TIADPE
Advanced Pervasive Computing
Positioning fusion by the Kalman estimator

Practicalities

About:	This note covers a module. A module consists of two consecutive lecture days.
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Subject

This module ties together the modules on: 1) distance measurements by RSSI, 2) absolute positioning, and 3) relative positioning. This is done by introducing a well known method for fusing predictions with measurements, e.g. on locations; the method is named the *Kalman filter* after its inventor, Rudolf E. Kalman. Although, the Kalman filter is more than 50 years old it is still one of the most important and common data fusion algorithms in use today. As a notable example, the Kalman filter was used in the navigation system on the Apollo mission helping Armstrong and co. to the moon and back.

Agenda

Day 1

- L1: Relative and absolute positioning fusion by the Kalman estimator
- L2: Relative and absolute positioning fusion by the Kalman estimator
- E1: Exercises
- E2: Exercises

Day 2

- L3-L4:
  12.15-12.35: Presentation of exam questions
  12.35-12.45: Break
  12.45-14.00: Guest lecture by Kasper Løvborg Jensen (see abstract and bio below)

Readings

1. J. Krumm (ed.), "Ubiquitous Computing Fundamentals", CRC Press, 2010, chapter 9 (background material)
2. R. Faragher, "Understanding the Basis of the Kalman Filter Via a Simple and Intuitive Derivation", IEEE Signal Processing Magazine, 2012, pp. 128–132
3. G. Welch, G. Bishop, "An Introduction to the Kalman Filter", Tech. Report 95-041, UNC-Chapel Hill, 2006, pp. 1–16 (optional reading)

Exercises

Positioning fusion by the Kalman estimator

1. Discuss how the Kalman filter fuses predictions with measurements.
2. The Kalman filter relies on that the product of two Gaussian functions is another Gaussian function.
   - Convince yourself about the correctness of this fact
   - Derive the expressions for the mean and the standard deviation for the product Gaussian
   - In Matlab, multiply two Gaussians and consider the results: What should the new mean be? Will the standard deviation by wider, narrower, or the same? Consider how this relates to fusing predictions with measurements.
3. In Matlab, implement a one dimensional Kalman filter. Add Gaussian noise to a constant (you can imagine this is, e.g. a sensor measurement of a one-dimensional location like in the train example in the reading) to simulate a *true* value and the *measurements* thereof. Apply your Kalman filter to *estimate* the constant.
   - How does the estimations converge (in absolute and relative terms) to the true value as a function of the standard deviation of the Gaussian noise?
   - What would happen to the convergence if the noise model was different from Gaussian?
4. Discuss how to implement the Kalman filter so that it merges the information from your relative and absolute positioning algorithms.
   - For those really keen: do the implementation.

Note on exercises

I will mark with a star ($\star$) those exercises I consider to be most important; if none are marked, they are all equally important. Mandatory hand-ins are marked with a dagger ($\dagger$). The exercises are to help you fully understand the contents of the course, and master the theories, methods, and techniques presented in the lectures. Also, doing the exercises helps you gain a self confidence that most often shines positively through in an exam situation. When you have done all exercises it is good idea to think critically about the course material covered. Spend a few moments to think about the following:

- Summarize the main topics of this module and reconsider what you learned
- How did you succeed in your learning, and can you improve your learning process?
- How can the teaching-learning process be improved?

Of course, I will be happy to discuss the exercises and the course contents with you; however, before coming to me, it is very important that you engage in a discussion with your fellow students. Most often, the challenges you encounter are also challenges for others. Discussing with your fellow students is a good and social way of learning.

Guest lecture

Title

Wearables in the Wild – A Practical Exploration of New Mobile Interaction Paradigms

Abstract

Should we believe in the hype of wearables? The technology has been around for decades, but lately major players in the consumer electronics space started shipping out a vast array of glasses, watches and other wearable products for the masses. The question is: how and if this will change the way we will be interacting with information and services in the near-future? While the talk is founded in a decade of research in the cross field of HCI and mobile/ubiquitous/pervasive computing, it will lean on personal experiences with Android Wear and Google Glass to provide a more pragmatic exploration of how designers and developers can take advantage of new interaction paradigms to maximize the potential of wearables.

Guest lecturer Kasper Løvborg Jensen

Kasper is currently the Chief Wizard at Leafcastle Labs where he strives to make a meaningful difference in the world by harnessing knowledge and technology into useful and usable systems that positively impact the lives of people. He is also engaged in tech lead and business development roles in several small startups. Kasper holds a MSc degree in Software Engineering and a PhD in the field of Mobile HCI (Human-Computer Interaction) from Aalborg University. He has been at the cutting edge of science and technology for more than a decade as a software engineer, entrepreneur, consultant, researcher and academic. His main research interests area in the domains of mobile, ubiquitous and pervasive computing, context-awareness, HCI, interaction design and ICT4D. Prior to starting Leafcastle Labs he was an assistant professor at Aalborg University, visiting researcher at Melbourne University and associate professor at the Polytechnic of Namibia where he started the Mobile Future Lab research group and he spearheaded the founding of the Mobile Lab at the Namibian Business Innovation Institute.