Code-Division Multiple Access (CDMA) Channel Estimation Using Fuzzy

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Multipath Fading in CDMA channel
The RAKE receiver

- The data reception is based on the conventional RAKE receiver.
Code-Division Multiple Access (CDMA)

- Accurate channel estimation is often necessary task for improving the system capacity

- The Kalman filter is an optimal solution to this problem

- But it requires an explicit mathematical model and is computationally complex to be realized in real time with an inexpensive hardware
Kalman Filter Equations

1) A priori prediction of the state
\[ \hat{\mathbf{x}}(k | k-1) = A\hat{\mathbf{x}}(k-1 | k-1) + B\mathbf{u}(k-1) \]
2) A priori estimate of the estimation error covariance matrix \( \mathbf{P} \)
\[ \mathbf{P}(k | k-1) = A\mathbf{P}(k-1 | k-1)A^\top + Q \]
3) Compute the weighting (Kalman) matrix \( \mathbf{K} \)
\[ \mathbf{K}(k) = \mathbf{P}(k | k-1)C^\top \left[ CP(k | k-1)C^\top + R \right]^{-1} \]

4) Compute the a posteriori state estimate
\[ \hat{\mathbf{x}}(k | k) = \hat{\mathbf{x}}(k | k-1) + \mathbf{K}(k)\left[ \mathbf{y}(k) - C\hat{\mathbf{x}}(k | k-1) \right] \]

5) A posteriori estimate of the estimation error covariance matrix \( \mathbf{P} \)
\[ \mathbf{P}(k | k) = \mathbf{P}(k | k-1) - \mathbf{K}(k)C\mathbf{P}(k | k-1)C^\top \]
An Alpha tracker

- It is an iterative method
- Channel coefficient $c_i(i)$ for the ith symbol is predicted with the aid of the previous
  - coefficient estimation $\hat{c}_i(i-1)$
  - Symbol estimation $\hat{b}(i-1)$
  - Measured data $y_i(i-1)$

For each path length

$$\hat{c}_i(i) = \hat{c}_i(i-1) + (1 - \alpha)(\bar{c}_i(i-1) - \hat{c}_i(i-1))$$

where

$$\bar{c}_i(i-1) = \hat{b}(i-1)y_i(i-1)$$
Fuzzy Logic in Tracking Channel Coefficient

- In the fuzzy estimation no exact process model is needed.
- The fuzzy tracker has two inputs:
  - The first one is the difference of the measured and the predicted Coefficients: \( \text{err}_i(i-1) = m\tilde{c}_i(i-1) - \hat{c}_i(i-1) \)
  - The second one is the chance of that difference: \( d\text{err}_i(i-1) = \text{err}_i(i-1) - \text{err}_i(i-2) \)
- The output of the tracker (the correction term) is given for the next coefficient: \( \hat{c}_i(i) = \hat{c}_i(i-1) + d\hat{c}_i(i-1) \)
Difference between the alpha and fuzzy tracker

- In a relative noisy circumstances fuzzy tracker gives a more smooth estimation.
Conclusion

- Fuzzy logic based methods particularly perform well under non-linear and time-variant conditions, where adaptive techniques have to be employed.

- When dealing with complex models that are not completely known and varying with time, fuzzy logic based methods can be used for faster convergence and reduced complexity with a slight degradation in performance compared to that of standard methods.

- Fuzzy Logic is also applied in channel equalization and decoding.
References
