Human Activity Detection Using Radio Waves

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1 INTRODUCTION

The current problem is divided onto two major parts: calculate channel state information (CSI) and movement detection based on obtained CSI. In the report our work on these two parts will be introduced separately.

2 CSI CALCULATION

We decided to apply Maximum Likelihood Estimator to calculate the CSI since it's reasonable to assume the noise is Gaussian distributed, which makes the logarithm likelihood function easy to obtain. In order to calculate likelihood function for each path, the received signal along each path shall be extracted. But it is not possible physically because the signals along each path at receiving end are superimposed. We decompose the superimposed received signal y proposed in [1] by

$$x_l(t;\theta_l) = s(t;\theta_l) + [y(t) - \sum_{l=1}^{L} s(t;\theta_l)] \tag{2.1}$$

where $\theta_l = [\tau_l,\ \alpha_l,\ \phi_l,\ \nu_l]$ denoted the parameters of lth path (time delay, complex amplitude, direction of arrival and doppler frequency), and

$$\begin{aligned} s(t;\theta_l) &= [s_1(t;\theta_l),...,s_M(t;\theta_l)]^T \\ &= c(\phi_l)\alpha_l e^{j2\pi\nu_l t} u(t-\tau_l) \end{aligned} \tag{2.2}$$

is the expected received signal along path l at each receiving antenna m. $c(\phi) = [c_1(\phi), ..., c_M(\phi)]^T$, whose component is $c_m(\phi) = e^{j2\pi/\lambda(m-1)dcos(\phi)}$ representing phase shift among receiving antennas due to the direction of arrival with respect to the antenna array. With signal decomposed, the log-likelihood function for this model is [2]

$$z(\tau, \phi, \nu; x_l) = \int u^*(t' - \tau)e^{-j2\pi\nu t'} c^H(\phi)x_l(t')dt' \tag{2.3}$$

Thus the coordinate ascend iteration is

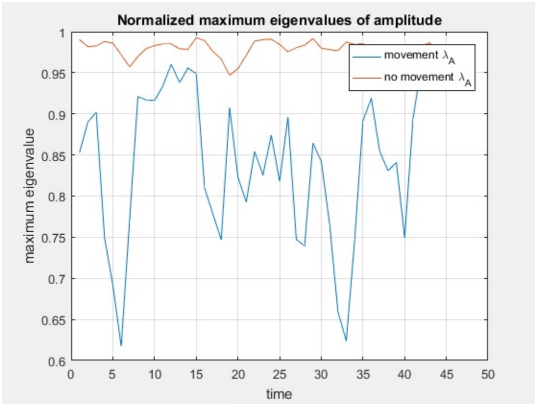
$$\begin{aligned}
\tau_l'' &= arg\max_{\tau}\{z(\tau, \phi_l', \nu_l'; x_l(t;\theta'))\}\\
\phi_l'' &= arg\max_{\phi}\{z(\tau_l'', \phi, \nu_l'; x_l(t;\theta'))\}\\
\nu_l'' &= arg\max_{\tau}\{z(\tau_l'', \phi_l'', \nu; x_l(t;\theta'))\}\\
\alpha_l'' &= \frac{1}{I||c(\phi_l'')||^2 T_a P_u} z\{\tau_l'', \phi_l'', \nu_l''; x_l(t;\theta')\}
\end{aligned} \tag{2.4}$$

The initialization of the iteration adopts the successive interference cancellation proposed in [3]. The simulated channel in our case contains 2 clusters of paths with time delay of $0.625\mu s$ and $1.56\mu s$. The amplitudes of each cluster is 0.2 and 0.5 respectively. The Doppler frequencies and directions of arrival can be arbitrary since it's irrelevant to the movement detection. The transmitted signal that is used in the simulation must be wide-band with respect to the coherence band-width of underlying channel only if which the multi-path can be resolved. The symbol rate is chose to be $3.2MHz$ because this is the maximum stable sampling rate of our SDR. The signal is a random binary sequence of 1000 bits repeated by 100 times. Two receiving antenna is assumed since this is the maximum amount of antenna we can get. Antennas are separated by half wave-length. The result shows only one path is resolved and we are still finding why. The estimated time delay is $0.473\mu s$, amplitude is 0.272, each has an error of 24% and 36%. This is far from ideal and we are still working on improving it.

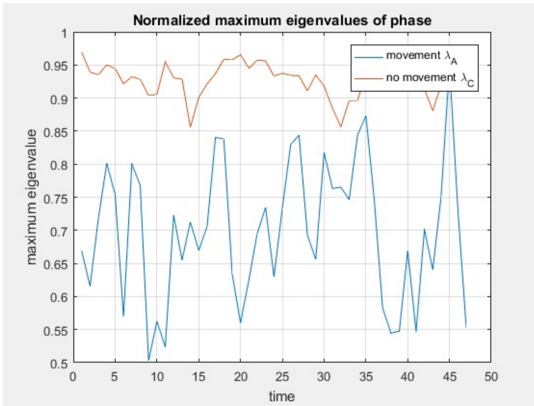
3 Movement Detection

CSI exhibits larger variations in case of moving humans than in case of static humans. In this part, we deal with CSIs extracted from SAGE. To test the method, we first use a sequence of simulation data with high and low correlation instead of real data.

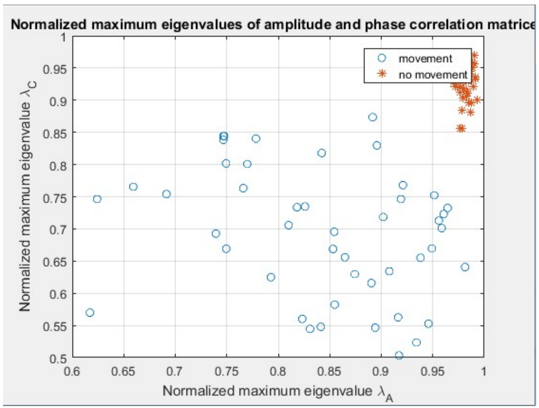
In case of moving human, we generated 50 groups of CSIs with the information of 10 paths. We use the initial CSI as a standard. In each time slot, we update the CSI by only changing three or four pathsâĂŹ parameters, which are chosen randomly. What's more, the path closing to the chosen paths may also change. And $1/n$ is used as the attenuation index in multi-path propagation. In case of static humans, we only make minor changes to the initial CSI so that the data has high correlation.



(a)



(b)



(c)

Figure 3.1: (a)Normalized Maximum Eigenvalues of Amplitude, (b)Normalized Maximum Eigenvalues of Phase, (c) Normalied Maximum Eigenvalues of Amplitude and Phase.

In order to obtain the correlation factor between each column of CSI samples H, we generate two n-by-n matrix A and C for amplitudes and phases, where each element denotes the correlation coefficient between H_i and H_j. Afterwards, we derive the eigenvectors of matrix A and C and exert the normalized maximum eigenvalues for moving human detection.

From the simulation, stationary channel results in large eigenvalues (close to 1). In the opposite case of moving channel, the eigenvalues tend to be small.

REFERENCES

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