A Deep Learning Approach to Camera Pose Estimation

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***Abstract*—Camera pose estimation aims to find the absolute position of the camera within a given frame of a video. The estimation can be use in may ways, from object identification inside a known environment, to feature extraction combined with pose for 3D reconstruction.**

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

I. Introduction

The camera pose can be expressed through two component:

1) a tuple of three elements that identifies the coordinates x, y and z

$$x_c = (x, y, z) \quad x, y, z \in \mathbb{R} \tag{1}$$

2) a quaternion of four elements that identifies the rotation of the camera

$$q_c = (qw, qx, qy, qz) \quad qw, qx, qy, qz \in \mathbb{R} \tag{2}$$

Consequentially the pose is referred as $p_c = (x_c, q_c)$. It is important to notice that this is not the only available representation of a pose.

Given an image I_c captured by a camera C, an absolute pose estimator E tries to predict the $3D$ pose orientation and location of C in world coordinates, defined for some arbitrary reference $3D$ model. The *absolute pose estimation (APE)* problem can be formally defined as the problem of estimating a function E taking an image I_c caputered by a camera C and outputting its respective pose:

$$E(I_c) = (x_c, q_c) \tag{3}$$

Another problem related to APE is *relative pose estimation (RPE)*, in this kind of task the estimator takes two image I_c^1 and I_c^2 captured by C and aims to predict the relative pose between them. The eq. (3) becomes:

$$E(I_c^1, I_c^2) = (x_c^{rel^2}, q_c^{rel}) \tag{4}$$

where x_c^{rel} can be the absolute pose with *coordinates reference system* in I_c^1 or a translation vector from I_c^1 to I_C^2.

II. State of art

III. Dataset generation

A. Approaches tested

The deep learning approaches explained in this document are *supervised learning* techniques that require a labeled dataset. Several paths were tested in order to generate this kind of dataset:

- *IMU sensors*: usage of gyroscope and accelerometer sensors of a smarthphone to estimate the position of the camera during a video given a fixed origin point.
- *digital video*: usage of free online 3 dimensional datasets in which video can be recorder in a digital way.
- *motion capture system*: usage of a motion capture system that estimates the camera position following some tracking objects attached to the subject.
- *structure from motion techniques*: techniques that computes a sparse and dense reconstruction from a sequence of images.

The main problem encountered with IMU sensors was the high noise presents during acquisitions, the final signal was very dirty and the resolution was not acceptable for the dataset generation. A possible solution could have been the usage of a well calibrated hardware used in other kind of contexts.

Most of the 3 dimensional acquisitions available online for free are acquired with *depth sensors* or *LIDAR sensors*, for this reason although the camera pose estimation would not have presented any errors the images would have been at low quality.

The motion capture system is able to follows the position of the tracked objects with extremely precision, the main problematic remains the associated of poses to video captured from the camera held by the tracked subject. Other difficulties involved the calibration of the tool.

The techniques of structure from motion were invented with the goal of generate structures for which a huge amount of photos is available. The overall idea is to feed the algorithm with data in order to extract feature and build a recomposition of the environment. A step required in order to obtain a result is the esimation of the pose of images. These intermediate requirement have been exploited by uus to generate a labeled dataset.

B. Pipeline

The implemented pipeline require a video captured by any camera, it is not required any calibration of the sensor. It is composed by several steps:

1) video split: the captured video is split into many frames;
2) structure from motion: images obtained from the previous step are fed into a structure motion tool called *COLMAP*;
3) cross validation dataset: positions obtained during the camera estimation of the reconstruction process are split into three batches: train, validation, test.

IV. Models

V. Results

VI. Conclusion

VII. Ease of Use

A. Maintaining the Integrity of the Specifications

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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.

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- 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".
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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:

$$a + b = \gamma \tag{5}$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use "(5)", not "Eq. (5)" or "equation (5)", except at the beginning of a sentence: "Equation (5) is . . ."

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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.

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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.)
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- In your paper title, if the words “that uses” can accurately replace the word “using”, capitalize the “u”; if not, keep using lower-cased.
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- 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 [7].

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

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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

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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.

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For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

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