TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Public summary of PhD-thesis of Thijs van de Laar
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Towards automated personalization of wearable devices

Wearable electronic devices are becoming increasingly popular, with products ranging from smart-watches and noise cancelling headphones to wristband health trackers. Some devices are medical necessities, such as epileptic seizure detectors, heart rhythm monitors and hearing aids. Because all these devices are often worn in the outside world, they are exposed to rapidly changing conditions and environments. Moreover, each wearer has unique quirks and preferences.

Because problems with signal processing quality often occur in the field (when a device is 'situated'), and because many variables about the wearer and their environment are unknown, flexible algorithm design applications that can respond to the situation by updating the algorithm would be of great value. For example, when a user is dissatisfied with current device performance, she should be able to send a rating to her smartphone. An automated algorithm design application that runs on her smartphone could then learn from this rating and immediately respond with an improved signal processing algorithm for her device, tuned to her preferences.

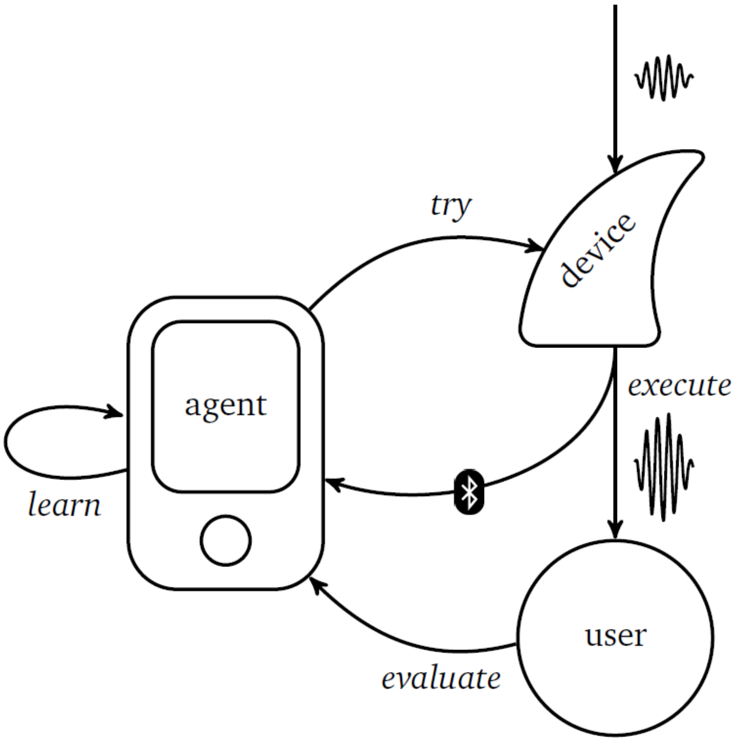
For the application to discover practical and personalized algorithms, it needs to be able to complete many design iterations (trial and error sessions) as quickly as possible. My dissertation focuses on the automation of signal processing algorithm design, with the goal to increase the affordable number of design iterations in a certain amount of time. I applied the results to hearing aid algorithm design, as a case study.

Because there is much uncertainty about the user and her environment, we use probability theory – the theory of how likely certain thing are – as a mathematical language for dealing with this uncertainty. Signal processing algorithms can be automatically derived from a probabilistic model. To automate signal processing algorithm design, we developed a new probabilistic programming software toolbox – which incorporates probabilistic reasoning into conventional programming – called ForneyLab. The ForneyLab toolbox is specifically tailored towards automatic and flexible derivation of signal processing algorithms.

Full automation of the algorithm design cycle also requires an experimental protocol to manage the interaction between the agent – the algorithm design app – and its environment. This dissertation formally describes such a protocol and demonstrates by simulation how this protocol, together with the ForneyLab toolbox, can be used to control agents that learn from and act on their environment. In principle, the described experimental protocol scales to more complex control systems as well.

As a practical study, we applied the ForneyLab toolbox to automate the derivation of personalized algorithms for hearing aid signal processing. The dissertation describes how hearing loss compensation algorithms, parameter fitting and performance evaluation can be automatically derived from a probabilistic model description of hearing loss. This hearing loss model can then be personalized from user feedback.

Although clinical and empirical evaluations are still required before the proposed methods can be applied in practice, this dissertation convincingly advocates for a situated approach to the design of personalized signal processing algorithms. The newly developed and freely available ForneyLab software suite provides the tools to implement these algorithm design principles in practice.



Title of PhD-thesis: Automated Design of Bayesian Signal Processing Algorithms. Supervisors: Bert de Vries, TU/e, GN Hearing.