# Supplementary Material: A Belief Propagation Algorithm for Multipath-Based SLAM

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## I. List of Symbols

Table I contains the list of important symbols used in [1].

## II. Additional Experiments

In the absence of any prior information, the estimated agent trajectory and feature map contain an arbitrary translation and rotation relative to the true positions, because our algorithm is based solely on relative range measurements between the agent and the PAs. In the case of only one PA (prior knowledge of PA 1), the estimated agent trajectory and feature map contains an arbitrary rotation relative to the true positions.

| Notation | Definition | Notation | Definition |
|---|---|---|---|
| $n$ | time step | $\mathcal{K}_n^{(j)}$ | set of potential features (PFs) |
| $J$ | number of physical anchors (PAs) | $K_n^{(j)}$ | number of PFs |
| $\mathcal{L}_n^{(j)}$ | set of features (virtual anchors (VAs)) | $\boldsymbol{y}_{k,n}^{(j)}$ | augmented PF state $\boldsymbol{y}_{k,n}^{(j)} = [\boldsymbol{a}_{k,n}^{(j)\mathrm{T}}\ r_{k,n}^{(j)}]^{\mathrm{T}}$ containing its positions $\boldsymbol{a}_{k,n}^{(j)}$ and binary existence variable $r_{k,n}^{(j)}$ |
| $L_n^{(j)}$ | number of VAs | $\tilde{\boldsymbol{y}}_{k,n}^{(j)}$ | state of legacy PFs $\tilde{\boldsymbol{y}}_{k,n}^{(j)} = [\tilde{\boldsymbol{a}}_{k,n}^{(j)\mathrm{T}}\ \tilde{r}_{k,n}^{(j)}]^{\mathrm{T}}$ |
| $r_n^{(j)}(t)$ | baseband signal received by $j$the PA | $\check{\boldsymbol{y}}_{k,n}^{(j)}$ | state of new PFs $\check{\boldsymbol{y}}_{k,n}^{(j)} = [\check{\boldsymbol{a}}_{k,n}^{(j)\mathrm{T}}\ \check{r}_{k,n}^{(j)}]^{\mathrm{T}}$ |
| $s(t)$ | transmitted radio signal | $c_{k,n}^{(j)}$ | feature-oriented data association (DA) variable |
| $w_{l,n}^{(j)}$ | complex amplitudes of multipath components (MPCs) | $b_{m,n}^{(j)}$ | measurement-oriented DA variable |
| $\tau_{l,n}^{(j)}$ | delays of MPCs | $\mu_{\mathrm{FA}}$ | mean number of false alarms |
| $d_n^{(j)}(t)$ | diffuse multipath | $f_{\mathrm{FA}}(\cdot)$ | pdf of false alarms |
| $n(t)$ | additive white Gaussian noise (AWGN) | $P_{\mathrm{d}}^{(j)}(\cdot,\cdot)$ | probability of detection |
| $\boldsymbol{a}_l^{(j)}$ | position of VA | $\mu_{\mathrm{n},n}$ | mean number of newly detected features |
| $\boldsymbol{x}_n$ | state of mobile agent $\boldsymbol{x}_n = [\boldsymbol{p}_n^{\mathrm{T}}\ \boldsymbol{v}_n^{\mathrm{T}}]^{\mathrm{T}}$ containing its position $\boldsymbol{p}_n$ and velocity $\boldsymbol{v}_n$ | $f_{\mathrm{n},n}(\cdot\|\cdot)$ | conditional pdf of newly detected features |
| $\mathcal{M}_n^{(j)}$ | set of measurements | $\mathcal{N}_{\check{\boldsymbol{r}}^{(j)}}$ | set of existing new PFs |
| $M_n^{(j)}$ | number of measurements | $\mathcal{D}_{\boldsymbol{c}_n^{(j)},\tilde{\boldsymbol{r}}^{(j)}}$ | set of existing legacy PFs |
| $\boldsymbol{z}_{m,n}^{(j)}$ | estimation parameters of the $m$th MPC of PA $j$ | $\gamma$ | gating threshold |
| $\sigma_{m,n}^{(j)}$ | noise standard deviation of the $m$th MPC of PA $j$ | $\sigma_a$ | standard deviation of driving process in PF evolution process |

TABLE I: List of important symbols.

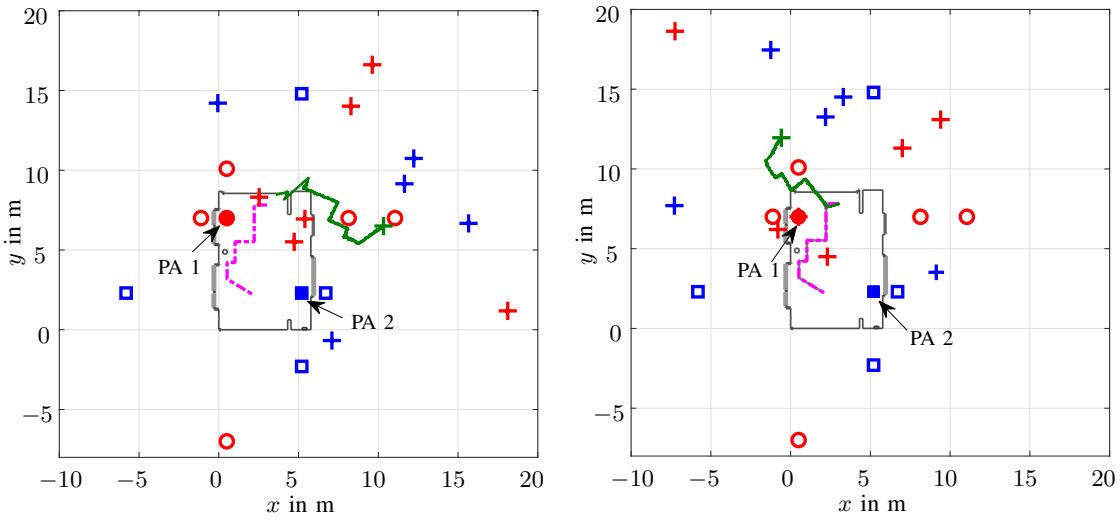


Fig. R-1: Simulation results for (a) a setup without any prior information about the initial mobile agent state, the PA positions, and the VA positions, and (b) a setup with prior knowledge of one PA position (prior knowledge of PA 1) and the initial mobile agent state but no prior information about the second PA position and the VA positions. The magenta dashed-dotted line represents the trajectory of the mobile agent, the red bullet and blue box represent PA 1 and 2, respectively, the green line represents the MMSE estimate of the mobile agent position, the red circles and blue squares outside the floor plan indicate some of the geometrically expected first-order VAs associated with PA 1 and PA 2, respectively, and the red and blue crosses indicate the MMSE estimates of the positions of the potential features (PFs) associated with PA 1 and 2, respectively.

Simulation results demonstrating these facts are shown in Fig. R-1 above. Fig. R-1(a) considers a setup without any prior information about the initial mobile agent state, the PA positions, and the VA positions. One can see that the agent trajectory as well as the PA and VA positions are estimated quite accurately up to a translation and a rotation. Fig. R-1(b) considers the case of prior knowledge of one PA position and the initial mobile agent state but no prior information about the second PA position and the VA positions. Here, the agent trajectory as well as the PA and VA positions are estimated essentially up to a rotation. We note that a quantitative performance evaluation for these setups is not straightforward, since the estimated mobile agent state and VA positions are in a rotated and possibly translated coordinate system.

## REFERENCES

[1] E. Leitinger, F. Meyer, F. Hlawatsch, K. Witrisal, F. Tufvesson, and M. Z. Win, "A scalable belief propagation algorithm for radio signal based SLAM," *ArXiv e-prints*, vol. arXiv:1801.04463v2, 2018. [Online]. Available: https://arxiv.org/abs/1801.04463v2