IONet: Learning to Cure the Curse of Drift in Inertial Odometry

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AAAI 2019 29\textsuperscript{th} Jan 2019
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Why we study inertial localization

**GNSS:**
- serious attenuation and multi-path effect

**Inertial sensors:**
- Unique, completely self-contained
- Widespread, deployed on smartphones, robots, drones
Indoor Pedestrian Navigation

Existing Methods:
Strapdown Inertial Navigation System (SINS)

Pedestrian Dead Reckoning (PDR)
The Curse of Drift

Attitude Update:

Direction Cosine \( \mathbf{C}_b^n(t) = \mathbf{C}_b^n(t - 1) \ast \mathbf{\Omega}(t) \) (1)

Angular Velocity \( \mathbf{\Omega}(t) = \mathbf{C}^{b_{t-1}}_{b_t} = I + \frac{\sin(\sigma)}{\sigma} [\sigma \times] + \frac{1 - \cos(\sigma)}{\sigma^2} [\sigma \times]^2 \) (3)

Relative Rotation Matrix

Velocity Update:

Velocity \( \mathbf{v}(t) = \mathbf{v}(t - 1) + ((\mathbf{C}_b^n(t - 1)) \ast \mathbf{a}(t) - \mathbf{g}_n) dt \) (4)

Gravity

Location Update:

Location \( \mathbf{L}(t) = \mathbf{L}(t - 1) + \mathbf{v}(t - 1) dt \) (5)

Accelerations
Tracking Down a Cure

Velocity

\[
[C_b^n \ v \ L]_t = f([C_b^n \ v \ L]_{t-1}, [a \ w]_t)
\]

Angular Velocity

Orientation
Location
Accelerations

Location Update

\[
\Delta L = \int_{t=0}^{n-1} v(t) \, dt
\]

- Break the cycle of continuous Integration
- Segment inertial data into independent windows
Sequence-based Model

\[
(\Delta l, \Delta \psi) = f_\theta(v^b(0), g^b_0, \hat{a}_{1:n}, \hat{w}_{1:n})
\]

Initial Velocity Gravity

Polar Vector

Inertial measurements

Location Update

\[
\begin{align*}
x_n &= x_0 + \Delta l \cos(\psi_0 + \Delta \psi) \\
y_n &= y_0 + \Delta l \sin(\psi_0 + \Delta \psi)
\end{align*}
\]

Inertial measurements

Polar Vector

Learning the parameters

\[
\theta^* = \arg \min_{\theta} \ell(f_\theta(X), Y)
\]

Loss function

\[
\ell = \sum \| \Delta \tilde{l} - \Delta l \|^2_2 + \kappa \| \Delta \tilde{\psi} - \Delta \psi \|^2_2
\]
Figure 3: Overview of IONet framework
Comparison of Different Frameworks

![Comparison of Different Frameworks](image.png)
Tests Involving Multiple Users and Devices

Figure 4: Performance in experiments involving different users.

Figure 5: Performance in experiments involving different devices.
Large-scale Indoor Localization

Figure 6: Trajectories on Floor A

(a) Handheld

(b) In Pocket

(c) In Handbag

Figure 7: Trajectories on Floor B

(a) Handheld

(b) In Pocket

(c) In Handbag
Trolley Tracking Experiment

(a) Ground Truth
(b) IONet
(c) Tango

Figure 9: Trolley tracking trajectories of (a) Ground Truth (b) IONet (c) Tango

Figure 12: CDF of Trolley Tracking
Contributions

- Cast the inertial tracking problem as a sequential learning approach.
- Propose the first deep neural network (DNN) framework that learns location transforms from raw IMU data.
- Conducted extensive experiments across different attachments, users/devices and new environment.
- In addition, our model can generalize to a more general motion.
Thanks for your attention!

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