An Exegesis of Ontological Hermeneutics

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***Abstract*—The abstract is a one-paragraph summary of the whole paper. Out of respect for busy readers, it gets right to the point. The first 2-3 sentences unpack the title and motivate the paper. The remainder briefly offers context (if necessary) and further describes the paper's method, explaining how it fills a gap in the existing literature. The abstract reveals all the paper's main results in language that is bold but truthful.**

An example for a paper titled "Deep urban unaided precise GNSS vehicle positioning":

This paper presents the most thorough study to date of vehicular carrier-phase differential GNSS (CDGNSS) positioning performance in a deep urban setting unaided by complementary sensors. Using data captured during approximately 2 hours of driving in and around the dense urban center of Austin, TX, a CDGNSS system is demonstrated to achieve 17-cm-accurate 3D urban positioning (95% probability) with solution availability greater than 87%. The results are achieved without any aiding by inertial, electro-optical, or odometry sensors. Development and evaluation of the unaided GNSS-based precise positioning system is a key milestone toward the overall goal of combining precise GNSS, vision, radar, and inertial sensing for all-weather high-integrity high-absolute-accuracy positioning for automated and connected vehicles. The system described and evaluated herein is composed of a densely-spaced reference network, a software-defined GNSS receiver, and a real-time kinematic (RTK) positioning engine. A performance sensitivity analysis reveals that navigation data wipeoff for fully-modulated GNSS signals and a dense reference network are key to high-performance urban RTK positioning. A comparison with existing unaided systems for urban GNSS processing indicates that the proposed system has significantly greater availability or accuracy.

***Index Terms*—urban vehicular positioning; CDGNSS; low-cost RTK positioning.**

I. Introduction

In the introduction:

- **Background:** Set the stage in a compelling way to draw the reader in.
- **Opportunity/Need:** Identify a need or an opportunity.
- **The status quo:** Review the state of the art.
- **Gap:** Mind the gap! Convince your reader that there is an important deficiency (gap) in the existing literature or practice, and that your paper will save the day by filling in/bridging this gap. Otherwise, why should your reader take time to read the paper?
- **Vision:** Invite the reader to imagine the way the world could be if only the gap could be bridged.
- **Contributions:** Clearly enumerate the paper's contributions.

What follows is an example introduction taken from [1].

FUTURE Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) connectivity will permit vehicles to relay their positions and velocities to each other with millisecond latency, enabling tight coordinated platooning and efficient intersection management. More ambitiously, broadband V2V and V2I enabled by 5G wireless networks will permit vehicles to share unprocessed or lightly-processed sensor data. *Ad hoc* networks of vehicles and infrastructure will then function as a single sensing organism. The risk of collisions, especially with pedestrians and cyclists—notoriously unpredictable and much harder to sense reliably than vehicles—will be significantly reduced as vehicles and infrastructure contribute sensor data from multiple vantage points to build a blind-spot-free model of their surroundings.

Such collaborative sensing and traffic coordination requires vehicles to know and share their own position. How accurately? The proposed Dedicated Short Range Communications (DSRC) basic safety message, a first step in V2V coordination, does not yet define a position accuracy requirement, effectively accepting whatever accuracy a standard GNSS receiver provides [2]. But automated intersection management [3], tight-formation platooning, and unified processing of sensor data—all involving vehicles of different makes that may not share a common map—will be greatly facilitated by globally-referenced positioning with sub-30-cm accuracy.

Poor weather also motivates high-accuracy absolute positioning. Every automated vehicle initiative of which the present authors are aware depends crucially on lidar or cameras for fine-grained positioning within their local environment. But these sensing modalities perform poorly in low-visibility conditions such as a snowy whiteout, dense fog, or heavy rain. Moreover, high-definition 3D maps created with lidar and camera data, maps that have proven crucial to recent progress in reliable vehicle automation, can be rendered dangerously obsolete by a single snowstorm, leaving vehicles who rely on such maps for positioning no option but to fall back on GNSS and radar to navigate a snow-covered roadway in low-visibility conditions. When, as is often the case on rural roads, such snowy surroundings offer few radar-reflective landmarks, radar too becomes useless. GNSS receivers operate well in all weather conditions, but only a highly accurate GNSS solution, e.g., one whose absolute errors remain under 30 cm 95% of the time, could prevent a vehicle's drifting onto a snow-covered road's soft shoulder. Code- and Doppler-based GNSS solutions can be asymptotically accurate (averaged over many sessions) to better than 50 cm, which may be adequate for digital mapping [4], but they will find it challenging to meet a 30 cm 95% stand-alone requirement, even with modernized GNSS offering wideband signals at multiple frequencies.

Carrier-phase-based GNSS positioning—also referred to as precise GNSS positioning even though it actually offers absolute accuracy, not just precision (repeatability)—can meet the most demanding accuracy requirements envisioned for automated and connected vehicles, but has historically been either too expensive or too fragile, except in open areas with a clear view of the overhead satellites, for widespread adoption. Coupling a carrier-phase differential GNSS (CDGNSS) receiver with a tactical grade inertial sensor, as in [5]–[8] enables robust high-accuracy positioning even during the extended signal outages common in dense urban areas. But GNSS-inertial systems with tactical-grade inertial measurement units (IMUs) cost tens of thousands of dollars and have proven stubbornly resistant to commoditization. Coupling a GNSS receiver with automotive- or industrial-grade IMUs is much more economical, and significantly improves performance, as shown in [9]. But such coupling only allows approximately 5 seconds of complete GNSS signal blockage before the IMU no longer offers a useful constraint for so-called integer ambiguity resolution [10], which underpins the fastest, most accurate, and most robust CDGNSS techniques, namely, single-baseline RTK, network RTK, and PPP-RTK [11], [12].

Previous research has suggested an inexpensive technique for robustifying RTK positioning: tightly coupling carrier-phase-based GNSS positioning with inertial sensing and vision [13], [14]. Such coupling takes advantage of the remarkable progress in high-resolution, low-cost cameras within the intensely competitive smartphone market. The current authors are engaged in developing a high-integrity RTK-vision system for high-accuracy vehicular positioning in rural and urban environments. Further coupling with radar will make the system robust to low-visibility conditions.

As a step toward this goal, it is of interest to evaluate the performance of stand-alone RTK techniques—those unaided by IMUs, odometry, or vision—in urban environments. Such a study will reveal why and when aiding is necessary, and how an RTK positioning system might behave if aiding were somehow impaired or unavailable, whether due to sensor faults or, in the case of exclusive visual aiding, poor visibility conditions.

Little prior work has explored unaided vehicular RTK performance in urban environments, no doubt because performance results have historically been dismal. Short-baseline RTK experiments between two vehicles in [15] revealed that multi-frequency (L1-L2) GPS and Glonass RTK yielded poor results in residential and urban environments. Only along a mountain highway with a relatively clear view of the sky was availability greater than 90% and accuracy better than 30 cm. RTK positioning in downtown Calgary was disastrous, with less than 60% solution availability and RMS errors exceeding 9 meters.

More recently, Li et al. [9] have shown that, with the benefit of greater signal availability, unaided professional-grade dual-frequency GPS + BDS + GLONASS RTK can achieve correct integer fixing rates of 76.7% on a 1-hour drive along an urban route in Wuhan, China. But Li et al. do not provide data on the incorrect fixing rate, nor a full error distribution, so the significance of their results is difficult to assess.

Recent urban RTK testing by Jackson et al. [16] indicates that no low-to-mid-range consumer RTK solution offers greater than 35% fixed (integer-resolved) solution availability in urban areas, despite a dense reference network and dual-frequency capability. A key failing of existing receivers appears to be their slow recovery after passing under bridges or overpasses.

This paper describes and evaluates an unaided RTK positioning system that has been designed for vehicular operation in both rural and urban environments. Preliminary performance results were published in a conference version of this paper [17]. The current paper improves on the conference version in four ways: (1) the test route is both more challenging and more comprehensive, (2) a proper independent ground truth trajectory is used as the basis of error evaluation, (3) data modulation wipeoff for improved carrier tracking robustness is applied not only on GPS L1 C/A signals, as previously, but now also on SBAS L1 signals, and (4) the performance benefit of vehicle GNSS antenna calibration is assessed.

This paper's primary contributions are (i) a demonstration of the performance that can be achieved with a low-cost software-defined unaided RTK GNSS platform in a dense urban environment, and (ii) an evaluation of the relative importance of various factors (e.g., data bit wipeoff, age of reference data, rover antenna calibration, reference network density) to the overall system performance.

To stimulate further innovation in urban precise positioning, all data from this paper's urban driving campaign have been posted at http://radionavlab.ae.utexas.edu under "Public Datasets," including wideband (10 MHz) intermediate frequency samples from both the reference and rover antennas, RINEX-formatted rover and reference observables, and the ground truth trajectory.

II. Tables

Captions should appear above tables. Use the full word Table to refer to a table in your paper; e.g., "Results of the study are shown in Table I." Follow the format of Table I and Table II.

TABLE I: Chi-square Values for Fits to Nakagami-m and Rice Distributions

Data Source	Sets, DOF	Nakagami-m	Rice
Wideband UHF	79, 8	11.8 ± 8.8	9.0 ± 4.3
GPS L_1	33, 7	8.42 ± 5.9	7.7 ± 5.7

III. Figures

1) Use Fig. instead of Figure to refer to a figure (per IEEE style guide). E.g., "Fig. (4) illustrates this point by plotting x vs. y."
2) Only use color in figures if necessary. Many figures look better in print if done in grayscale. See the example figures in the writing templates.
3) Try to make figure captions sufficient, or nearly so, to describe the figure. For example, the caption should explain what the various lines or enclosed regions in a

TABLE II: Scintillation Effects Comparison: Empirical Truth Data

Parameters			Truth Scint.		Synthetic Scint.	
S_4	τ_0 (s)	T (s)	σ_φ (deg)	N_s	σ_φ (deg)	N_s
0.87	0.18	200	16.4	32	17.5 ± 0.5	35.9 ± 4.7
1.0	0.36	265	14.1	37	15.0 ± 0.5	41.6 ± 5.9
0.69	0.18	174	12.7	12	11.8 ± 0.9	5.6 ± 1.6
0.87	0.26	225	11.6	23	12.7 ± 0.5	19.2 ± 4.6
0.61	0.47	162	3.96	0	3.63 ± 0.2	0.10 ± 0.3
0.96	0.09	81	28.5	60	32.7 ± 1.0	69.4 ± 5.8
0.95	0.26	123	14.1	21	15.6 ± 0.5	19.8 ± 3.7
0.51	0.71	138	2.12	0	1.60 ± 0.1	0 ± 0

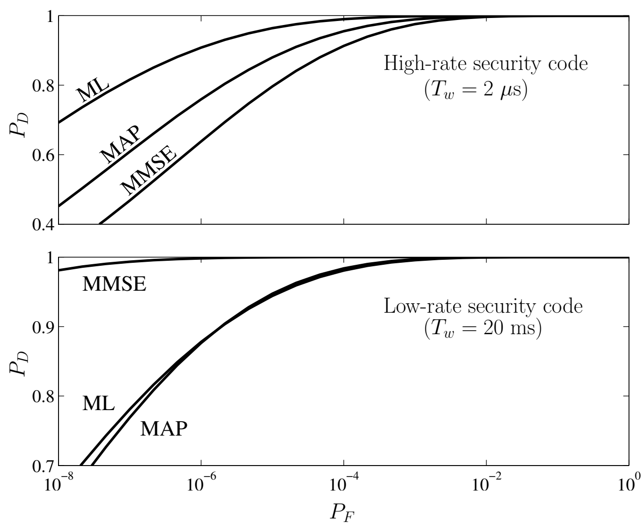

Fig. 1: ROCs for the ML, MAP, and MMSE security code estimation strategies under the following scenario: $(C/N_0)_s =$ 54 dB-Hz, $(C/N_0)_r = 48$ dB-Hz, $\eta = 1$, $d = 0$, $N = 400$. Top panel: High-rate security code with $T_w = 2$ μs. Bottom panel: Low-rate security code with $T_w = 20$ ms.

figure mean. Push description from the text to the caption to avoid duplication.

4) Avoid legends in figures; prefer labels that point with lines directly to the object being labeled.
5) Make figures as small as they can be while remaining clearly legible and conveying their message. Often, you can use `subplot(211)` in Matlab to cut a figure height in half.
6) Figures should not have titles on top. All relevant information should be put in the caption.
7) Ensure that each figure's x and y axis labels, and all internal labels, are in the same or similar font as the text and are large enough to read easily. A rule of thumb: make labels no smaller than the caption font. You can use `figset.m` to change native Matlab font to one that more closely resembles LaTeX default font and increase its size.

Have a look at Fig. 1 as an example. Todd uses an application called xfig to add labels and LaTeX symbols directly to eps figures. It's old school, but he hasn't found a better alternative for perfectly matching the LaTeX fonts in the text.

Sometimes you have to take up both columns with a figure, as in Fig. 2.

IV. Algorithms

Use the full word Algorithm to refer to an algorithm in your paper; e.g., "Algorithm 1 shows the pseudocode for this process." Use the following format for algorithms. Note that variables should be written in mathematical italic font, whereas functions can be written either in typewriter font; e.g.,

$$D_\mathrm{m} = \texttt{toOGM}\left(\boldsymbol{p}_\mathrm{m}^W - \boldsymbol{t}_k^V, \delta t\right)$$

or in mathematical italic font.

Algorithm 1: `fastGlobalAlign`

Input : $\boldsymbol{p}_\mathrm{m}^W$, $\boldsymbol{p}_{\mathrm{b},1:k}^B$, $\boldsymbol{t}_{1:k}^V$, $\phi_{1:k}^V$, σ_t, σ_ϕ, δt, $\delta\phi$
Output: $\widehat{\boldsymbol{\Theta}}$

$D_\mathrm{m} = \texttt{toOGM}\left(\boldsymbol{p}_\mathrm{m}^W - \boldsymbol{t}_k^V, \delta t\right)$
$\tilde{D}_\mathrm{m} = \texttt{FFT2}\left(\texttt{pad}\left(D_\mathrm{m}, 3\sigma_t\right)\right)$

$\boldsymbol{p}_{\mathrm{b},1:k}^V = R\left(\phi_{1:k}^V\right)\boldsymbol{p}_{\mathrm{b},1:k}^B + \boldsymbol{t}_{1:k}^V$
$D_\mathrm{b} = \texttt{toOGM}\left(\boldsymbol{p}_{\mathrm{b},1:k}^V - \boldsymbol{t}_k^V, \delta t\right)$
$\tilde{D}_\mathrm{b} = \texttt{FFT2}\left(\texttt{pad}\left(D_\mathrm{b}, 3\sigma_t\right)\right)$

$n = 3\sigma_t/\delta t$
$m = 3\sigma_\phi/\delta\phi$
for i = *-m:m* **do**
  $\Delta\phi = i\delta\phi$
  $\tilde{D}_\mathrm{b}^{\Delta\phi} = \texttt{rotate2}\left(\tilde{D}_\mathrm{b}, \Delta\phi\right)$
  $\mathsf{R}[i,:,:] = \texttt{IFFT2}\left(\tilde{D}_\mathrm{m} \circ \texttt{conj}\left(\tilde{D}_\mathrm{b}^{\Delta\phi}\right)\right)[-n:n, -n:n]$
end
$\widehat{\boldsymbol{\Theta}} = \operatorname{argmax}(\mathsf{R})$

Algorithm 2: $\mathrm{IB}(\hat{\boldsymbol{z}}, L)$

Input : $\hat{\boldsymbol{z}} \in \mathbb{R}^m$, $L \in \mathbb{R}^{m \times m}$
Output: $\check{\boldsymbol{z}} \in \mathbb{Z}^m$

$\hat{\boldsymbol{z}}_\mathrm{c} = \hat{\boldsymbol{z}}$
for i = *1:m* **do**
  $\check{z}_i = \lfloor \hat{z}_{\mathrm{c}i} \rceil$
  $\check{\epsilon}_{\mathrm{c}i} = \hat{z}_{\mathrm{c}i} - \check{z}_i$
  for j = *i+1:m* **do**
    $\hat{z}_{\mathrm{c}j} = \hat{z}_{\mathrm{c}j} - l_{ij}\check{\epsilon}_{\mathrm{c}i}$
  end
end

V. Stylistic Conventions

A. Mathematical Notation

1) Define *all* mathematical notation that you introduce unless it's been previously defined. Where possible, introduce notation *before* presenting the equation involving the notation.
2) Put units in straight font, not italics or math font; e.g., cm not cm.
3) Write subscripts that represent indices or are just one letter long in the usual mathematical italic font; e.g., x_{ak}.

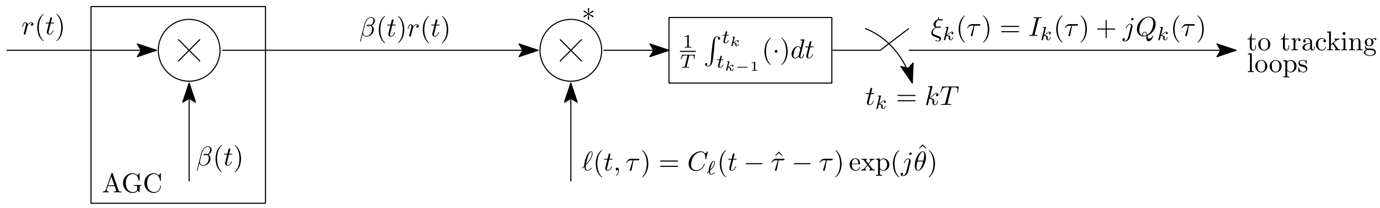

Fig. 2: Block diagram of the standard AGC, correlation, and accumulation operations in a GNSS receiver. The product of the AGC-scaled incoming signal $\beta(t)r(t)$ and the conjugate of the local replica $\ell(t, \tau)$ is accumulated over T seconds to produce the discrete complex-valued accumulation product $\xi_k(\tau)$. For notational convenience, the accumulation product has been scaled by $1/T$.

Write subscripts that are words or abbreviated words in roman type: x_{max}.

4) Defining `newcommand` macros for the paper can make it easier to repeatedly write complicated LaTeX math expressions; e.g., F_{c1}, F_{s}, F_{sr}.

B. *Punctuation*

Use American Style punctuation. This website is a good reference. Note that American style quotations include commas and periods within the quotation, even if they are not actually part of what was quoted; e.g.,

> "Economic systems," according to Professor White, "are an inevitable byproduct of civilization, and are, as John Doe said, 'with us whether we want them or not.'"

This style is not as sensible as British English, but it's the convention on this side of the pond.

C. *Abbreviations*

1) With few exceptions, define all abbreviations/acronyms used in the paper (e.g., UAV, GNSS, IMU, etc.). Exceptions are those that have become so common that they're part of everyday vernacular (radar, GPS).

D. *References*

1) Never start a sentence with the actual numerical citation (e.g., "[2] presents an optimal ..."). Prefer instead "Reference [2] ..." or "The authors of [2]..." or "Durge et al. present in [2] an optimal ..."

E. *Signposts*

Busy readers rarely read a paper straight through from abstract to conclusions. Instead, they tend to sample bits and pieces *a la carte*. For these readers, and even for sequential readers who may need some guidance on where they are and what is to come, it's helpful to start off each major section with a *signpost*—a brief summary of what the reader now knows and what he can expect to learn from that section. Sometimes the section title, perhaps in combination with the first sub-section title, sufficies. In other cases, a few sentences are needed to orient the reader. Here is an example of a few-sentence signpost at the beginning of a section:

> The model of road user behavior presented above applies to human decisions. Autonomous vehicles are likely to respond very differently, because they are fundamentally unable to win the game of chicken. Moreover, they are likely to obey the rules of the road far more than human drivers, particularly in safety-critical situations. This section elaborates such reasoning.

VI. Conclusions

Like the abstract, this section should give a recap of the whole paper. Write in simple past tense. Don't assume the reader has read the paper.

Example:

A real-time kinematic (RTK) positioning system tailored for urban vehicular positioning has been described and evaluated. To facilitate performance comparison against similar systems, the system was tested without any benefit of aiding by inertial or electro-optical sensors. Over nearly 2 hours of urban testing, including multiple passes through Austin's dense urban center, the system achieved an 85% probability of correct integer fix for a 2.4% probability of incorrect fix, resulting in 3D positioning errors smaller than 17 cm (95%). A performance sensitivity analysis revealed that navigation data bit prediction on fully-modulated GNSS signals is key to high-performance urban RTK positioning, and that a dense reference network, carrier tracking bandwidth adaptation, and rover antenna calibration each offer a significant integrity benefit. A comparison with existing unaided systems for urban GNSS processing indicates that the proposed system has a significant advantage in availability and/or accuracy.

Acknowledgments

Example:

This work was supported in part by the U.S. Department of Transportation (USDOT) under the University Transportation Center (UTC) Program Grant 69A3552047138 (CARMEN), and by affiliates of the 6G@UT center within the Wireless Networking and Communications Group at The University of Texas at Austin.

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