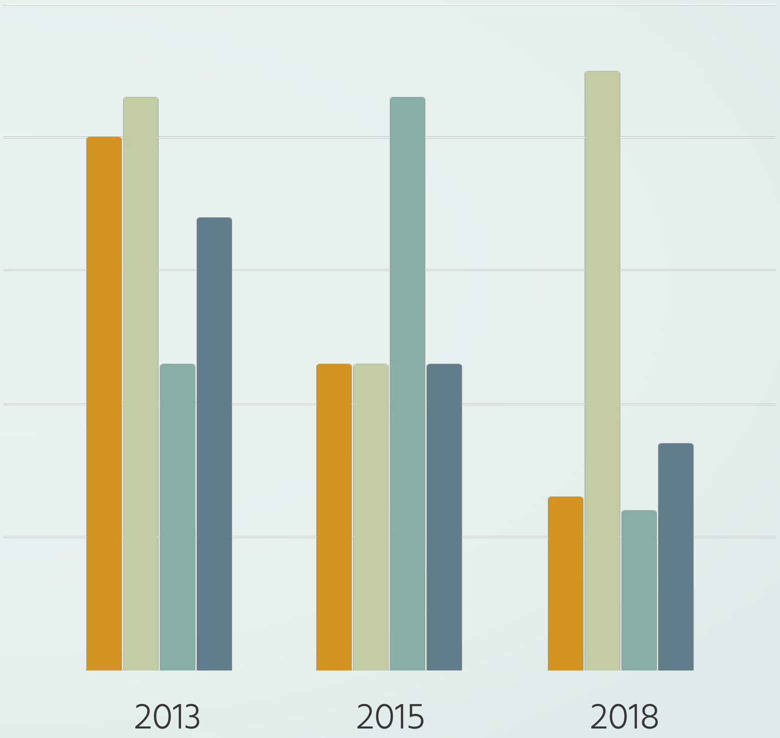
IN DEPTH

MERCURY
Mercury is the closest planet to the Sun

MARS
Despite being red, Mars is actually a cold place

VENUS
Venus has a beautiful name, but it's terribly hot

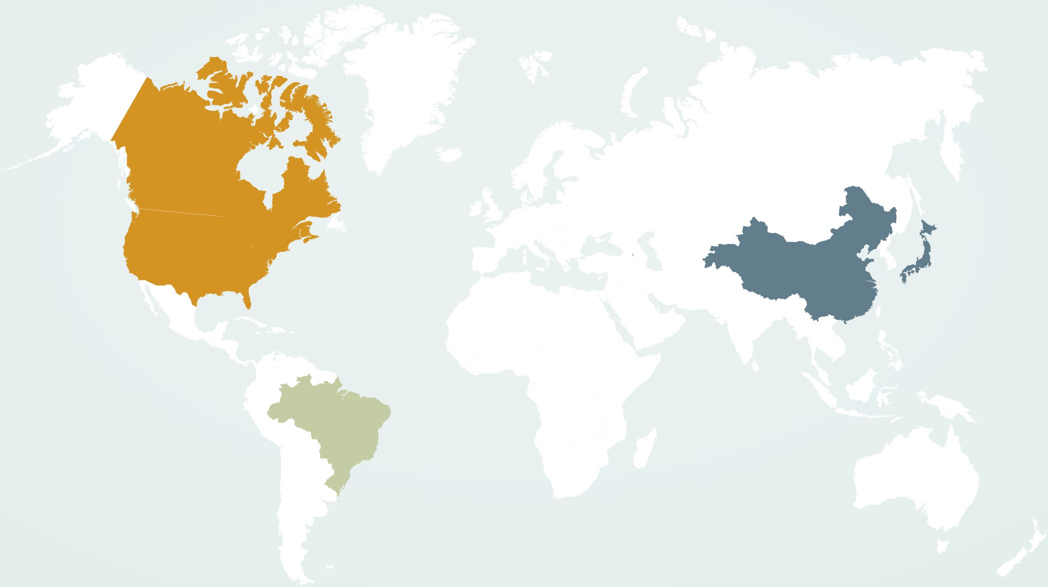
NEPTUNE
Neptune is the farthest planet from the Sun



OUR NUMBERS

	MASS (EARTHS)	GRAVITY (EARTHS)	DIAMETER (EARTHS)
MARS	100	355	370
MERCURY	490	150	890
VENUS	1,000	260	245

OUR LOCATIONS



MARS

Despite being red, Mars is a cold place

SATURN

Saturn is the ringed planet and a gas giant

MERCURY

Mercury is the closest planet to the Sun

04

WELCOME

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WELCOME

JULIA LARA

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HELENA PATTERSON

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05

EVENTS

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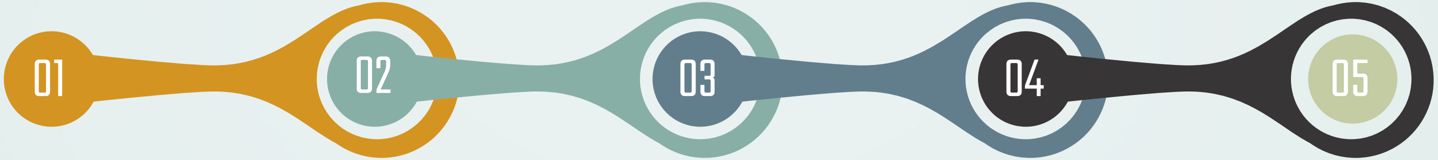
REVIEW OF PAST EVENTS



JUPITER

It’s the biggest planet of them all

SATURN

Saturn is the ringed one and a gas giant

MERCURY

Mercury is the closest planet to the Sun

NEPTUNE

It’s the farthest planet from the Sun

VENUS

It’s the second planet from the Sun

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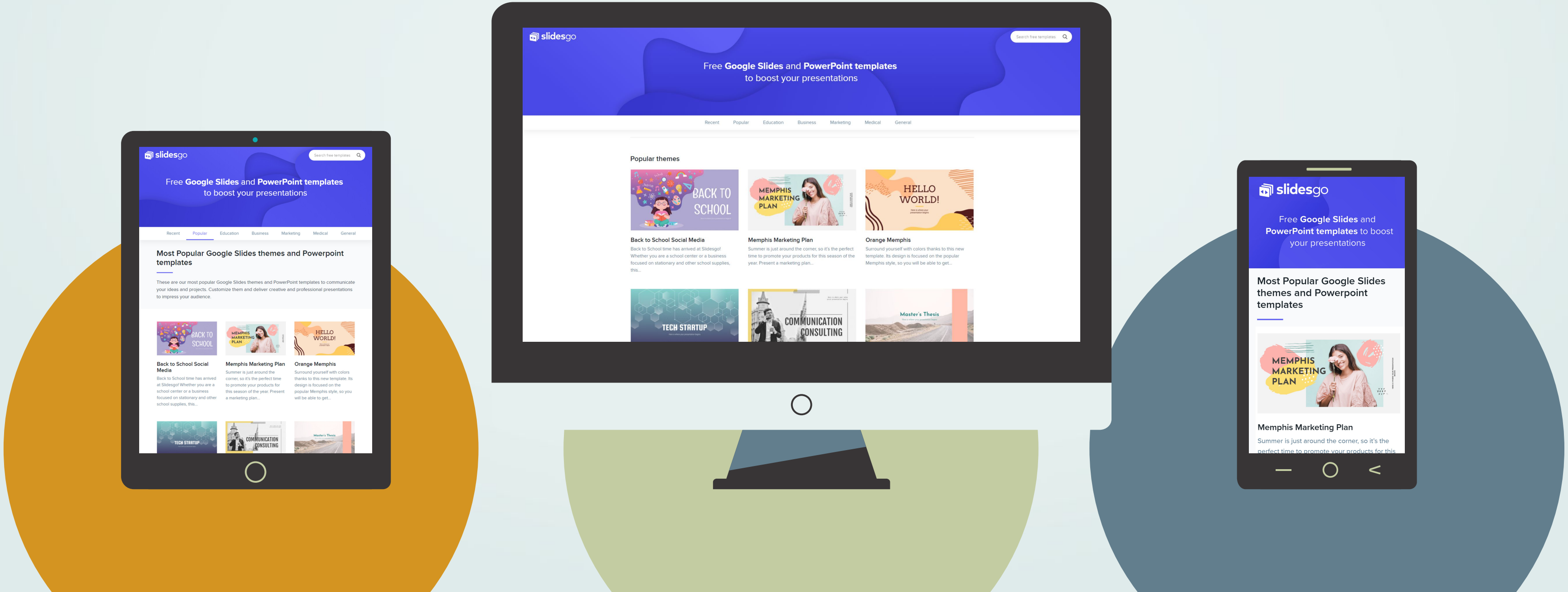

THANKS

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- Flat chemistry background II

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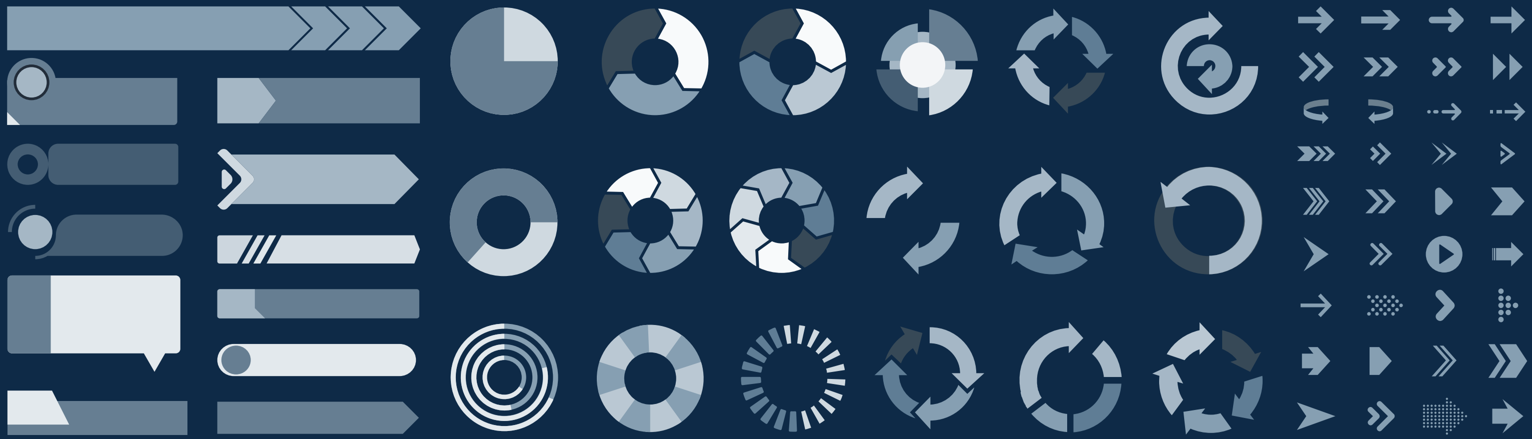







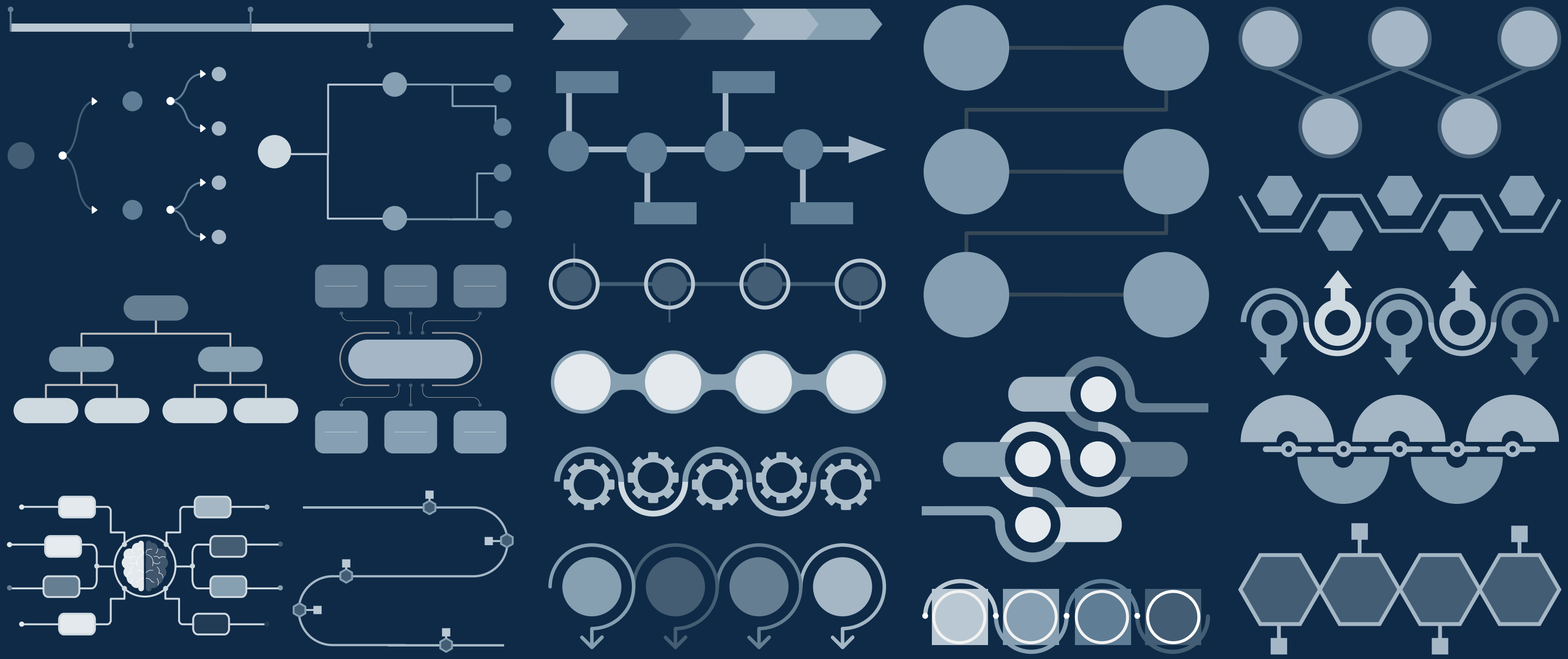


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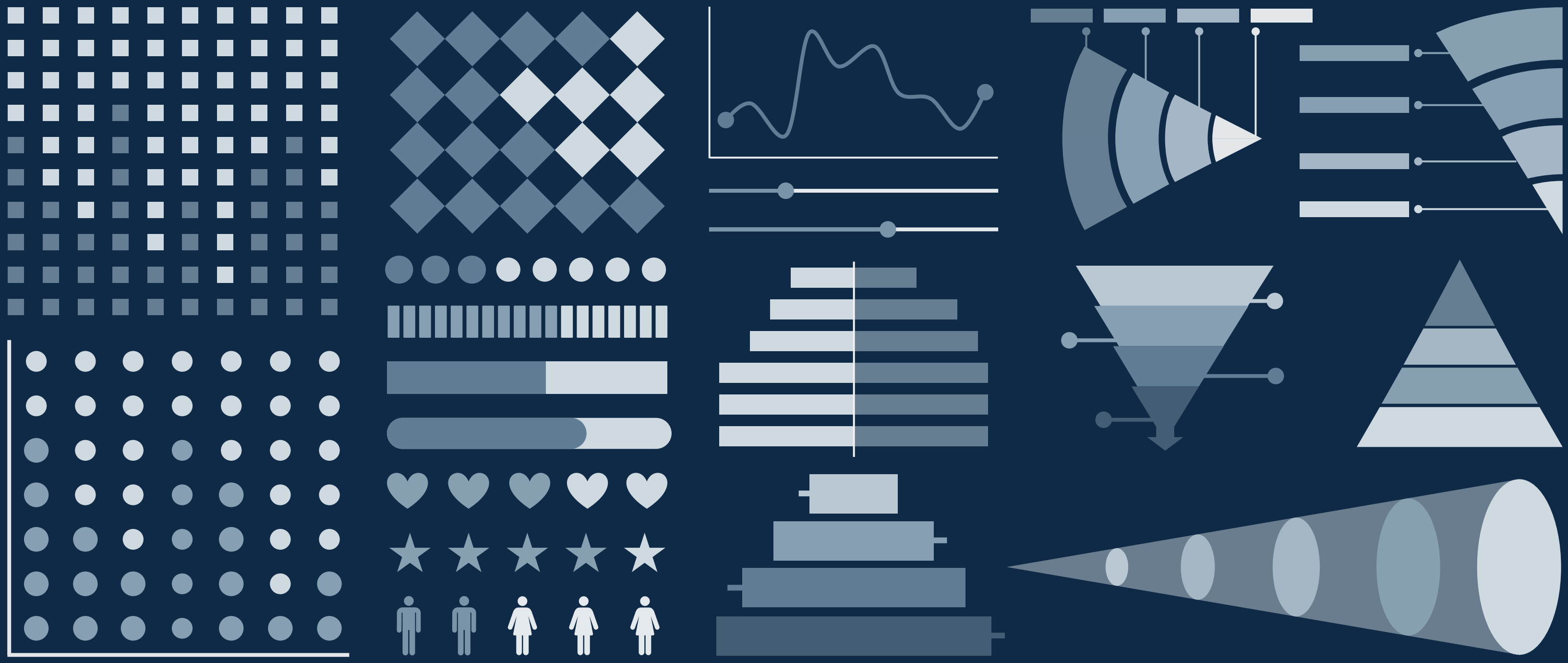

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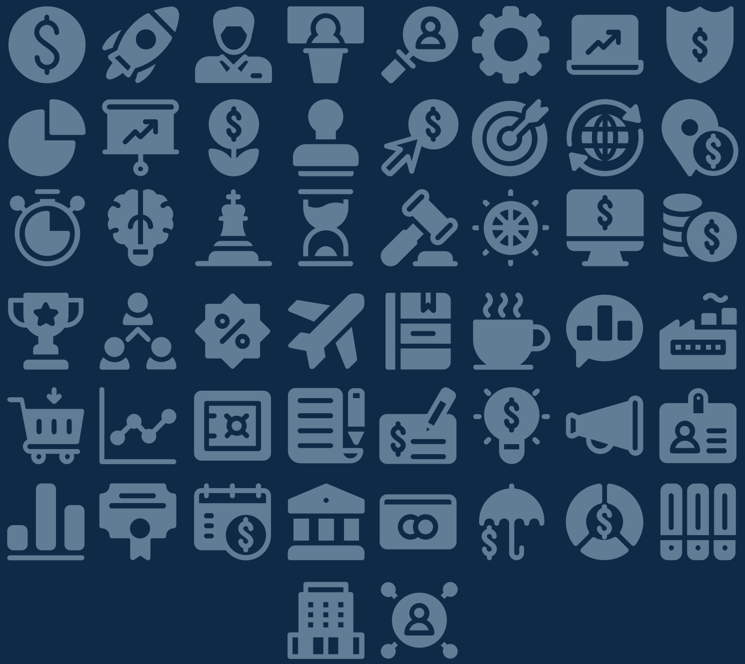

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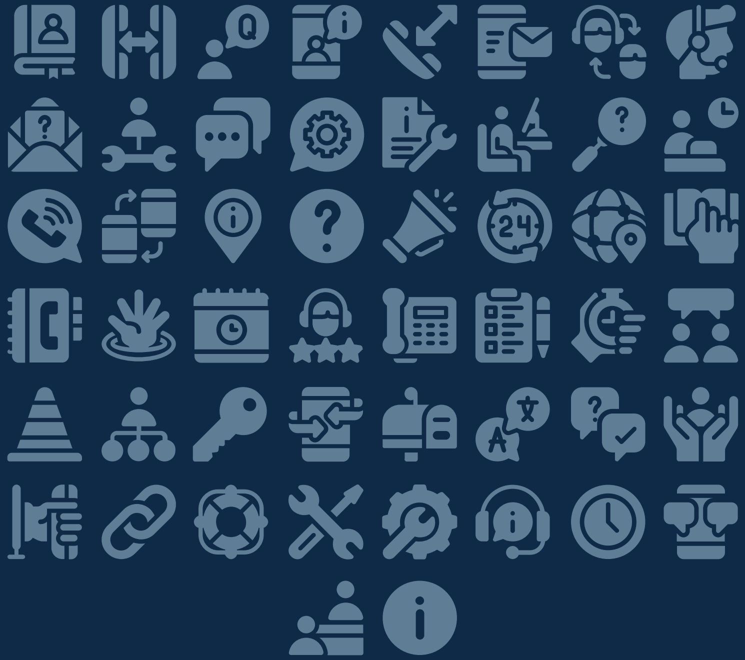

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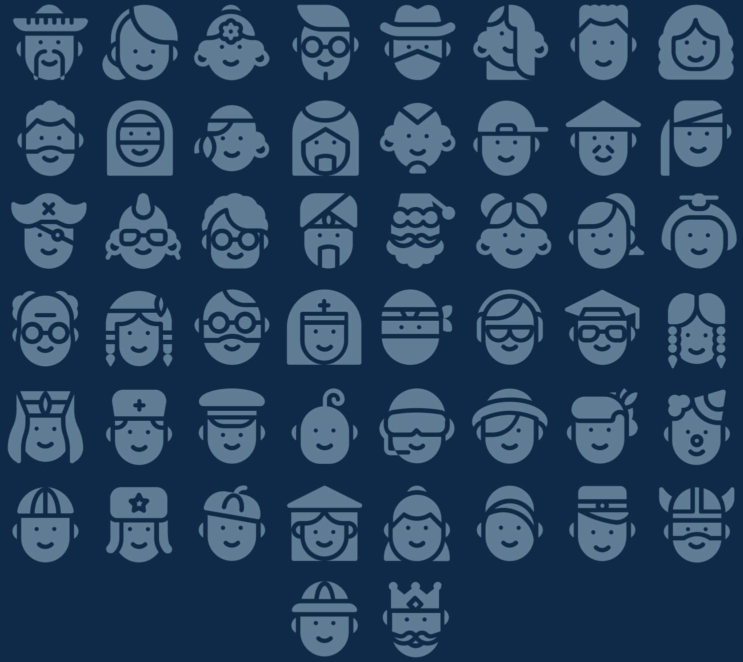

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