

Power, Area and Thermal Prediction in 3D Network-on-Chip using Machine Learning

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I. EXPERIMENTAL RESULTS

This section focuses on the experimental setup, dataset generation, dataset preprocessing, performance of different models, and comparison of their performance.

A. Experimental Setup

The dataset is generated using PAT-Noxim, a cycle-accurate simulator, and a shell script. The entire experiment is executed on a computer setup with the configurations: HP HP EliteDesk 800 G8 Tower PC, 16.0 GiB memory, 11th Gen Intel® Core™ i5-11500 @ 2.70GHz × 12 graphics, Mesa Intel® Graphics (RKL GT1), 1.0 TB disk capacity and Ubuntu 22.04.4 LTS.

B. Dataset Generation

The dataset is generated by simulating various configurations on PAT-Noxim. The configurations include mesh sizes ranging from 2 x 2 x 2 to 16 x 16 x 2, pir values from 0.01 to 0.1 with step size of 0.01, and buffer sizes 4, 6, 8, and 10. Three different routing algorithms are used: XYZ, Fully Adaptive, and Odd-Even 3D. The simulations are run for 200000 cycles. The traffic considered is Random.

C. Data Preprocessing

The simulation results of PAT-Noxim include various metrics. The parameters considered in this experiment are power metrics such as average power, average core power, average router power, and average power per router; area metrics such as layer area, area per core, and total area; temperature metrics such as steady state temperature, core average temperature, memory average temperature, and router average temperature. The categorical column, such as the routing algorithm, is encoded. The dataset is split into training and test sets (80% train and 20% test). The parameters are standardized to the same scale, which improves the performance of ML models.

D. Models Used

The generated dataset is trained using the following models:

- Random Forest
- Decision Tree
- AdaBoost
- AdaBoost with Decision Tree
- Support Vector Regressor (SVR)

- Linear Regression
- K-Nearest Neighbors

E. Performance Metrics

The performance metrics used for evaluating the performance of different models are:

- **Mean Squared Error (MSE)**: Average of the squares of the difference between the predicted values and actual values..
- **Mean Absolute Error (MAE)**: Average of the absolute difference between the predicted values and actual values..
- **R² (Coefficient of Determination)**: The dependent variable variance proportion explained by the independent variables.

F. Results Analysis

1) *Temperature Analysis*: The *Temperature Analysis* subsection focuses on the performance of different algorithms specifically on the temperature-related datasets (*steady_state_temp_L0* and *steady_state_temp_L1*). Below are tables showcasing the performance metrics for each algorithm.

TABLE I: Performance Metrics for Different Algorithms - steady_state_temp_L0

Algorithm	MSE	MAE	R ²
AdaBoost with Decision Tree	0.0011	0.0125	0.9989
Random Forest	0.0012	0.0154	0.9987
Decision Tree	0.0021	0.0171	0.9978
KNN	0.0380	0.1171	0.9604
SVR	0.0613	0.1250	0.9362
AdaBoost	0.1979	0.3712	0.7939
Linear Regression	0.4100	0.4848	0.5731

2) *Power Analysis*: The *Temperature Analysis* subsection focuses on the performance of different algorithms specifically on the temperature-related datasets (*steady_state_temp_L0* and *steady_state_temp_L1*). Below are tables showcasing the performance metrics for each algorithm.

TABLE II: Performance Metrics for Different Algorithms - steady_state_temp_L1

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	0.0011	0.0127	0.9988
Random Forest	0.0012	0.0153	0.9987
Decision Tree	0.0020	0.0169	0.9979
KNN	0.0383	0.1175	0.9601
SVR	0.0622	0.1252	0.9353
AdaBoost	0.1931	0.3624	0.7990
Linear Regression	0.4123	0.4862	0.5709

TABLE III: Performance Metrics for Different Algorithms - core_avg_temp_L0

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	0.0077	0.0415	0.9922
Random Forest	0.0069	0.0436	0.9930
Decision Tree	0.0106	0.0506	0.9892
AdaBoost	0.3740	0.4481	0.6203
KNN	0.2283	0.2017	0.7683
SVR	0.4741	0.2536	0.5188
Linear Regression	0.6070	0.4970	0.3839

3) *Area Analysis*: The *Temperature Analysis* subsection focuses on the performance of different algorithms specifically on the temperature-related datasets (*steady_state_temp_L0* and *steady_state_temp_L1*). Below are tables showcasing the performance metrics for each algorithm.

TABLE IV: Performance Metrics for Different Algorithms - core_avg_temp_L1

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	0.0034	0.0267	0.9966
Random Forest	0.0027	0.0265	0.9973
Decision Tree	0.0043	0.0307	0.9958
SVR	0.3460	0.2720	0.6582
KNN	0.2191	0.2000	0.7835
AdaBoost	0.2557	0.4098	0.7474
Linear Regression	0.9037	0.5865	0.1072

TABLE V: Performance Metrics for Different Algorithms - mem_avg_temp_L0

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	0.0064	0.0432	0.9936
Random Forest	0.0051	0.0398	0.9949
Decision Tree	0.0082	0.0471	0.9918
KNN	0.4311	0.2576	0.5710
AdaBoost	0.1985	0.3481	0.8025
SVR	0.9742	0.3193	0.0304
Linear Regression	0.8829	0.4742	0.1213

TABLE VI: Performance Metrics for Different Algorithms - mem_avg_temp_L1

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	0.0020	0.0212	0.9980
Random Forest	0.0017	0.0198	0.9983
Decision Tree	0.0030	0.0235	0.9971
KNN	0.2512	0.2029	0.7556
AdaBoost	0.1464	0.2762	0.8576
SVR	0.3990	0.2770	0.6118
Linear Regression	1.0030	0.5763	0.0242

TABLE VII: Performance Metrics for Different Algorithms - router_avg_temp_L0

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	0.0047	0.0313	0.9952
Random Forest	0.0050	0.0362	0.9950
Decision Tree	0.0075	0.0413	0.9925
KNN	0.2341	0.1797	0.7651
AdaBoost	0.2079	0.3494	0.7915
SVR	0.5236	0.2204	0.4748
Linear Regression	0.5870	0.4415	0.4112

TABLE VIII: Performance Metrics for Different Algorithms - router_avg_temp_L1

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	0.0020	0.0193	0.9981
Random Forest	0.0020	0.0211	0.9981
Decision Tree	0.0033	0.0244	0.9968
KNN	0.2300	0.1786	0.7807
AdaBoost	0.1616	0.3120	0.8459
SVR	0.3708	0.2496	0.6464
Linear Regression	0.9080	0.5579	0.1340

TABLE IX: Performance Metrics for Different Algorithms - avg_cores_power

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	0.0004	0.0063	0.9996
Random Forest	0.0004	0.0076	0.9996
Decision Tree	0.0007	0.0081	0.9993
SVR	0.0027	0.0429	0.9974
KNN	0.0062	0.0614	0.9939
AdaBoost	0.0695	0.2264	0.9309
Linear Regression	0.1159	0.2551	0.8849

TABLE X: Performance Metrics for Different Algorithms - avg_power

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	0.0007	0.0086	0.9993
Random Forest	0.0007	0.0101	0.9993
Decision Tree	0.0012	0.0108	0.9988
SVR	0.0029	0.0427	0.9971
KNN	0.0066	0.0611	0.9933
AdaBoost	0.1072	0.2854	0.8927
Linear Regression	0.1355	0.2651	0.8644

TABLE XI: Performance Metrics for Different Algorithms - avg_power_per_router

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	0.0040	0.0204	0.9959
Random Forest	0.0079	0.0371	0.9919
KNN	0.0080	0.0368	0.9918
Decision Tree	0.0121	0.0393	0.9877
SVR	0.0143	0.0796	0.9854
AdaBoost	0.1188	0.2933	0.8785
Linear Regression	0.1873	0.3189	0.8085

TABLE XII: Performance Metrics for Different Algorithms - avg_routers_power

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	0.0012	0.0123	0.9987
Random Forest	0.0023	0.0170	0.9976
Decision Tree	0.0034	0.0186	0.9965
SVR	0.0058	0.0494	0.9941
KNN	0.0085	0.0552	0.9913
AdaBoost	0.2717	0.4722	0.7219
Linear Regression	0.2406	0.3368	0.7537

TABLE XIII: Performance Metrics for Different Algorithms - layer_area

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	3.37E-32	2.77E-17	1.0000
Random Forest	8.04E-05	0.0029	0.9999
Decision Tree	0.0003	0.0025	0.9997
SVR	0.0041	0.0568	0.9960
KNN	0.0057	0.0594	0.9944
AdaBoost	0.0335	0.1462	0.9673
Linear Regression	0.1023	0.2403	0.9000

TABLE XIV: Performance Metrics for Different Algorithms - total_area

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	1.81E-10	6.88E-07	1.0000
Random Forest	8.04E-05	0.0029	0.9999
Decision Tree	0.0003	0.0025	0.9997
SVR	0.0041	0.0568	0.9960
KNN	0.0057	0.0594	0.9944
AdaBoost	0.0333	0.1469	0.9674
Linear Regression	0.1023	0.2403	0.9000

TABLE XV: Performance Metrics for Different Algorithms - area_per_core

Algorithm	MSE	MAE	R^2
AdaBoost with Decision Tree	0	0	1
AdaBoost	0	0	1
Random Forest	0	0	1
Decision Tree	0	0	1
SVR	0	0	1
KNN	0	0	1
Linear Regression	0	0	1