**1) Baseline XGBoost**

Data: 80% Training 20% Validation

colsample\_bytree=0.3,

learning\_rate=0.1,

max\_depth=5,

n\_estimators=100

Baseline XGBoost MSE (Train): 0.623058598718014

Baseline XGBoost MSE (Test): 0.6420943976217208

**XGB HHO (Harris Hawks Optimization),**

max\_iters=100

population\_size=30

Best Parameters from HHO: [ 0.15904768 3.15382353 52.56399205]

HHO Optimized MSE (Train/Test): 0.6736009438931361 0.611900698210180

**XGB PSO (Particle Swarm Optimization)**

PSO Optimization of hyperparameters is done using the pyswarm library

bounds = ([0.01, 3, 50], [0.2, 10, 200])

swarmsize=50,

maxiter=100

PSO Optimized MSE (Train/Test): 0.6736009306703107 0.611900692378837

**XGB GA (Genetic Algorithm)**

max\_num\_iteration': 200,

'population\_size': 50,

'mutation\_probability': 0.1,

'elit\_ratio': 0.01,

'crossover\_probability': 0.5,

'parents\_portion': 0.3,

'crossover\_type':'uniform',

'max\_iteration\_without\_improv': 50

Best Parameters from GA: [ 0.15902394 3.74492169 52.67433708]

Best MSE from GA: 0.6119021163371854

GA Optimized MSE (Train/Test): 0.6736057906273277 0.6119021163371854

**XGB BBO (Biogeography-Based Optimization**

n\_estimators", 50, 200

max\_depth", 3, 10

Best Parameters from BBO (Optuna): 'learning\_rate': 0.12054631325814388, 'max\_depth': 3, 'n\_estimators': 64}

Best MSE from BBO (Optuna): 0.617080042477531

BBO (Optuna) Optimized MSE (Train/Test): 0.6779396558659353 0.617080042477531

**2) Extreme Learning Machine (ELM)**

Data: 80% Training 20% Validation

ELM MSE (Train): 0.8880013376796757

ELM MSE (Test): 0.7826613626311693

n\_hidden = 30

input\_weights = None

biases = None

output\_weights = None

def sigmoid = 1 / (1 + np.exp(-x))

**ELM HHO (Harris Hawks Optimization),**

dimension=1, lower=10, upper=100

max\_evals=100

population\_size=30

HHO Optimized ELM MSE (Train): 0.8952705039205147

HHO Optimized ELM MSE (Test): 0.7888287446207194

**ELM PSO (Particle Swarm Optimization)**

lb = [10]

ub = [100]

Best n\_hidden from PSO: 41

Best MSE from PSO: 0.6032802430193484

PSO Optimized ELM MSE (Train): 0.8679245729209053

PSO Optimized ELM MSE (Test): 0.8629605522987526

**ELM GA (Genetic Algorithm)**

Best n\_hidden from GA: 40

Best MSE from GA: 0.6024373828780031

GA Optimized ELM MSE (Train): 0.8138031763512372

GA Optimized ELM MSE (Test): 0.914098731729617

**ELM BBO (Biogeography-Based Optimization**

vn\_hidden", 10, 100

n\_trials=100

Best n\_hidden from BBO (Optuna): 34

Best MSE from BBO (Optuna): 0.641367240173688

**3) Random Forest (RF)**

Data: 80% Training 20% Validation

MSE: 35702235.74418667, R2: -6.043527755178625

**RF HHO (Harris Hawks Optimization),**

max\_iters=100

population\_size=30

Optimized Parameters (HHO): n\_estimators = 99, max\_depth = 3

Best MSE achieved: 0.58787776732519

**RF PSO (Particle Swarm Optimization)**

lb = [10, 1] # Lower bounds for n\_estimators and max\_depth

ub = [100, 20] # Upper bounds for n\_estimators and max\_depth

swarmsize=10, maxiter=10

Best Optimized Parameters (PSO): [41.70629072 3.85779957]

Best Optimized Mean Squared Error (PSO): 0.5905351801080733

Optimized RF Model (PSO) - Mean Squared Error: 0.5926641543108092

Optimized RF Model (PSO) - R^2 Score: 0.37844445135111004

**RF GA (Genetic Algorithm)**

Optimized Parameters (GA): [0, 4]

GA optimized parameters: [0.1781056152379834, 4.250662476314364, 226.21730517442415]

Optimized RF Model (GA) - Mean Squared Error: 0.5920059751706191

Optimized RF Model (GA) - R^2 Score: 0.37913471563251544

**RF BBO (Biogeography-Based Optimization**

'n\_estimators', 10, 100

max\_depth = trial.suggest\_int('max\_depth', 1, 20

Optimized Parameters (Optuna): {'n\_estimators': 100, 'max\_depth': 3

**4) LSTM Baseline Model**

Data: 80% Training 20% Validation

LSTM(units=50, return\_sequences=False)

Dropout(0.2)

Dense(1))

LSTM()

Dropout()

Epoch : 20

train loss: 0.7021 -

val\_loss: 0.6184

**LSTM HHO (Harris Hawks Optimization),**

max\_evals=100

population\_size=20

Optimized Parameters (HHO): lstm\_units = 47, dropout\_rate = 0.1

**LSTM PSO (Particle Swarm Optimization)**

Optimized Parameters (PSO): lstm\_units = 100, dropout\_rate = 0.1, learning\_rate = 0.009061625299078394, batch\_size = 52

Best MSE achieved: 0.594499901737335

Train loss: 0.6931

**LSTM GA (Genetic Algorithm Optimization)**

max\_num\_iteration': 100,

'population\_size': 50

Optimized Parameters (GA): lstm\_units = 76, dropout\_rate = 0.25290333922644315, learning\_rate = 0.005376892691117486, batch\_size = 20

Train loss: 0.6898

**LSTM BBO (Biogeography-Based Optimization**

Trial 29 finished with value: 0.6183785246981112 and parameters: {'units': 25, 'dropout\_rate': 0.10033135848157035}. Best is trial 25 with value: 0.6120825705376208.