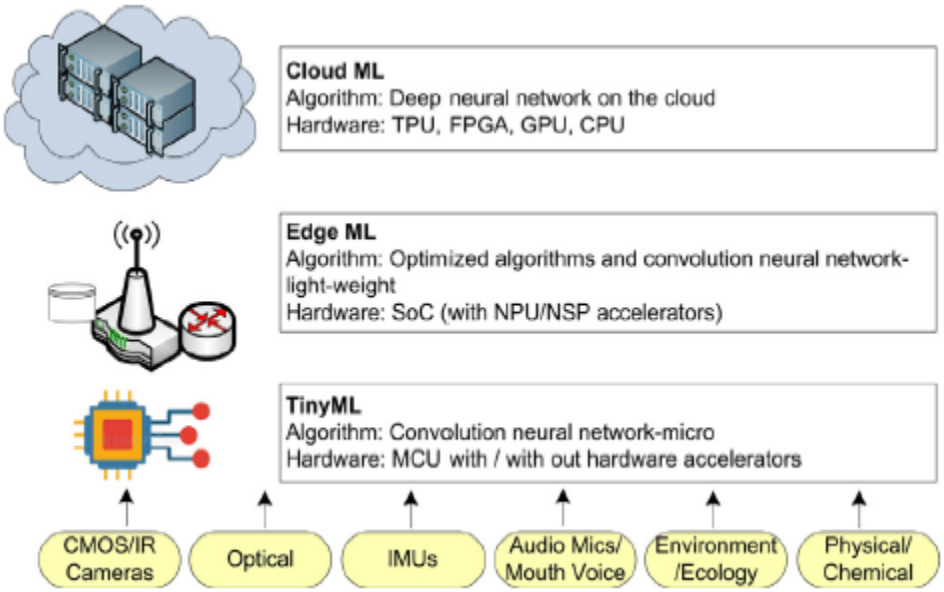
TINY ML

SUPERVISOR:ADLEN KSENTINI

GANESAN Venithraa MAGUDESWARAN nandhini

INTRODUCTION

Edge computing brings computation and data storage closer to the origin of data. The major advantage of edge computing is to provide low latency and high-availability of several network aware services. Edge computing provides better privacy, security, and reliability to the network end-users.IoT devices are deployed at the edge of the network with very-low processing capacity and memory footprint. As an IoT-edge facility highly depends on the edge platforms for data collection and end-to-end data propagation, it minimally depends on the data transceiving through the long backhaul.



TinyML is a paradigm that facilitates running machine learning at the embedded edge devices having very less processor and memory.

As the Dependency on cloud-based machine learning services paves few challenges such as,
(i) huge energy consumption
(ii) privacy issues,
(iii) network and processing latency
(iv) reliability issues

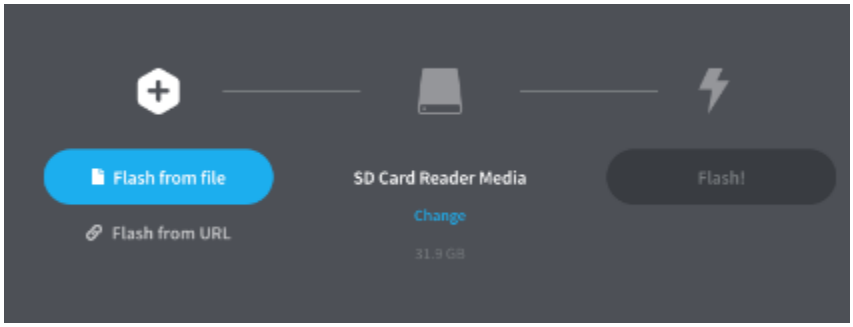
TinyML is aware that the physical world is smarter than the existing scenario.This setting results in the following improvements,
(i) energy efficiency
(ii) better privacy of local data
(iii) low processing latency
(iv) minimal connectivity dependency

PROJECT OVERVIEW

In this project we tried to compare the computational process of a computer and a tiny ML application using raspberry pi model 3. This was performed by running various datasets with different machine learning models and compared time and CPU memory to run this model.

INSTALLATION PROCESS

1) Downloading the raspberry pi os in the computer and uploading in the sd card
- We download balena etcher which is an open-source utility used for writing image files.
- For the image file for the raspberry os we have download it from the raspberry pi official website.
- Then flash is using the balena etcher.



2) Inserting the sd card to the raspberry pi and connecting to the computer (using hdmi)
- We have to configure our wifi configurations.
- We found the ip address of wifi by giving “ifconfig” in the terminal.
- Then we connected the vnc viewer by giving the same ip address. (This is for wireless connection)
- After connecting the vnc viewer we can access its GUI and open its terminal to enter command.
3) Configuring the OS and installing the libraries..

METHODOLOGY

- FIRSTLY, WE INSTALLED THE RASPBERRY OS IN RASPBERRY PI AND INSTALLED FEW LIBRARIES IN ORDER TO RUN THE MODELS

- TOOLS : SKLEARN, TENSORFLOW LITE, TENSOR FLOW
- DATASET : KAGGLE (MOVIE DATA), SKLEARN (IRIS, DIABATIC) , MOBILENET
- WE COMPARED 2 SMALL MODELS BY RUNNING IT IN THE COMPUTER AND AS WELL AS THE RASPBERRY PI
- BIGGER DATA SET - TOTAL SAMPLES (5000)
- DATASET IN CSV FILE
- USING DIFFERENT REGRESSION MODELS

    - RIDGE REGRESSION

    - KNN

    - BAYESIAN

    - DECISION TREE

    - SVM

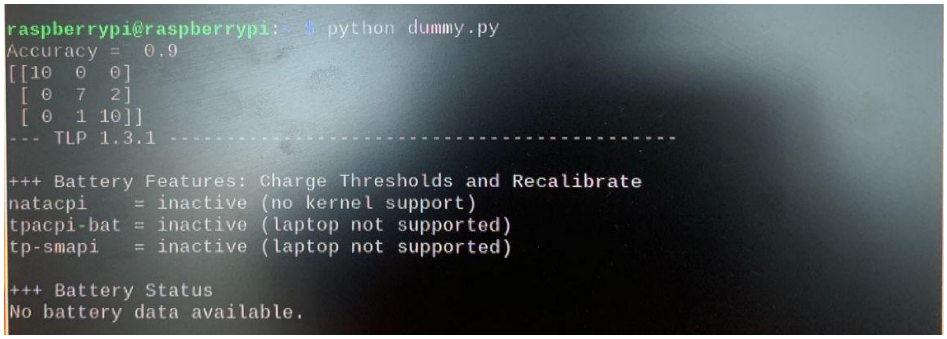
RESULTS

Power consumption:
TLP is a free open source, feature-rich and command line tool for advanced power management, which helps to optimize battery life in laptops powered by Linux.

```
nandhini@Nandhini:/mnt/c/Users/NANDHINI/Desktop$
nandhini@Nandhini:/mnt/c/Users/NANDHINI/Desktop$ python3 project_data_trial.py
Accuracy =  0.9
[[10  0  0]
 [ 0  7  2]
 [ 0  1 10]]
--- TLP 1.3.1 ----------------------------------------------

+++ Battery Features: Charge Thresholds and Recalibrate
natacpi    = inactive (laptop not supported)
tpacpi-bat = inactive (laptop not supported)
tp-smapi   = inactive (laptop not supported)

+++ Battery Status: BAT1
/sys/class/power_supply/BAT1/manufacturer                 = (not available)
/sys/class/power_supply/BAT1/model_name                   = Microsoft Hyper-V Virtual BatterVirtual
/sys/class/power_supply/BAT1/cycle_count                  = (not supported)
/sys/class/power_supply/BAT1/energy_full_design           =   5000 [mWh]
/sys/class/power_supply/BAT1/energy_full                  =   5000 [mWh]
/sys/class/power_supply/BAT1/energy_now                   =   2729 [mWh]
/sys/class/power_supply/BAT1/power_now                    =   2657 [mW]
/sys/class/power_supply/BAT1/status                       = Charging

Charge                                                    =   54.6 [%]
Capacity                                                  =  100.0 [%]
```

```
nandhini@Nandhini:/mnt/c/Users/NANDHINI/Desktop$ python3 project_data_trial.py
Accuracy =  0.9
[[10  0  0]
 [ 0  7  2]
 [ 0  1 10]]
--- TLP 1.3.1 ----------------------------------------------

+++ Battery Features: Charge Thresholds and Recalibrate
natacpi    = inactive (laptop not supported)
tpacpi-bat = inactive (laptop not supported)
tp-smapi   = inactive (laptop not supported)

+++ Battery Status: BAT1
/sys/class/power_supply/BAT1/manufacturer                 = (not available)
/sys/class/power_supply/BAT1/model_name                   = Microsoft Hyper-V Virtual BatterVirtual
/sys/class/power_supply/BAT1/cycle_count                  = (not supported)
/sys/class/power_supply/BAT1/energy_full_design           =   5000 [mWh]
/sys/class/power_supply/BAT1/energy_full                  =   5000 [mWh]
/sys/class/power_supply/BAT1/energy_now                   =   2789 [mWh]
/sys/class/power_supply/BAT1/power_now                    =      0 [mW]
/sys/class/power_supply/BAT1/status                       = Discharging

Charge                                                    =   55.8 [%]
Capacity                                                  =  100.0 [%]
```

while using this command, we are able to find battery consumption in our cpu.



If we use this in pi,the battery consumption will be discharged,i.e.nil because it is connected via the cable so there is no battery status.

COMPUTER:
classifier:
Logistic regression

```
venithra@DESKTOP-1M3V6R1: /mnt/c/Users/Venithraa Ganesan/Downloads
top - 11:06:25 up 1 min,  0 users,  load average: 0.09, 0.04, 0.01
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  0.0 us,  0.0 sy,  0.0 ni,100.0 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
MiB Mem :   6246.5 total,   5944.2 free,    163.9 used,    138.4 buff/cache
MiB Swap:   2048.0 total,   2048.0 free,      0.0 used.   5890.8 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
   72 venithra  20   0  740972 121720  38416 S   0.0   1.9   0:03.62 python3
```

Iris data:
Linear regression:

```
venithra@DESKTOP-1M3V6R1: /mnt/c/Users/Venithraa Ganesan/Downloads
top - 11:59:57 up 54 min,  0 users,  load average: 0.06, 0.03, 0.00
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  0.0 us,  0.0 sy,  0.0 ni,100.0 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
MiB Mem :   6246.5 total,   5952.5 free,    145.2 used,    148.8 buff/cache
MiB Swap:   2048.0 total,   2048.0 free,      0.0 used.   5904.3 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
  125 venithra  20   0  738812  92724  35788 S   0.0   1.4   0:02.04 python3
```

Movie data:
Ridge regression :

```
venithra@DESKTOP-1M3V6R1: /mnt/c/Users/Venithraa Ganesan
top - 13:36:11 up 19 min,  0 users,  load average: 0.14, 0.07, 0.01
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  0.0 us,  0.0 sy,  0.0 ni,100.0 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
MiB Mem :   6246.5 total,   5862.4 free,    196.8 used,    187.3 buff/cache
MiB Swap:   2048.0 total,   2048.0 free,      0.0 used.   5833.6 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
   92 venithra  20   0  908552 157020  48956 S   0.0   2.5   0:06.72 python3
```

Knn :

```
venithra@DESKTOP-1M3V6R1: /mnt/c/Users/Venithraa Ganesan
top - 14:25:40 up 12 min,  0 users,  load average: 0.32, 0.18, 0.08
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  0.0 us,  0.0 sy,  0.0 ni,100.0 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
MiB Mem :   6246.5 total,   5611.8 free,    450.7 used,    184.0 buff/cache
MiB Swap:   2048.0 total,   2048.0 free,      0.0 used.   5581.2 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
  194 venithra  20   0  908888 170372  49556 S   0.0   2.7   0:08.07 python3
```

Bayesian:

```
venithra@DESKTOP-1M3V6R1: /mnt/c/Users/Venithraa Ganesan
top - 17:10:58 up  2:22,  0 users,  load average: 0.13, 0.03, 0.01
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  0.0 us,  0.0 sy,  0.0 ni,100.0 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
MiB Mem :   6246.5 total,   5838.8 free,    230.6 used,    177.1 buff/cache
MiB Swap:   2048.0 total,   2048.0 free,      0.0 used.   5804.8 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
   72 venithra  20   0  910208 190284  49236 S   0.0   3.0   0:06.23 python3
```

Decision tree :

```
venithra@DESKTOP-1M3V6R1: /mnt/c/Users/Venithraa Ganesan
top - 17:11:53 up  2:23,  0 users,  load average: 0.05, 0.02, 0.00
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  0.0 us,  0.0 sy,  0.0 ni,100.0 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
MiB Mem :   6246.5 total,   5717.6 free,    351.5 used,    177.4 buff/cache
MiB Swap:   2048.0 total,   2048.0 free,      0.0 used.   5683.7 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
   99 venithra  20   0  908812 165832  48460 S   0.0   2.6   0:03.79 python3
```

Svm:

```
venithra@DESKTOP-1M3V6R1: /mnt/c/Users/Venithraa Ganesan
top - 17:12:49 up  2:24,  0 users,  load average: 0.02, 0.02, 0.00
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  0.0 us,  0.0 sy,  0.0 ni,100.0 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
MiB Mem :   6246.5 total,   5593.6 free,    475.5 used,    177.4 buff/cache
MiB Swap:   2048.0 total,   2048.0 free,      0.0 used.   5559.7 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
  126 venithra  20   0  908452 166636  49408 S   0.0   2.6   0:05.59 python3
```

In raspberry pi:

Classifier:

```
File  Edit  Tabs  Help
top - 10:53:29 up  1:13,  2 users,  load average: 1.07, 0.98, 1.00
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  1.3 us,  0.3 sy,  0.0 ni, 98.5 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
MiB Mem :    923.1 total,    119.5 free,    294.4 used,    509.2 buff/cache
MiB Swap:    100.0 total,     97.5 free,      2.5 used.    562.9 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
 2740 raspber+  20   0   97632  58908  27324 S   0.0   6.2   0:02.84 python
```

Iris dataset :

```
File  Edit  Tabs  Help
top - 10:07:42 up 27 min,  2 users,  load average: 0.68, 0.77, 0.77
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  0.3 us,  0.3 sy,  0.0 ni, 99.4 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
MiB Mem :    923.1 total,    178.6 free,    259.8 used,    484.7 buff/cache
MiB Swap:    100.0 total,     98.0 free,      2.0 used.    597.8 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
 2015 raspber+  20   0  121340  73864  29832 S   0.0   7.8   0:04.69 python
```

Movie data:
Ridge regression:

```
raspberrypi@raspberrypi:~/Downloads $ python3 regression.py
Train error = 12.729437097203272 percent in Ridge Regression
Test error = 14.296076292990003 percent in Ridge Regression
accuracy =85.70392370700999

Process ID:2790

top - 17:49:54 up 9 min,  2 users,  load average: 1.59, 1.86, 1.13
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  1.3 us,  0.4 sy,  0.0 ni, 98.2 id,  0.1 wa,  0.0 hi,  0.0 si,  0.0 st
MiB Mem :    923.1 total,     41.0 free,    560.2 used,    321.9 buff/cache
MiB Swap:    100.0 total,      0.0 free,    100.0 used.    257.1 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
 2790 raspber+  20   0  153264  95004  36320 S   0.0  10.1   0:05.59 python3
```

Knn:

```
raspberrypi@raspberrypi:~/Downloads $ nano knn.py
raspberrypi@raspberrypi:~/Downloads $ python3 knn.py
Train error = 12.492260951644399 percent in Knn algorithm
Test error = 7.5758084201221685 percent in knn algorithm
accuracy =92.42419157987783

Process ID:2779

top - 17:49:19 up 8 min,  2 users,  load average: 1.55, 1.89, 1.12
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  1.2 us,  0.4 sy,  0.0 ni, 98.4 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
MiB Mem :    923.1 total,     32.3 free,    521.7 used,    369.2 buff/cache
MiB Swap:    100.0 total,     19.0 free,     81.0 used.    294.9 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
 2779 raspber+  20   0  153680  95032  35884 S   0.0  10.1   0:06.50 python3
```

Bayesian :

```
raspberrypi@raspberrypi:~/Downloads $ python3 bayesian.py
Train error = 12.786542528523304 percent in Bayesian Regression
Test error = 0.0 percent in Bayesian Regression
accuracy =100.0

Process ID:2803

top - 17:50:27 up 9 min,  2 users,  load average: 1.51, 1.81, 1.14
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  5.1 us,  2.0 sy,  0.0 ni, 92.3 id,  0.5 wa,  0.0 hi,  0.1 si,  0.0 st
MiB Mem :    923.1 total,     35.1 free,    618.2 used,    269.9 buff/cache
MiB Swap:    100.0 total,      0.0 free,    100.0 used.    199.3 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
 2803 raspber+  20   0  153328  95140  36224 S   0.0  10.1   0:05.69 python3
```

Decision tree :

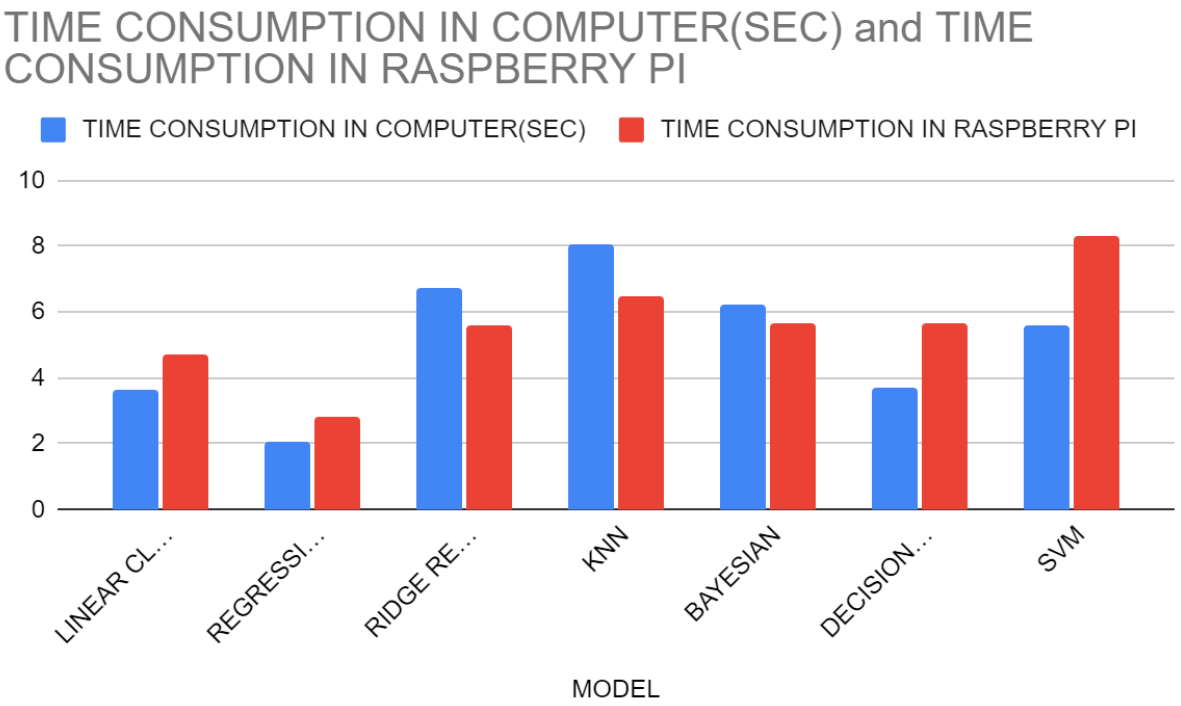
```
raspberrypi@raspberrypi:~/Downloads $ python3 deci.py
Train error = 14.264513407018608 percent in Decision Tree Regressor
Test error = 6.869388599255374 percent in Decision Tree Regressor
accuracy =93.13061140074463

Process ID:2813

top - 17:50:50 up 10 min,  2 users,  load average: 1.22, 1.71, 1.12
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  3.0 us,  2.0 sy,  0.0 ni, 94.6 id,  0.3 wa,  0.0 hi,  0.1 si,  0.0 st
MiB Mem :    923.1 total,     54.6 free,    676.1 used,    192.5 buff/cache
MiB Swap:    100.0 total,      0.0 free,    100.0 used.    141.5 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
 2813 raspber+  20   0  153544  95816  36736 S   0.0  10.1   0:05.64 python3
```

Svm:

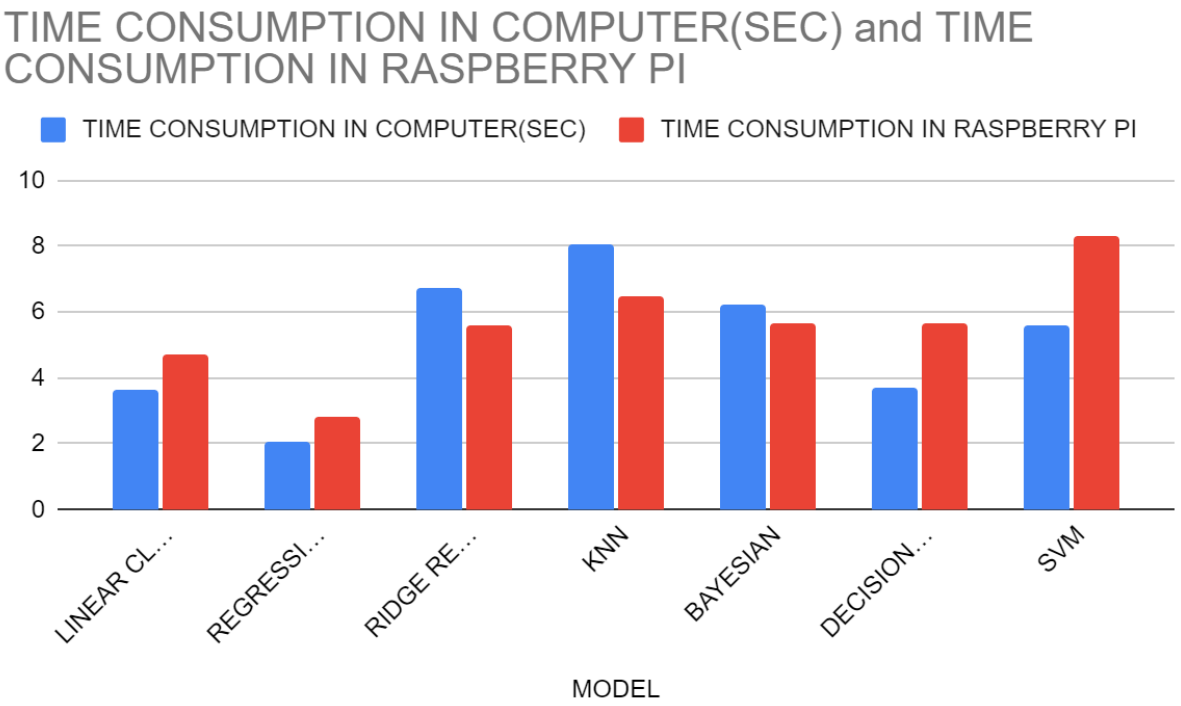
```
raspberrypi@raspberrypi:~/Downloads $ python3 svm.py
Train error = 14.987900330902509 percent in SVM Regressor
Test error = 6.582677940007284 percent in SVM Regressor
accuracy =93.41732205999271

Process ID:2833

top - 17:52:17 up 11 min,  2 users,  load average: 1.51, 1.69, 1.17
Tasks:   1 total,   0 running,   1 sleeping,   0 stopped,   0 zombie
%Cpu(s):  2.6 us,  1.3 sy,  0.0 ni, 86.0 id,  9.8 wa,  0.0 hi,  0.3 si,  0.0 st
MiB Mem :    923.1 total,     27.7 free,    731.3 used,    164.1 buff/cache
MiB Swap:    100.0 total,      0.0 free,    100.0 used.     87.2 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
 2833 raspber+  20   0  154020  67836   8248 S   0.0   7.2   0:28.37 python3
```

CONCLUSION

TIME CONSUMPTION IN COMPUTER(SEC)	TIME CONSUMPTION IN RASPBERRY PI	MODEL
3.62	4.69	LINEAR CLASSIFIER
2.04	2.84	REGRESSION
6.72	5.59	RIDGE REGRESSION
8.07	6.5	KNN
6.23	5.69	BAYESIAN
3.72	5.64	DECISION TREE
5.59	8.34	SVM



CPU MEMORY CONSUMPTION IN COMPUTER(SEC)	CPU MEMORY CONSUMPTION IN RASPBERRY PI	MODEL
1.4	6.2	LINEAR CLASSIFIER
1.9	7.8	REGRESSION
2.5	10.1	RIDGE REGRESSION
2.7	10.1	KNN
3	10.1	BAYESIAN
2.6	10.1	DECISION TREE
2.6	7.2	SVM



- FOR MACHINE LEARNING MODELS

  TIME CONSUMPTION DOESN'T NOT DEPEND ON THE DATA SET. IT MAY VARY ACCORDING TO THE MODEL

  THE CPU MEMORY CONSUMPTION OF THE PI WAY ALWAYS MORE THAN THE COMPUTER

- FOR OBJECT DETECTION

  THE PI PERFORMED BETTER THAN THE COMPUTER

REFERENCE

OBJECT DETECTION USING TENSOR FLOW - https://www.mygreatlearning.com/blog/object-detection-using-tensorflow/

OBJECT DETECTION USING TENSORFLOW LITE - https://blog.paperspace.com/tensorflow-lite-raspberry-pi/

REGRESSION MODELS (MOVIE DATA) - https://www.kaggle.com/code/ankitjha/comparing-regression-models/notebook

CLASSIFICATION MODEL - https://scikit-learn.org/stable/modules/generated/sklearn.datasets.load_diabetes.html