Machine Learning with the NVIDIA Jetson Platform

*Note: Sub-titles are not captured in Xplore and should not be used

1st Cox, Jason
The Governor's School for Science and Technology (of Aff.)
Hampton, United States
jason.cox@nhrec.org

2nd Chestnut, William
The Governor's School for Science and Technology
Hampton, United States
william.chestnut@nhrec.org

***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

This document is a model and instructions for LaTeX. Please observe the conference page limits.

II. Literature Review

A. Introduction

The NVIDIA Jetson is an embedded AI computing platform focussed on combining low-power with speed and accuracy. The embedded nature of devices like these allow for developments such as autonomous navigation, with Visual Simultaneous Localization and Mapping, or vision-based depth reconstruction on mobile platforms like exploration vehicles. These devices additionally make artificial intelligence more accessible to the common person. While not perfect, as this technology has much room for improvement, the Jetson allows for developers to create machine learning applications on a small scale without requiring a lot of power or cost, while still remaining effective and efficient. These developments have and will continue to have impacts in the fields of manufacturing, robotics, security, and customer experiences. This paper will review example cases of the use of the NVIDIA Jetson as well as go over analysis of the effectiveness of the device.

B. Overview of Machine Learning on NVIDIA Jetson

Designing hardware accelerators for neural networks or other machine learning applications involves a very precarious balance between constraints of low-power and high accuracy and throughput. (Mittal, 2019) The goal of the NVIDIA Jetson is to meet the above objectives and contribute to the developing interest in fields such as image processing, natural language processing, data analytics etc. The study from Halawa et al. characterizes the Jetson and concludes that the asymmetric nature of the CPU and GPU as well as the frequency balance point allow the developer to optimize performance while ensuring energy efficient computing. (Halawa et al., 2017) Making a device like the Jetson which can be so easily implemented into daily life encourages making artificial intelligence a part of the life of every person. The survey from Mittal explains numerous real-life implementations of the Jetson and highlights the goal of "AI for all".

C. SLAM Methods on Rovers with NVIDIA Jetson

Exploration vehicles such as those used on missions to Mars need accurate localization and autonomous navigation in order to be effective. (Giubilato et al., 2019) The first mission to Mars implemented wheel odometry, in which motion sensors were used to determine the robot's change in position, such as counting the number of wheel revolutions. However, due to rover wheels slipping in the sand, this method was highly inaccurate and a more effective way of measuring motion was required. This method was found in visual odometry, or more specifically, SLAM (Simultaneous Localization and Mapping). SLAM is essentially an application of machine learning in which the computer simultaneously builds a map and localizes a robot within it.

This technology is now being implemented via embedded computers such as the NVIDIA Jetson. The paper from Giubilato et al. reviewed the effectiveness and implementation of the Jetson on a ground rover using SLAM methods. Their evaluation showed the viability of the Jetson in this environment and provided a novel benchmark for visual SLAM algorithms on embedded computing platforms. The NVIDIA Jetson enables technologies like this and continues to make artificial intelligence more applicable and possible in real-world scenarios.

D. Vision-based Depth Reconstruction

Another example of the use of the NVIDIA Jetson is within vision-based depth reconstruction, a challenging problem that has been extensively studied in computer science. (Bokovoy et al., 2019) This technology deals with being able to judge depth from a single image. Sensors that can provide range

Identify applicable funding agency here. If none, delete this.

measurements are usually expensive, large, heavy, and power hungry. The study from Bokovoy et al. attempts to use the NVIDIA Jetson to solve these problems as it is inherently built to be the opposite of those qualifications. This analysis uses fully convolutional neural networks (FCNNs) in order to evaluate depth in real time using both a PC And the NVIDIA Jetson. They demonstrated that the models proposed were able to run effectively in real-time with state-of-the-art accuracy, once again establishing the Jetson as a viable way to easily and cheaply use artificial intelligence to solve problems in growing fields of mobile robotics, augmented reality, computer aided design etc.

E. Stereo Visual Implementation on NVIDIA Jetson

Embedded computing platforms have also demonstrated their place in real-time stereo vision systems. Stereo based 3-dimensional construction of a scene from an image has been studied in the past but most of these algorithms have extreme execution times, even on the most powerful computers. (Cui Dahnoun, 2019) The paper from Cui and Dahnoun demonstrates that a high power consumption processor would not work for autonomous applications of stereo vision, however, they show how an NVIDIA Jetson can be used to reduce computation cost and improve output quality. With their implementation, the paper concludes that the Jetson can reach performance faster than real-time requirements. The Jetson fills the gap of a low-power, low-cost, lightweight, and fast processor that can solve problems from location mapping, to depth measurement and 3D reconstruction.

F. Conclusion

These examples of implementations of the NVIDIA Jetson provide approaches to different problems that all revolve around a common necessity. A device that can be low-power and cost but highly effective. Embedded AI platforms make machine learning and artificial intelligence accessible in more fields of everyday life and having a device that can be used so flexibly expands the possibilities in AI.

III. Prepare Your Paper Before Styling

Before you begin to format your paper, first write and save the content as a separate text file. Complete all content and organizational editing before formatting. Please note sections III-A–III-E below for more information on proofreading, spelling and grammar.

Keep your text and graphic files separate until after the text has been formatted and styled. Do not number text heads—LaTeX will do that for you.

A. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

B. 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”.)

C. 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 . . .”

D. 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.

E. 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 [**?**].

F. 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).

G. 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.

H. 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] Bokovoy, A., Muravyev, K., Yakovlev, K. (2019). Real-time vision-based depth reconstruction with Nvidia Jetson. 2019 European Conference on Mobile Robots (ECMR). https://doi.org/10.1109/ecmr.2019.8870936

[2] J.Cui, H., Dahnoun, N. (2019). Real-time Stereo Vision Implementation on nvidia jetson TX2. 2019 8th Mediterranean Conference on Embedded Computing (MECO). https://doi.org/10.1109/meco.2019.8760027

[3] Giubilato, R., Chiodini, S., Pertile, M., Debei, S. (2019). An evaluation of ROS-compatible stereo visual slam methods on a Nvidia Jetson TX2. Measurement, 140, 161–170. https://doi.org/10.1016/j.measurement.2019.03.038

[4] Halawa, H., Abdelhafez, H. A., Boktor, A., Ripeanu, M. (2017). Nvidia Jetson Platform Characterization. Lecture Notes in Computer Science, 92–105. https://doi.org/10.1007/978-3-319-64203-1$_7$

[5] Mittal, S. (2019). A survey on optimized implementation of deep learning models on the Nvidia Jetson Platform. Journal of Systems Architecture, 97, 428–442. https://doi.org/10.1016/j.sysarc.2019.01.011