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Aligning Map Patches to Estimate Lane Marker Geometry

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ABSTRACT

Accurate lane marker geometry is important for autonomous vehicles to navigate roads safely and efficiently. Map patches provide valuable data for estimating lane marker geometry but need to be aligned before they can be used to estimate the lane marker geometry. Traditional feature-based approaches for aligning map patches are unsuitable for map patches that include only lane markers, which typically lack distinctive features. This disclosure describes techniques for aligning map patches, specifically aligning lane markers on road geometries. Per the technique, correspondence between lane markers is determined, focusing on smooth curves without distinct features. Map patch alignment technique combines sensor observations from different vehicles to infer the lane marker geometry and update a digital map. An objective function is defined that includes a regularization term on the magnitude of rotation and translation. The techniques involve estimating the rotation angle directly using a nonlinear solver, forming correspondences between lane markers, and using the area between lane markers as a distance metric. The techniques bring together multiple map patches that each represent a segment of the roadway and position the patches correctly relative to each other.

KEYWORDS

- Map patch
- Patch alignment
- Lane marker
- Point cloud
- Digital map
- Autonomous vehicle

BACKGROUND

Accurate lane marker geometry is important for autonomous vehicles to navigate roads safely and efficiently. Map patches - collections of lane marker geometries and sign locations for a stretch of roadway (e.g., 20 meters, 100 meters, 200 meters, etc.) - provide valuable data for estimating lane marker geometry. However, map patches need to be aligned before they can be used to estimate the lane marker geometry.

Traditional methods for aligning map patches often rely on feature-based approaches, which identify and match distinct features like corners or edges to form correspondences between patches. However, lane markers typically lack these distinctive features, making them more difficult to align.

DESCRIPTION

This disclosure describes techniques for aligning map patches relative to each other, enabling the computation of mean lane marker geometry with enhanced accuracy. A modification of algorithms designed for aligning 3D point clouds addresses the specific challenges of aligning lane markers in map patches.

Per the techniques, map patches are aligned with each other in a way that minimizes a global objective function. The map patches may be obtained from sensors on vehicles, with user permission to use the map patches for lane marker alignment in a digital map. The objective function extends the existing alignment algorithm (as described in [1]) by adding a regularization term on the magnitude of rotation and translation, estimating the rotation angle directly using a nonlinear solver, forming correspondences between lane markers instead of sampled points, and using the area between lane markers as a distance metric. The objective function is minimized using any suitable technique for modeling and solving optimization problems.

$$\Psi(\theta_1, \theta_2, \ldots, \theta_N, \mathbf{b}_1, \mathbf{b}_2, \ldots, \mathbf{b}_N) = \sum_{i<j} \sum_{(\mathbf{p},\mathbf{q}) \in C_{ij}} \rho_d \left(d \left(\mathbf{R}(\theta_i)\mathbf{p} + \mathbf{b}_i, \mathbf{R}(\theta_j)\mathbf{q} + \mathbf{b}_j \right) \right) + \beta_\theta \sum_{k=1}^{N} \rho_a(\theta_k) + \beta_b \sum_{l=1}^{N} \rho_b(\mathbf{b}_l),$$

Fig. 1: Objective function

In Fig. 1, θ_i represents a rotation angle of map patch i, b_i represents a two-dimensional (2D) translation of map patch i, $C_{\{ij\}}$ represents a set of lane marker correspondences between map patches i and j, {p, q} represents a correspondence between lane marker polylines p and q, β represents weights on the translation and rotation regularizers, and ρ represents loss functions. The utilization of a robust loss function on the initial term, responsible for determining alignment cost, enhances robustness to outliers resulting from inaccurate correspondences.

Correspondences between lane markers are determined by identifying the lane marker in map patch A that corresponds to a lane marker in map patch B. A cost is computed for each potential association pair. The alignment of lane markers within map patches is optimized by adding regularization terms on rotation and translation magnitudes. Regularization terms are added to a cost function that penalizes deviations from the actual measurement locations. For example, penalties are imposed for each neighbor of lane marker A that fails to match a neighbor of lane marker B in terms of lateral distance and pattern/color. For instance, if lane marker A has two white dashed lane markers at lateral distances of +/- 5m and lane marker B exhibits a similar configuration, the cost is deemed zero. However, if lane marker B has only one matching neighbor at +5m, the cost is equivalent to the penalty for the missing neighbor.

Furthermore, contextual clues such as the surrounding geometry and lane marker characteristics are utilized to help determine a contextual score and identify the correct lane marker correspondences. For example, a lane marker in the right lane of a freeway is required to have a solid yellow line to the right and a dashed white line to the left. By considering these contextual clues, the system can more accurately match lane markers between different patches. Additionally, a metric that measures the lateral distance between two points is utilized. The metric is based on the area between the two points and is robust to changes in orientation. This is particularly important for lane markers as they can be skewed or rotated without significantly changing their overall shape.

The final association cost is derived from the sum of the contextual score and the initial lateral distance between markers. The identification of associations minimizing the sum of association costs is accomplished using an assignment solver.

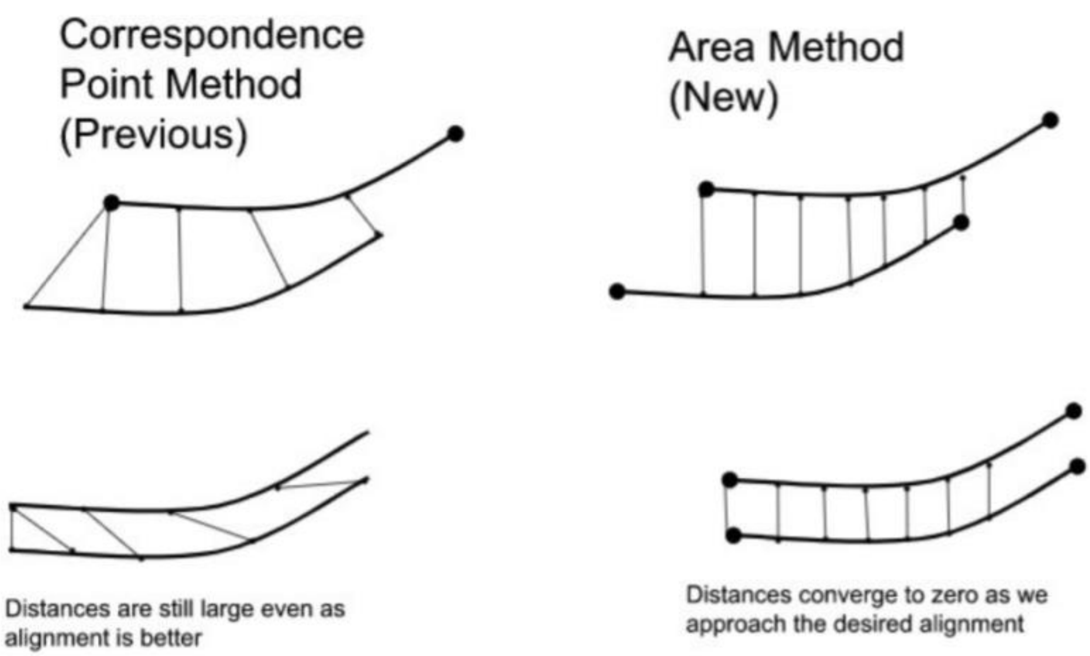

Fig. 2: Area method wherein objective function is used to minimize the area between the lane markers

Subsequent to determining the association pairs, the objective function is utilized to minimize the area between the lane markers, as shown in Fig. 2. Area-based minimization serves to overcome the issue where distances between initial correspondence points may not converge to zero as the markers approach optimal alignment. This is due to the absence of distinct features like corners in lane markers that can be matched. The area-based approach ensures that the alignment cost is reduced to zero when the markers coincide. This is essential for estimating lane marker geometry and updating maps which are important for autonomous vehicle navigation.

The described techniques enable updating lane markers quickly, e.g., within days or weeks after a change, rather than months. The lane information can be provided via a digital map or navigation application. This can improve navigation experience for any vehicle that uses lane information from the digital map. In various implementations, different optimizers, cost functions, or distance metrics may be utilized. Further, the described techniques are applicable for any application where there is a need to estimate a polyline-based geometry from small, noisy samples of true geometry.

Further to the descriptions above, a user may be provided with controls allowing the user to make an election as to both if and when systems, programs, or features described herein may enable the collection of user information (e.g., information about sensor observations from a vehicle, a user's preferences, or a user's current location), and if the user is sent content or communications from a server. In addition, certain data may be treated in one or more ways before it is stored or used so that personally identifiable information is removed. For example, a user's identity may be treated so that no personally identifiable information can be determined for the user, or a user's geographic location may be generalized where location information is obtained (such as to a city, ZIP code, or state level) so that a particular location of a user cannot be determined. Thus, the user may have control over what information is collected about the user, how that information is used, and what information is provided to the user.

CONCLUSION

This disclosure describes techniques for aligning map patches, specifically aligning lane markers on road geometries. Per the technique, correspondence between lane markers is determined, focusing on smooth curves without distinct features. Map patch alignment technique combines sensor observations from different vehicles to infer the lane marker geometry and update a digital map. An objective function is defined that includes a regularization term on the magnitude of rotation and translation. The techniques involve estimating the rotation angle directly using a nonlinear solver, forming correspondences between lane markers, and using the area between lane markers as a distance metric. The techniques bring together multiple map patches that each represent a segment of the roadway and position the patches correctly relative to each other.

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