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Traditio et Innovatio

FAKULTÄT FÜR INFORMATIK UND ELEKTROTECHNIK

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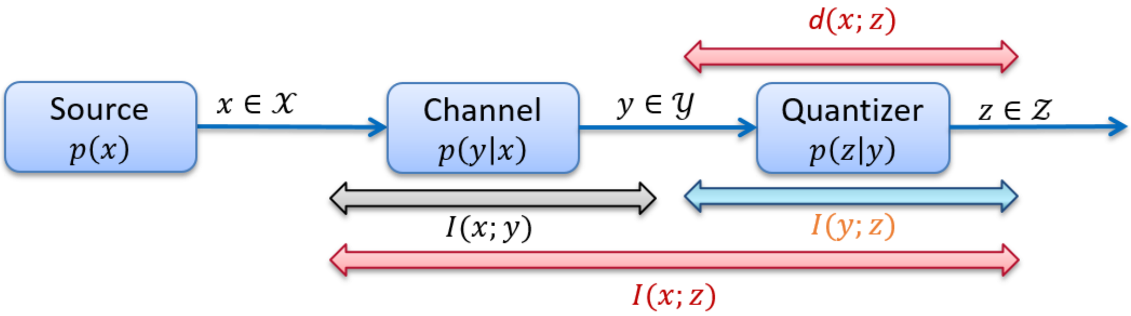
Master Thesis / Specialization Module EE

The Deterministic Information Bottleneck Algorithm

Description:

Mobile communication systems have to deal with strictly limited hardware resources, such as the battery. This leads to severe requirements for the energy consumption for those systems. Since the energy consumption of analog-to-digital converters grows exponentially with their amplitude resolution, receiver design with low resolution quantization and subsequent signal processing is of interest. Hence, the question arises how a quantizer has to be designed such that its low resolution output is very informative about the original transmit signal?



One approach for clustering/quantization originates from information theory and is called "Information Bottleneck (IB) Method". It tries to compress a noisy observation such that it preserves most of a predefined relevant information. The simplest setup consists of the *relevant* random variable $\mathcal{X}$, the *observed/noisy* random variable $\mathcal{Y}$ and the *compressed* random variable $\mathcal{Z}$. These three random variables form the Markov chain $\mathcal{X} \to \mathcal{Y} \to \mathcal{Z}$. More precisely, the Information Bottleneck method tries to design a compression mapping $p(z|y)$ which maps each observation $y \in \mathbb{Y}$ onto realizations of a compact compression variable $z \in \mathbb{Z}$, such that, $|\mathbb{Z}| < |\mathbb{Y}|$ while $I(\mathcal{X};\mathcal{Z})$ is maximized. This problem can be posed as a Lagrangian optimization problem and, hence, solved by minimizing the IB functional

$$\mathcal{F}\{p(z|y)\} = I(\mathcal{Y};\mathcal{Z}) - \beta I(\mathcal{X};\mathcal{Z}), \qquad (1)$$

where the Lagrangian multiplier β serves as trade-off parameter between maximum preservation of relevant information ($\beta \to \infty$) and maximum compression ($\beta \to 0$). It can be shown that $\beta \to \infty$ yields a *deterministic* clustering $p(z|y)$, which is very convenient from

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an implementation perspective because it can be realized as a static lookup table. For finite β the clustering $p(z|y)$ is *stochastic*.

Varying the IB functional and introducing a new parameter $\alpha \in [0, 1]$ leads to the so called "Deterministic Information Bottleneck Algorithm (DIB)":

$$\mathcal{F}\{p(z|y)\} = H(\mathcal{Z}) - \alpha H(\mathcal{Z}|\mathcal{Y}) - \beta I(\mathcal{X}; \mathcal{Z}) \tag{2}$$

By choosing $\alpha \to 0$ this algorithm leads to a deterministic clustering $p(z|y)$ even for finite β.

In this thesis you have to implement the original IB approach, i.e. the (Iterative Information Bottleneck Algorithm), and the slightly different Deterministic Information Bottleneck Algorithm in Python. Comparing these two algorithms, the influence of α in (2) has to be investigated.

For a master thesis only, it has to be investigated, if the DIB approach can be extended to a distributed sensing scenario. Following the approach proposed in latest publications, distributed scalar quantizers have to be designed by an alternating Information Bottleneck algorithm, which sequentially optimizes one quantizer using the mappings of other quantizer as side-information. Therefore, the approach of (2) has to be extended to the distributed sensing case. After deriving a solution the distributed DIB can be integrated in an existing implementation of the alternating Information Bottleneck algorithm.

The required tasks for this thesis are:

- Literature review on Information Bottleneck and the Deterministic Information Bottleneck algorithm
- Implementing Iterative IB and Deterministic IB in Python
- Comparison of different algorithms and investigation of the influence of α
- Master thesis: Extending the Deterministic IB to the distributed sensing scenario

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