NVIDIA Jetson Nano Project

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***Abstract*—This document is a model and instructions for LaTeX. This and the IEEEtran.cls file define the components of your paper [title, text, heads, etc.]. *CRITICAL: Do Not Use Symbols, Special Characters, Footnotes, or Math in Paper Title or Abstract.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

Machine learning and artificial intelligence are both becoming a larger part of today's world with seemingly endless applications in all sectors such agriculture, business, and many more. While it has great use cases and problem solving capabilities, machine learning requires a great amount of computing power with some algorithms pushing even the most high level cards to their limits. This need for high computational power is not always feasible, especially in situations where low power consumption is required. To help deal with this requirement of low power consumption machine learning platforms, companies like Nvidia and Raspberry Pi have created their line up of embedded heterogeneous systems such as the Nvidia Jetson series and Raspberry Pi series. Embedded systems, single motherboard computers that have components with distinct parts, such as the Jetson Nano and Raspberry Pi 4 have the goal of providing decent performance at a very low power consumption [1]. By doing this and designing specifically for machine learning, as the Jetson line up has, these embedded platforms create a low power and portable option for machine learning that could become a very important part in the future of artificial intelligence as a whole [1].

II. Background and Overview

A. NVIDIA Jetson Nano Performance

The three main platforms utilized in research regarding embedded machine learning include: the Raspberry Pi 4, the Nvidia Jetson Nano, and the Nvidia Jetson TX2. As shown in the figure below, the Raspberry Pi 4 has the lowest cost but also has the lowest performance, while the Nvidia Jetson TX2 provides the highest performance with by far the highest cost. Meanwhile, the Nvidia Jetson Nano is priced around 50 dollars above the Raspberry Pi yet still provides a relatively large amount of performance. This gives the Jetson Nano the highest price to performance among the three cards and is part of the reason why many researchers use it as their platform of choice.

	Raspberry Pi 4	Jetson Nano	Jetson TX2
Performance	13.5 GFLOPS	472 GFLOPS	1.3 TFLOPS
CPU	Quad-core ARM Cortex-A72 64-bit (1.5 GHz)	Quad-Core ARM Cortex-A57 64-bit (1.42 GHz)	Quad-Core ARM Cortex-A57 (2 GHz) + Dual-Core NVIDIA Denver2 (2 GHz)
GPU	Broadcom Video Core VI (32-bit)	NVIDIA Maxwell w/ 128 CUDA core (921 MHz)	NVIDIA Pascal 256 CUDA cores (1300 MHz)
Power under load	2.56W - 7.30W	5W - 10W	7.5W - 15W
Price	$35	$89	$399

[1]

B. Demonstrated Applications

There are many applications for the Nvidia Jetson Nano, but most of the projects employing the Nano involve image recognition. For example, researchers in Hong-Kong wanted to make a way for a computer to translate Hong-Kong sign language so deaf people can better communicate with others. Since they wanted this device to be portable, the usual high powered computing hardware was not an option for this application, so the researchers chose to utilize the Nvidia Jetson Nano [5]. Using a 3D CNN algorithm with a resolution input of 480 x 640 and a sampling rate of 30 fps, the researchers were able to achieve an accuracy of 93.3% with a total response time of 5.82 seconds [5]. This is a perfect application of the Nvidia Jetson Nano and shows what doors it can open in the world of machine learning.

Researchers have also been exploring the option of utilizing the Nvidia Jetson platform to drive autonomous robots with LiDAR and optical positioning tracking [2]. However, since this requires a lot of processing power, the researchers opted to utilize the larger Nvidia Jetson TX2 rather than the Nano. They tested algorithms including: ORB-SLAM2, VISO2, RTAB-MAP, SPTAM, and ZED-VO, and briefly described how each

algorithm works and how they are applied to the robot [2]. The researchers concluded that "ORB-SLAM2 and RTAB-MAP" provided the most performance, but they did acknowledge that it may be necessary to consider changing the source code of the algorithms to help increase speed on the Nvidia Jetson platform [2].

C. Future Research

There have been many projects involving Nvidia Jetson platforms, which have all shown the exceptional performance of the devices, but they have also described room for improvement. This room for improvement extends to both the software and hardware. In terms of software, many researchers recommend exploring the option of changing the source code of algorithms to perform better on the Jetson platform [2]. While this will require a good amount of effort, it could prove to be worth it with large gains in performance. In terms of hardware, many researchers have recommended circuit level improvements such as smaller feature sizes to increase integration density and non-volatile memories to achieve near-zero idle power [4]. Researchers have also recommended microarchitecture improvements such as closer integration between the CPU and GPU to reduce data-transfer overheads [4].

Other researchers have suggested more general changes such as making the process of developing software on the Nvidia Jetson platform easier [3]. Currently, in order to optimize for the Nvidia Jetson, developers have to rewrite large amounts of their application for each processor [3]. They also suggest enabling better dynamic frequency scaling to allow the Jetson to change frequency for applications to optimize for both performance and power consumption. Lastly, the Jetson should also improve the memory bandwidth at low frequencies, which has been found to bottleneck programs that run at lower operating frequencies [3].

These options may take a lot of work to implement, but their performance benefit may prove to be worth it. In future research, the practicality of these options should be explored and researchers should demonstrate whether their performance increase is worth the effort.

D. Units

- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as "3.5-inch disk drive".
- Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.
- Do not mix complete spellings and abbreviations of units: "Wb/m^2" or "webers per square meter", not "webers/m^2". Spell out units when they appear in text: ". . . a few henries", not ". . . a few H".
- Use a zero before decimal points: "0.25", not ".25". Use "cm^3", not "cc".)

E. Equations

Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

$$a + b = \gamma \tag{1}$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use "(1)", not "Eq. (1)" or "equation (1)", except at the beginning of a sentence: "Equation (1) is . . ."

F. LaTeX-Specific Advice

Please use "soft" (e.g., `\eqref{Eq}`) cross references instead of "hard" references (e.g., `(1)`). That will make it possible to combine sections, add equations, or change the order of figures or citations without having to go through the file line by line.

Please don't use the `{eqnarray}` equation environment. Use `{align}` or `{IEEEeqnarray}` instead. The `{eqnarray}` environment leaves unsightly spaces around relation symbols.

Please note that the `{subequations}` environment in LaTeX will increment the main equation counter even when there are no equation numbers displayed. If you forget that, you might write an article in which the equation numbers skip from (17) to (20), causing the copy editors to wonder if you've discovered a new method of counting.

BibTeX does not work by magic. It doesn't get the bibliographic data from thin air but from .bib files. If you use BibTeX to produce a bibliography you must send the .bib files.

LaTeX can't read your mind. If you assign the same label to a subsubsection and a table, you might find that Table I has been cross referenced as Table IV-B3.

LaTeX does not have precognitive abilities. If you put a `\label` command before the command that updates the counter it's supposed to be using, the label will pick up the last counter to be cross referenced instead. In particular, a `\label` command should not go before the caption of a figure or a table.

Do not use `\nonumber` inside the `{array}` environment. It will not stop equation numbers inside `{array}` (there won't be any anyway) and it might stop a wanted equation number in the surrounding equation.

G. Some Common Mistakes

- The word "data" is plural, not singular.
- The subscript for the permeability of vacuum μ_0, and other common scientific constants, is zero with subscript formatting, not a lowercase letter "o".

- In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
- A graph within a graph is an "inset", not an "insert". The word alternatively is preferred to the word "alternately" (unless you really mean something that alternates).
- Do not use the word "essentially" to mean "approximately" or "effectively".
- In your paper title, if the words "that uses" can accurately replace the word "using", capitalize the "u"; if not, keep using lower-cased.
- Be aware of the different meanings of the homophones "affect" and "effect", "complement" and "compliment", "discreet" and "discrete", "principal" and "principle".
- Do not confuse "imply" and "infer".
- The prefix "non" is not a word; it should be joined to the word it modifies, usually without a hyphen.
- There is no period after the "et" in the Latin abbreviation "et al.".
- The abbreviation "i.e." means "that is", and the abbreviation "e.g." means "for example".

An excellent style manual for science writers is [**?**].

H. Authors and Affiliations

The class file is designed for, but not limited to, six authors. A minimum of one author is required for all conference articles. Author names should be listed starting from left to right and then moving down to the next line. This is the author sequence that will be used in future citations and by indexing services. Names should not be listed in columns nor group by affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization).

I. Identify the Headings

Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is "Heading 5". Use "figure caption" for your Figure captions, and "table head" for your table title. Run-in heads, such as "Abstract", will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

Text heads organize the topics on a relational, hierarchical basis. For example, the paper title is the primary text head because all subsequent material relates and elaborates on this one topic. If there are two or more sub-topics, the next level head (uppercase Roman numerals) should be used and, conversely, if there are not at least two sub-topics, then no subheads should be introduced.

J. Figures and Tables

a) Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation "Fig. 1", even at the beginning of a sentence.

TABLE I
TABLE TYPE STYLES

Table Head	**Table Column Head**		
	Table column subhead	***Subhead***	***Subhead***
copy	More table copy[a]		

[a]Sample of a Table footnote.

Fig. 1. Example of a figure caption.

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity "Magnetization", or "Magnetization, M", not just "M". If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write "Magnetization (A/m)" or "Magnetization {A[m(1)]}", not just "A/m". Do not label axes with a ratio of quantities and units. For example, write "Temperature (K)", not "Temperature/K".

ACKNOWLEDGMENT

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression "one of us (R. B. G.) thanks ...". Instead, try "R. B. G. thanks...". Put sponsor acknowledgments in the unnumbered footnote on the first page.

REFERENCES

Please number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use "Ref. [3]" or "reference [3]" except at the beginning of a sentence: "Reference [3] was the first ..."

Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the abstract or reference list. Use letters for table footnotes.

Unless there are six authors or more give all authors' names; do not use "et al.". Papers that have not been published, even if they have been submitted for publication, should be

cited as “unpublished” [4]. Papers that have been accepted for publication should be cited as “in press” [5]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [**?**].

REFERENCES

[1] A. A. Süzen, B. Duman and B. Şen, (2020). ”Benchmark Analysis of Jetson TX2, Jetson Nano and Raspberry PI using Deep-CNN,” Isparta University of Applied Sciences.

[2] Giubilato, R., Chiodini, S., Pertile, M., Debei, S. (2019). “An Evaluation of ROS-compatible Stereo Visual SLAM Methods on a nVidia Jetson TX2.” Industrial Engineering Dept., University of Padova

[3] Halawa H., Abdelhafez H.A., Boktor A., Ripeanu M. (2017). “NVIDIA Jetson Platform Characterization.” The University of British Columbia, Vancouver, Canada.

[4] Mattal, Sparsh. (2018). “A Survey on Optimized Implementation of Deep Learning Models on the NVIDIA Jetson Platform.” Indian Institute of Technology Roorkee.

[5] Zhenxing Zhou, Yisiang Neo, King-Shan Lui, Vincent W.L. Tam, Edmund Y. Lam, and Ngai Wong. (2020). “A Portable Hong Kong Sign Language Translation Platform with Deep Learning and Jetson Nano.” The University of Hong Kong.

This is a rather rushed rough draft, as shown by how the ending of the background information better fits at the end of the document under future research, but we had to include future research in our literature review.