KTH VETENSKAP OCH KONST

The *FlexCode* Project

Bastiaan Kleijn

Flexcode Seminar Helsinki

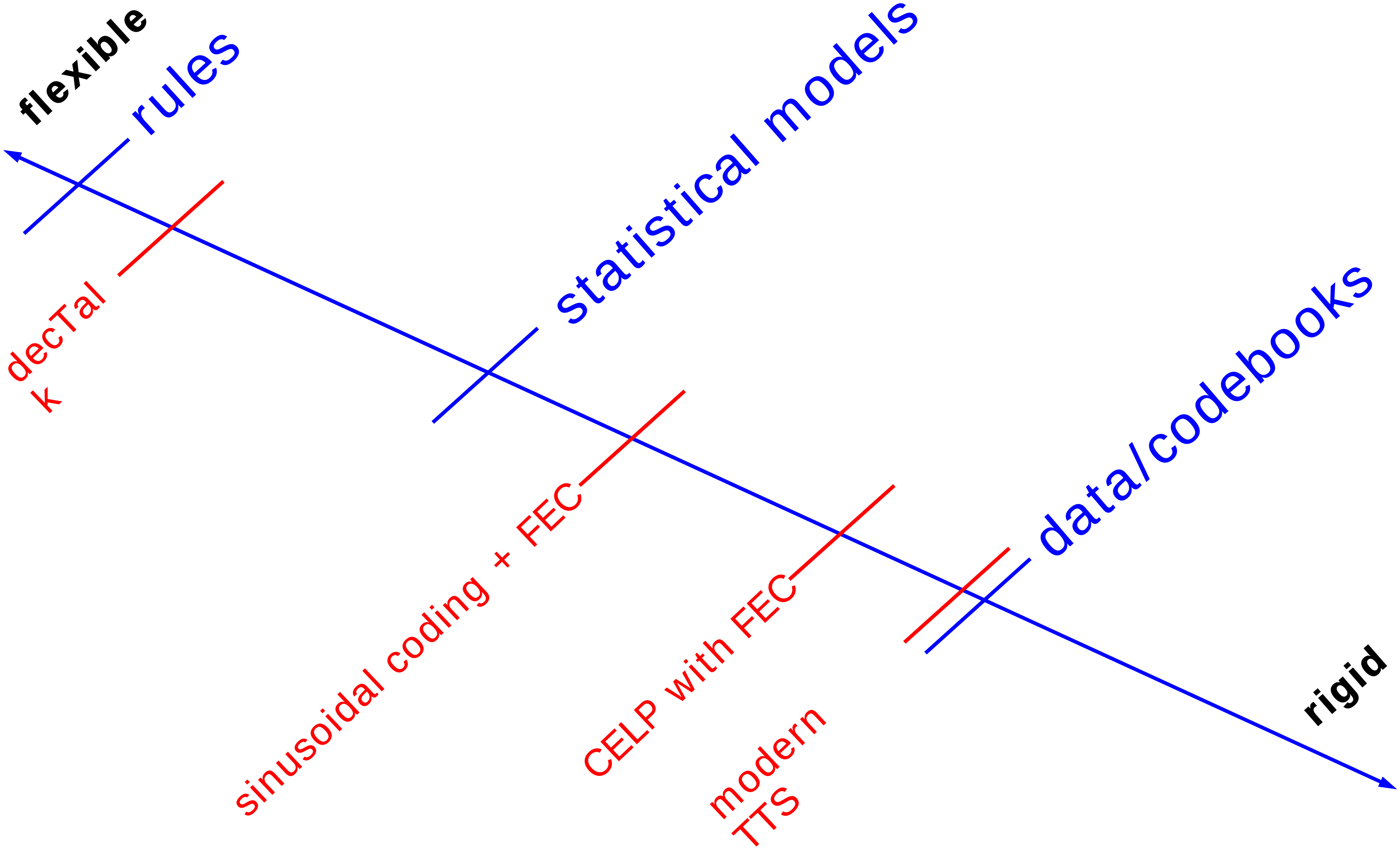
Nov 29, 2006

FlexCode

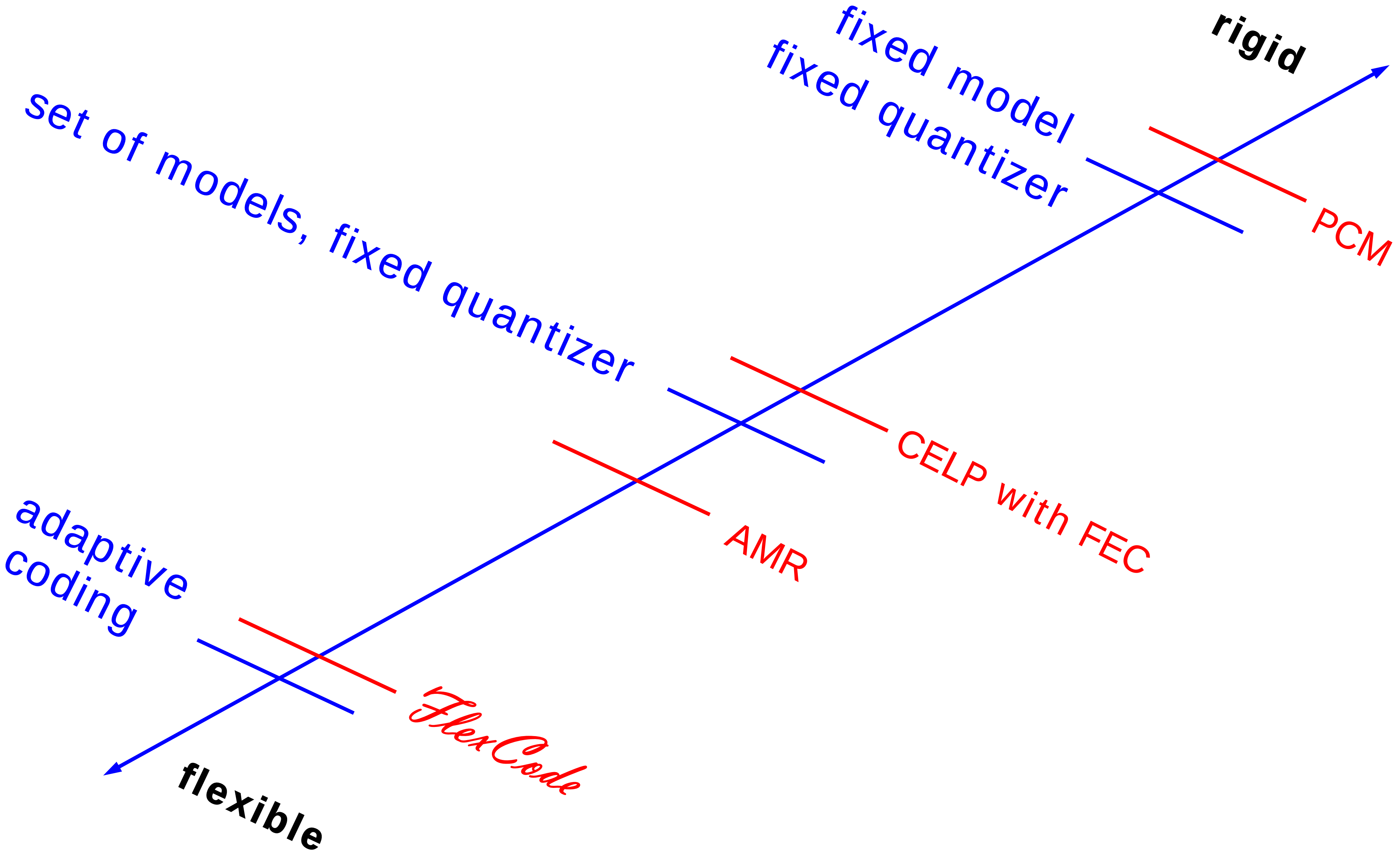
Overview

- **The problem**
- Who is going to solve it
- The solution
- The tools
- The process
- Conclusion

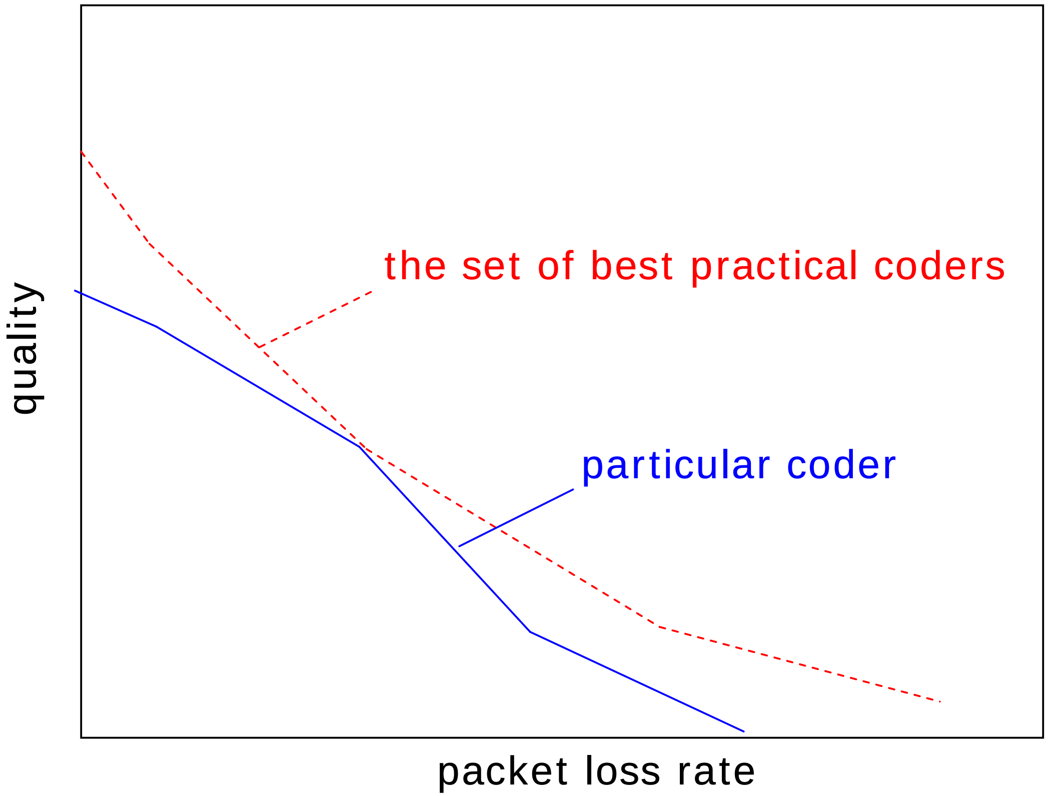
Of Rules, Statistical Models, and Data



Adaptation and Coding



Non-Adaptive Coding



The Problem

- Heterogeneity of network increasing
  - Increasing variation in environment
  - Demands for external rate/quality control
  - Existing coders used in new applications
  - Proliferation of standards
- Network inherently variable (mobile users)
- Feedback about the channel exists

- Coders not designed for the specific environment
  - One size fits all
- Coders inflexible since codebooks and FEC are used
  - Adaptive modeling but *not* adaptive coding
- Feedback channel underutilized

Overview

- The problem:
  - Non-adaptive coding with narrow application range
- **Who is going to solve it**
- The solution
- The tools
- The process
- Conclusion

The Problem Solvers

Flexcode

The Problem Solvers

Flexcode

The Problem Solvers

- **The Ericsson Multimedia Technologies Department** within Ericsson Research has comprehensive expertise in the areas speech, audio and video signal processing and coding as well as in the area of transport of such media in various networks. The department has actively participated in standardizations in 3GPP, ITU-T, 3GPP2, MPEG, IETF and others.
- Within the **France Telecom** TECH R&D centre, **the Speech and Sound Technologies and Processing (SSTP) Laboratory** develops the basis for new modes of interaction between the users and the services and between the users and the terminals through the use of speech and sounds. SSTP provides France Telecom with expertise on the technologies required for the dialogue and interaction through speech and audio coding, speech synthesis, speech recognition, acoustic, and audio watermarking. The SSTP laboratory has contributed to many standardization activities in speech and sound coding
- **The KTH Sound and Image Processing (SIP) Laboratory** performs research in signal processing and source coding as it applies to audio and video signals.
- **The Nokia Research Center Multimedia Technologies laboratory** has broad expertise in signal processing and media coding research. Laboratory experts have been actively contributing in various forums such as ETSI, 3GPP, 3GPP2, OMA, IETF, ITU, MPEG on media formats and transport
- **The RWTH Aachen Institute of Communication Systems and Data Processing (IND)** possesses longtime expertise in the area of mobile communication and digital signal processing, especially with respect to speech coding, perception, noise reduction, echo cancellation, error concealment as well as combined source-channel coding and modulation. Over the last decade, RWTH/IND has continuously made contributions to international speech and audio codec standards.

Overview

- The problem:
  - Non-adaptive coding with narrow application range
- Who is going to solve it:
  - Ericsson, France Telecom, KTH, Nokia, RWTH Aachen
- **The solution**
- The tools
- The process
- Conclusion

Adaptive Quantizers

- Encoder and Decoder know
  - Probability density function of variable (=statistical model)
  - Distortion constraint
- Encoder and Decoder compute
  - Optimal quantizer
- Encoder encodes variable; decoder decodes variable

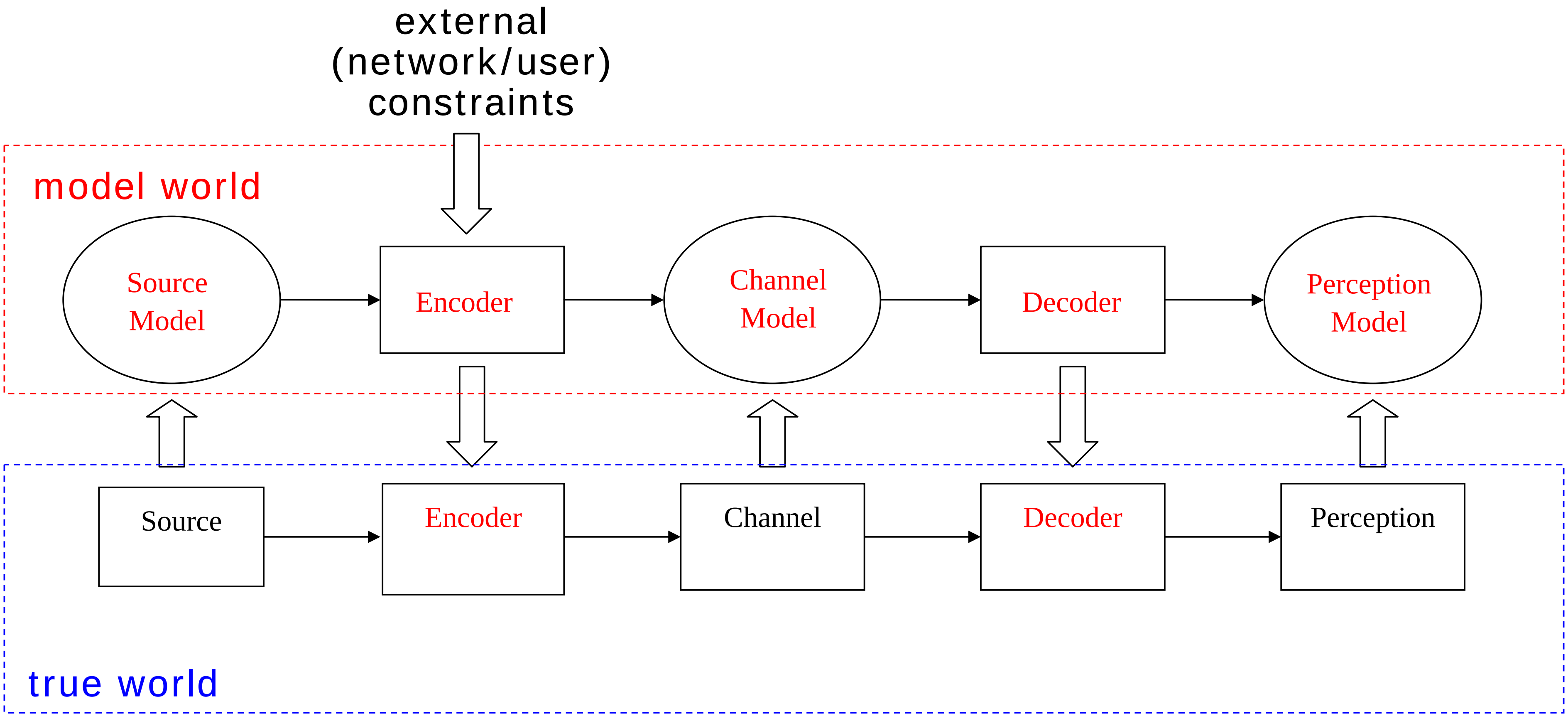
- Concept is extended to include packet loss, bit errors
  - Probabilistic model of the channel

The *FlexCode* Philosophy

- *Flexibility through knowledge*:
  - Adaptive coding based on *source and channel statistics*
    - Equations replace codebooks and data /
      Quantizer specification by equations
    - Facilitates real-time design
    - Estimate statistics for source and channel
      - No need for perfection; real-time / knowledge based
  - Adaptivity constrained to coder *family*
  - Separate channel coding (bit errors) and source coding

- Compare to conventional approach:
  - Non-adaptive coding based on *data / codebooks*
    - Requires off-line design (*iterative*)
    - Computational problems
      - Constrained resolution: huge searches
      - Constrained entropy: (not common) huge codeword mappings

The FlexCode System



Overview

- The problem:
  - Non-adaptive coding with narrow application range
- Who is going to solve it:
  - Ericsson, France Telecom, KTH, Nokia, RWTH Aachen
- The solution:
  - Analytic solutions lead to adaptive coding
- **The tools**
- The process
- Conclusion

The Tools

- Tools include
  - High-rate quantization theory
  - Multiple description coding (MDC)
  - Signal modeling
  - Distortion measures using sensitivity matrix

- Tools are generally recent developments
  - Many loose ends
    - High-dimension MDC
    - Distribution bit rate model and signal
    - Fast computation sensitivity matrix
  - Must be made to work together
    - Model and MDC

Tool 1: High-Rate Q Theory

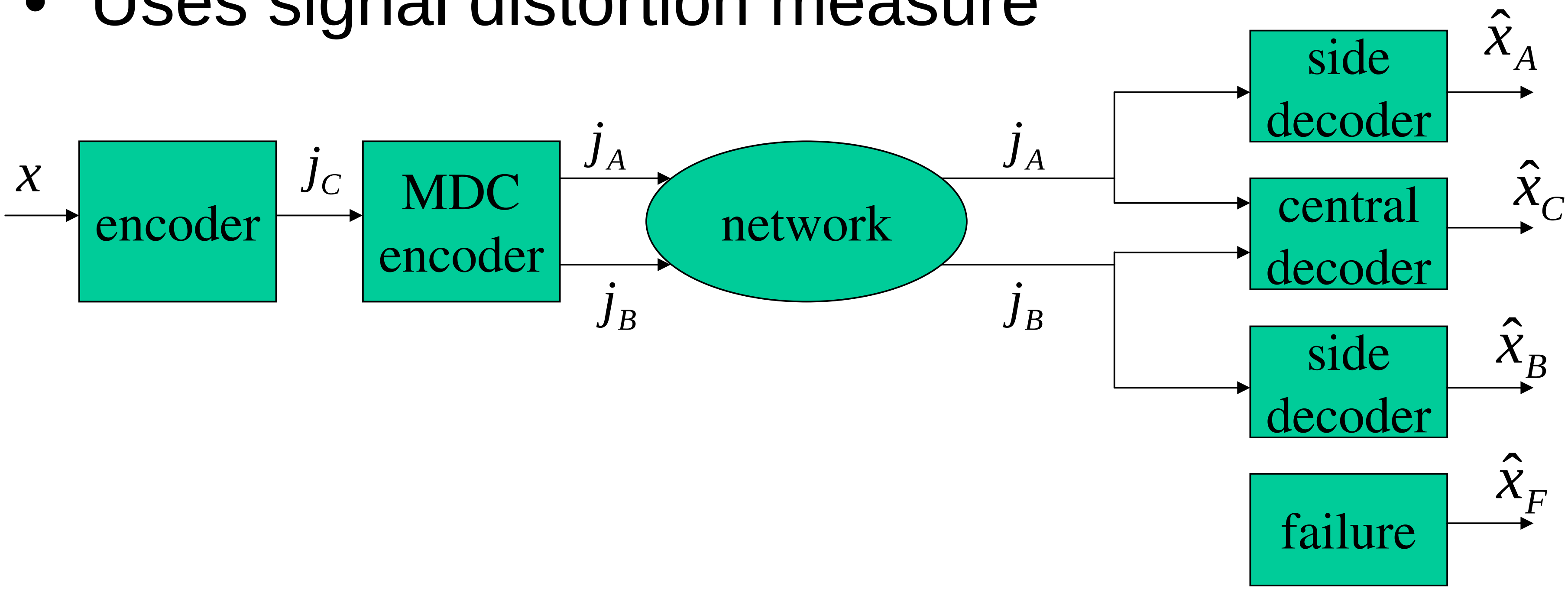
- Bennett 1948
- High-rate quantization theory assumptions:
  - Data density uniform in quantizer cell
  - Reconstruction points can be represented as density
  - Geometry of the cells is fixed
- Facilitates practical quantizer design
- Experience: assumptions valid in practical data range

Tool 1: High-Rate Q Theory

- Practical implementation:
  1. Estimate data density (*parameterize*)
  2. Provide density estimate to encoder *and* decoder
  3. Reconstruction point *density*=function(data density, distortion)
  4. Define local cell geometry
     - Quantizer uniform for constrained-entropy case
     - No consensus constrained-resolution case
       – Companding one solution
  5. (CE only) lossless encoder based on data density
     - Solution for Gaussian mixture density expansion

Tool 2: Multiple Description Coding

- Transmit two (N) descriptions, *A* and *B*
- Receive nothing, *A*, *B*, or *A* and *B*
- Combines with high-rate theory
- Uses signal distortion measure



Tool 2: Multiple Description Coding

- Trade central decoder performance against performance side decoders for optimal performance given channel statistics
- Illustration is for symmetric side-distortion

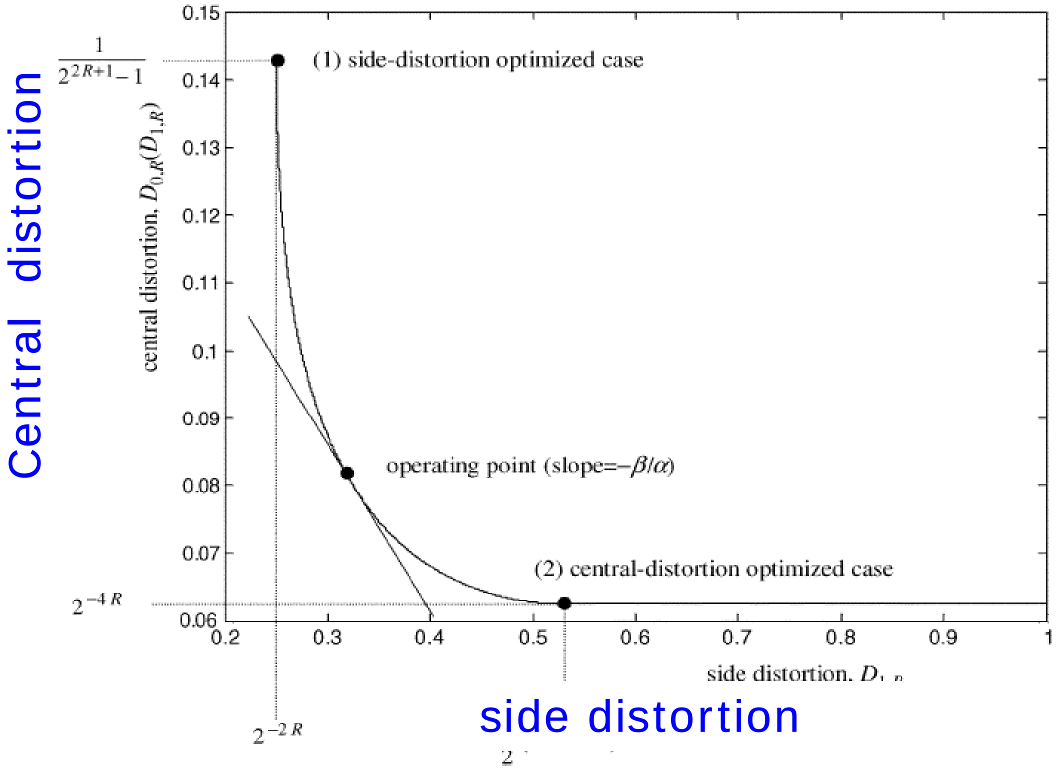


Fig. 3. Achievable R-D bound and operating point of MDC ($R = 1$ b/sample).

Tool 3: Signal Model

- Signal model in *FlexCode*:
  - Statistical model = description of pdf
    - Facilitates adaptive quantizers
    - Example: AR model with AR (predictor) parameters
    - Example: transform model with spectral envelope model
  - Facilitates computationally efficient (do-able) coding

- Two equivalent approaches:
  - pdf consists of sum of simple pdfs (mixture)
    - Ignore overlap in practice
  - Data can satisfy one of a set of pdfs
    - Select best pdf (AR: max likelihood leads to Yule-Walker)
    - Set of pdfs can be all quantized linear-predictor parameters

Tool 3: Signal Model

- *FlexCode* will start with existing models
  - Transform
  - Autoregressive model (linear-predictive)

- *FlexCode* will analyze
  - Distribution of rate between model and data
    - Example: predictor parameters and excitation coefficients
    - Relation with overall rate
    - Relation with bit errors and packet loss

Tool 4: Sensitivity Matrix

- Identical philosophy to high-rate coding:
  - Quantization cells are “small”
- For given signal vector, approximate sophisticated *static* criterion by lowest-order nontrivial expansion around minimum: quadratic criterion
  - Weighting of criterion is: sensitivity matrix

Overview

- The problem:
  - Non-adaptive coding with narrow application range
- Who is going to solve it:
  - Ericsson, France Telecom, KTH, Nokia, RWTH Aachen
- The solution:
  - Analytic solutions lead to adaptive coding
- The tools:
  - High-rate theory, MDC, signal models, channel models
- **The process**

- Conclusion

The Process

- Determine typical scenarios and acquire typical channel data (Ericsson)
- Work out theory and create simulations (KTH, RWTH)
- Build a real-time prototype (Nokia)
- Test and compare (France Telecom)
- Disseminate (seminars and papers)

Overview

- The problem:
  - Non-adaptive coding with narrow application range
- Who is going to solve it:
  - Ericsson, France Telecom, KTH, Nokia, RWTH Aachen
- The solution:
  - Analytic solutions lead to adaptive coding
- The tools:
  - High-rate theory, MDC, signal models, channel models
- The process:
  - Data acquisition, theory, prototype, dissemination
- **Conclusion**

Conclusion

- *FlexCode* objectives are
  - To build an adaptive coder
  - To use the feedback channel
  - To facilitate external rate/quality control
  - To have the right coder for any time and any place
  - To extend existing coding paradigms

- *FlexCode* consequence
  - To reverse the proliferation of new standards?