Feedback Control of the Electrical Stimulation Induced Muscular Recruitment Determined by the Evoked Electromyogram

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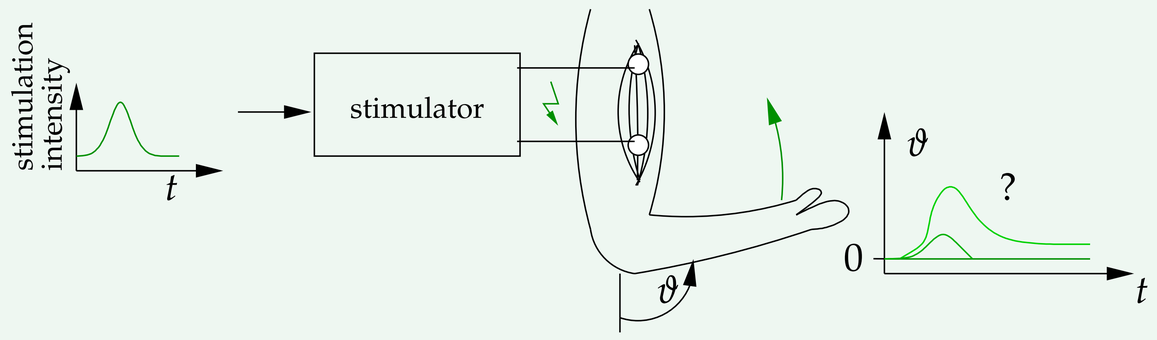
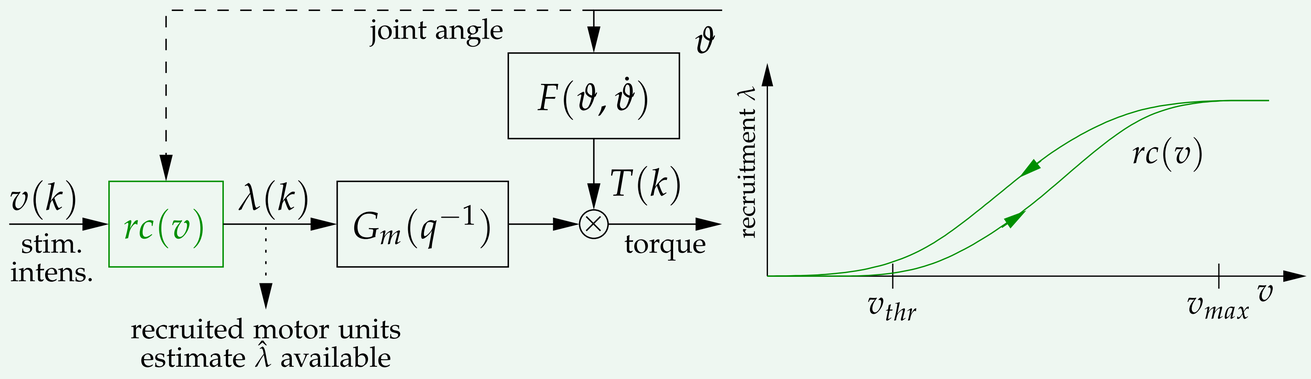
Difficulties of feedback controlled FES



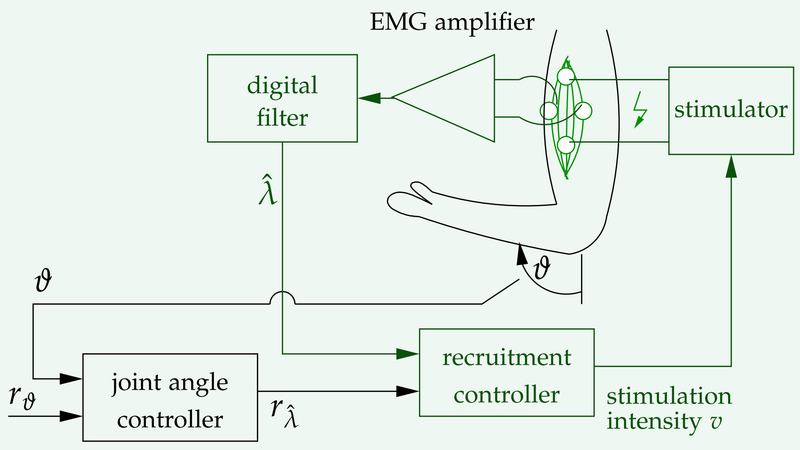
- The outcome of a stimulation pattern is difficult to predict.
- Complex models require long lasting identification experiments. Parameters are difficult to identify.

Model & Problem Analysis



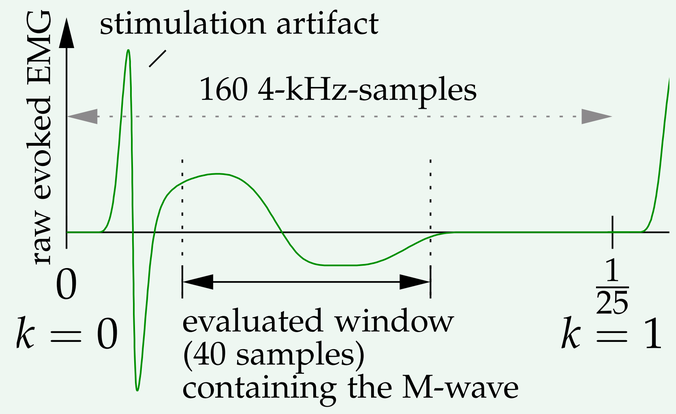
- A static non-linear function describes the amount λ of recruited motor units in dependence of the stimulation intensity v.
- Usually there are hysteresis effects along with a time variant behaviour.

Proposed Solution: Feedback of evoked EMG



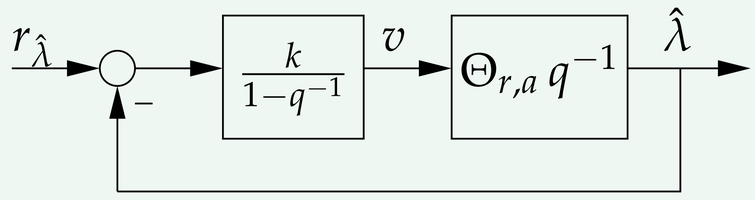
- Measurement and signal processing of EMG gives $\hat{\lambda}$, the controlled variable.
- The function rc is linearised by the feedback loop.
- At an outer loop e.g. the joint-angle ϑ is controlled by using the reference $r_{\hat{\lambda}}$.
- Sampling rate: 25Hz

Digital Filter



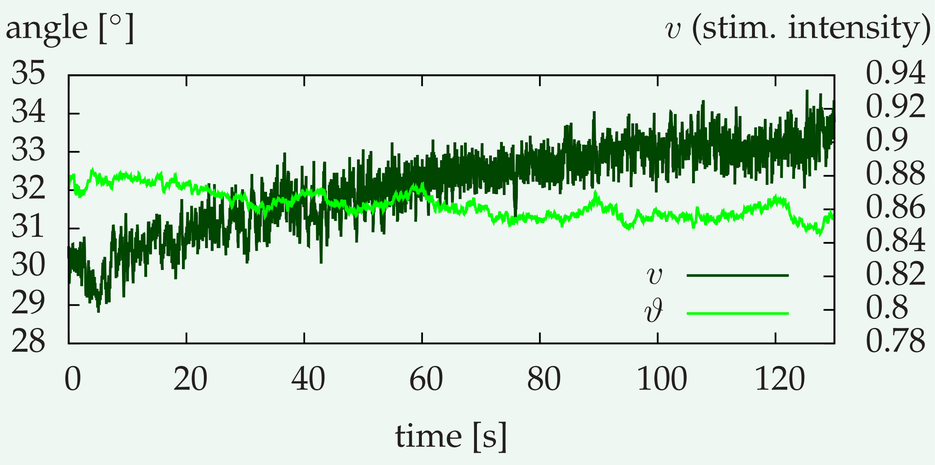
- EMG is recorded and evaluated for every stimulation period.
- The standard derivation of the evaluated window gives $\hat{\lambda}$.

λ-Controller



I-controller: A discrete-time integrating controller
Assumed plant: Time delay and a gain

Compensation of Fatigue



- For a constant reference $r_{\hat{\lambda}}$, the stimulation intensity increases, while the angle stays constant.

Results

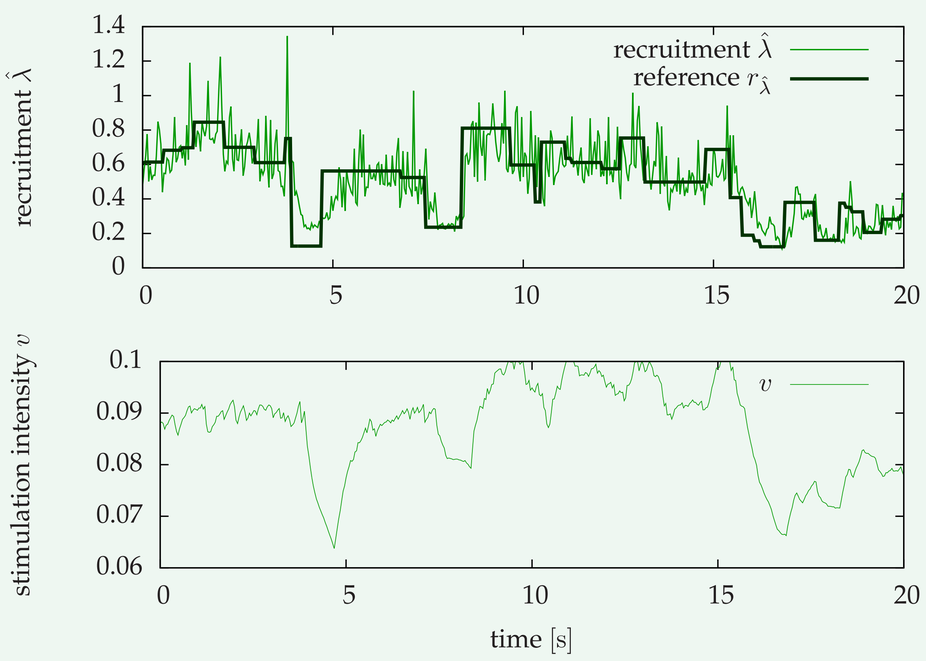


Fig. A: Evaluation of the λ-Controller. (controlled muscular recruitment)

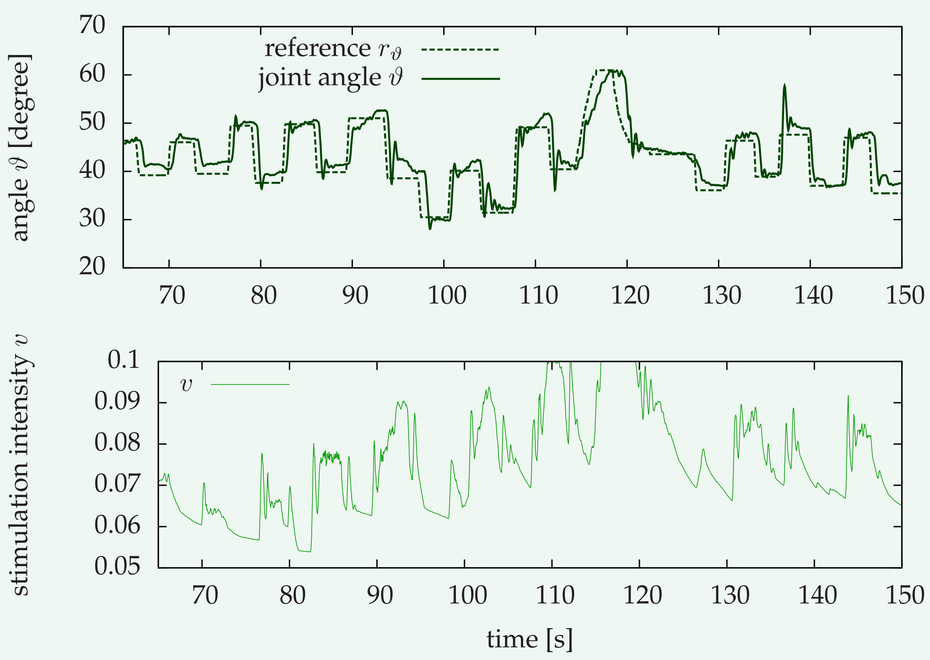


Fig. B: Results of an joint-angle control experiment for a healthy subject using the underlying λ-Controller.

Conclusion

λ-Control

- The recruitment function can be linearised by feedback of evoked EMG.
- Reduced effort for identification (hysteresis, threshold and non-linearity of $rc(v)$ can be neglected)

Future

- Adaptive control: Closed-loop online identification.

[1] Klauer C., Raisch J., Schauer T.: *Linearisation of electrically stimulated muscles by feedback control of the muscular recruitment measured by evoked EMG*, Proc. of MMAR 2012, IEEE, 2012