Centralized State Estimation of Distributed Maritime Autonomous Surface Oceanographers ⋆

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Abstract: This paper considers the subject of running a centralized controller for the purpose of navigating a small Autonomous Surface Vehicle (ASV). The centralized controller is using a Kalman filter as a state predictor to improve the precision of the navigational aids mounted aboard. The work presents the design of the motion control system as well as the development of a protocol used to push through as much data on a standard 9.6 kbps data link simplex link. The performance for the algorithms developed in this project, have been tested in Limfjorden in Aalborg, and towards the end, results of these tests are shown.

1. INTRODUCTION

As up to date mapping of the coastal areas around Greenland is not available, and the process of creating these are a both time consuming and expensive task. One way to reduce both the costs and the amount of time invested in such a project could be to develop small autonomous drones to carry out this task.

These drones should be controlled by a mothership, which would utilize a simple data link, both to preserve bandwith, but also to make the duration at which the ships are able to sail as long as possible, by limiting the power consumption.

Currently the main focus of autonomous vehicles have been on aerial, ground and underwater vehicles, why there is close to no research going on about small autonomous surface vessels. An example of such a vessel is the Stingray ASV developed by Isreali Based Elbit Systems. The purpose of this vehicle is somewhat military related, where the purpose of measuring the coastal areas around Greenland are purely humanitarian,

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1.1 Problem statement

Hypothesis 1. Is it possible to develop a centralized state estimator for use in the maritime environment using a small data link

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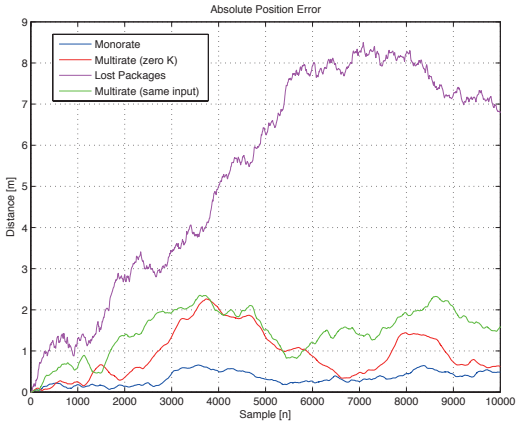

Fig. 1. Bifurcation: Plot of local maxima of x with damping a decreasing

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Some words might be appropriate describing equation (1), if we had but time and space enough.

$$\frac{\partial F}{\partial t} = D\frac{\partial^2 F}{\partial x^2}. \quad (1)$$

See Able [1956], Able et al. [1954], Keohane [1958] and Powers [1985].

A subsubsection This equation goes far beyond the celebrated theorem ascribed to the great Pythagoras by his followers.

Theorem 2. The square of the length of the hypotenuse of a right triangle equals the sum of the squares of the lengths of the other two sides.

Proof. The square of the length of the hypotenuse of a right triangle equals the sum of the squares of the lengths of the other two sides.

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Use either SI as primary units. Other units may be used as secondary units (in parentheses). This applies to papers in data storage. For example, write $15Gb/cm^2$ ($100Gb/in^2$). An exception is when English units are used as identifiers in trade, such as 3.5 in 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 in an equation. The SI unit for magnetic field strength H is A/m. However, if you wish to use units of T, either refer to magnetic flux density B or magnetic field strength symbolized as $\mu_0 H$. Use the center dot to separate compound units, e.g., $A \cdot m^2$.

5. HELPFUL HINTS

5.1 Figures and Tables

Figure axis labels are often a source of confusion. Use words rather than symbols. As an example, write the quantity Magnetization, or Magnetization M, not just M. Put units in parentheses. Do not label axes only with units. As in Fig. 1, for 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.

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5.3 Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have already been defined in the abstract. Abbreviations such as IFAC, SI, ac, and dc

do not have to be defined. Abbreviations that incorporate periods should not have spaces: write C.N.R.S., not C. N. R. S. Do not use abbreviations in the title unless they are unavoidable (for example, IFAC in the title of this article).

5.4 Equations

Number equations consecutively with equation numbers in parentheses flush with the right margin, as in (1). First use the equation editor to create the equation. Then select the Equation markup style. Press the tab key and write the equation number in parentheses. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Use parentheses to avoid ambiguities in denominators. Punctuate equations when they are part of a sentence, as in

$$\int_0^{r_2} F(r,\varphi) dr d\varphi = [\sigma r_2/(2\mu_0)] \cdot \int_0^{\inf} exp(-\lambda|z_j - z_i|)\lambda^{-1} J_1(\lambda r_2) J_0(\lambda r_i) d\lambda \tag{2}$$

Be sure that the symbols in your equation have been defined before the equation appears or immediately following. Italicize symbols (T might refer to temperature, but T is the unit tesla). Refer to (1), not Eq. (1) or equation (1), except at the beginning of a sentence: Equation (1) is ... .

5.5 Other Recommendations

Use one space after periods and colons. Hyphenate complex modifiers: zero-field-cooled magnetization. Avoid dangling participles, such as, Using (1), the potential was calculated. [It is not clear who or what used (1).] Write instead, The potential was calculated by using (1), or Using (1), we calculated the potential.

A parenthetical statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.) Avoid contractions; for example, write do not instead of dont. The serial comma is preferred: A, B, and C instead of A, B and C.

6. CONCLUSION

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

ACKNOWLEDGEMENTS

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Appendix A. A SUMMARY OF LATIN GRAMMAR

Appendix B. SOME LATIN VOCABULARY