Smart City Project - S1

Sensory vs. Human inputs: Assessing the impact of weighing human input

or

How can continuing observations from users and infrastructure be fused over time without drift, lock-in, or excessive sensitivity to individual observations?

Background

Smart-city applications increasingly combine measurements from infrastructure sensors with observations contributed by users. These two information sources are complementary but have different characteristics. Infrastructure sensors can provide continuous and repeatable measurements, while user observations can capture local conditions, subjective experiences, temporary obstacles, or phenomena for which dedicated sensing infrastructure is unavailable.

Work in [1] focused on developing and implementing an adaptive pedestrian-routing application in which user feedback on individual links could be incorporated into the route calculation. The implemented feedback mechanism, $\boldsymbol{A_0}$, updates a device-measured attribute value according to the difference between its current value and a new human rating, reducing the influence of additional ratings as the number of previous observations increases. The thesis demonstrates that these updates can influence route selection, but identified important limitations: observations do not decay with time, accumulated feedback can create persistent values from which the system recovers slowly (or not at all), and the model does not explicitly distinguish between different sources or user groups.

Follow-up work [2] proposes an alternative algorithm, $\boldsymbol{A_1}$, in which a current sensor/reference observation is combined with temporally weighted user observations. User contributions decay according to a configurable half-life, while the sensor contribution remains explicitly represented in the estimate. Early experiments indicate that this formulation can reduce the drift and lock-in observed with A_0, while introducing a tunable trade-off between responsiveness to users and stability around the sensor signal.

Aim and purpose

The purpose of the project is to investigate how continuing observations from users and infrastructure can be fused over time without excessive sensitivity to individual observations, long-term drift, or lock-in to outdated information. For this the aim is to **systematically verify and evaluate the proposed A_1 feedback/data-fusion algorithm and determine under which conditions it provides a robust improvement over the original A_0 formulation**. Thus, the project should move the existing work from exploratory simulation toward a reproducible and quantitatively evaluated methodology.

Special attention should be given 1) to the influence of the three parameters of A_1, namely: sensor weight w_s, initial user-observation weight w_0, and observation half-life h and 2) to whether a single parameterization is appropriate under different sensing and feedback conditions.

Project description

The student is expected to:

- Reproduce the existing A_0 and A_1 algorithms and verify that the reported MATLAB simulation behaviour can be independently replicated (in either MATLAB or Python)
- Review and formalize the experimental scenarios already proposed for A_1: sporadic user feedback, continuous feedback, shock followed by recovery, and sensor outliers/faults.
- Verify the existing preliminary results, including the observed drift of A_0, the compromise between sensor and user information in A1, and the recovery behaviour following temporary bursts of user feedback.
- Implement a systematic parameter-sensitivity analysis for w_s, w_0, and h. The existing work proposes Monte-Carlo evaluation over multiple parameter combinations but does not yet provide a completed analysis of these experiments.
- Define quantitative performance metrics, including estimation error, recovery time, minimum value following a disturbance, overshoot, convergence behaviour, and sensitivity to individual observations.
- Test robustness under controlled faults and biases, for example noisy sensors /outages, isolated erroneous user reports, systematic user bias, abrupt/sudden environmental changes, and strongly conflicting sensor/user observations.

Organization

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Project Group

The project should be conducted by a group of 2-4 students: since the number of group members is variable, there may be need to propose a clear and fair separation of responsibilities to the supervisor from the project specification.

Project outline

The project covers the following steps:

1) Familiarise yourselves through reproduction and baseline verification: implement A_0 and A_1 in MATLAB or Python, reproduce existing/new scenarios, and confirm that the previously reported behaviour can be obtained consistently.
2) Experimental formalization and sensitivity analysis: Formalize the sporadic, continuous, shock/recovery, and sensor-fault scenarios, then perform a systematic parameter sweep for w_s, w_0, and h., using repeated Monte Carlo simulations.
3) Performance and robustness evaluation: Define quantitative metrics for convergence, estimation error, recovery time, overshoot, disturbance response, and sensitivity to individual observations, and evaluate robustness under noisy, biased, missing, or conflicting sensor/user inputs.
4) Comparative analysis and conclusions: Compare A_0 and A_1 across all scenarios, identify the conditions under which A_1 provides a meaningful improvement, and derive recommendations for parameter selection and refinement of the feedback mechanism.

Project Grading

Each project can be graded **Fail, 3, 4 or 5** according to the corresponding ECTS grading scale. The work will be evaluated with respect to aspects such as technical complexity, correctness of implementation, systematic treatment of the problem, reproducibility, reasonability of assumptions, quality of analysis, and clarity of presentation.

For the grade **3**, at least the following steps must be carried out:

- A detailed project specification and project plan, written in professional English.
- A concise literature review covering participatory sensing, sensor-data fusion, and temporal weighting of observations, with particular reference to the $A0$and $A1$ feedback mechanisms.
- A correct implementation of the $A0$and $A1$algorithms in MATLAB or Python, together with successful reproduction of the main existing simulation scenarios: sporadic feedback, continuous feedback, and shock followed by recovery.
- A basic quantitative comparison of the two algorithms using appropriate performance measures, with the obtained results discussed in relation to the expected behaviour.

For the grade **4**, all grade 3 requirements must be fulfilled, together with:

- A systematic parameter-sensitivity analysis of $A1$, considering at least the sensor weight w_s, initial user-observation weight w_0, and observation half-life h.
- A structured robustness analysis including at least two additional challenging conditions, such as noisy or missing sensor data, sensor outliers, erroneous user observations, systematic user bias, abrupt environmental changes, or strongly conflicting sensor and user observations.

For the grade **5**, the grade 3 and 4 requirements must be fulfilled with a high degree of technical and methodological quality. In addition:

- The experimental design and analysis should be systematic and reproducible, with well-justified parameter ranges, suitable repeated/Monte Carlo experiments, and a clear interpretation of trade-offs between responsiveness, stability and recovery.
- The discussion should critically identify the conditions under which $A1$improves upon $A0$, as well as cases where its assumptions or parameterization remain problematic.
- The report and final presentation should be exemplary in structure, technical clarity and presentation of results, and should conclude with a well-developed set of recommendations for future development of the feedback/data-fusion mechanism.

References

[1] Ekström, I. (2025). Inclusive Pedestrian Routing Through Personalization and Real-Time Feedback in Smart Cities: Implementing and evaluating an adaptive navigation application in the city of Lund. Master's thesis, Linköping University, Department of Science and Technology. LiU-ITN-TEK-A--25/059--SE. URN: urn:nbn:se:liu:diva-217634

[2] Ekström, I. Sensor Sensitivity Tests Iris Ekström, internal report 17th of September 2025 link also in the QR below