Analyses of Optimal ANC System Arrangement

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Introduction & Background

► In modern cities, the increasing heavy urbanization leads to the challenge for urban planners, such as the noise pollutions near around the residential areas. Frequent exposure to high levels of low frequency noise will leads to cardiovascular diseases and anxiety as reported widely in the 2011 World Health Organisation (WHO) and 2014 European Environmental Agency reports.

► Our research group leading by Professor Gan Woon Seng in Nanyang Technological University of Singapore has been working on mitigating the urban noise through open windows using active noise control window system.

► For a complex system like ANC window and the apartment room in our project, it is nearly impossible to use trial and error to find optimal arrangement, since there are unlimited spatial choices for the arrangements of secondary sources, reference microphones and error microphones.

► We propose a combined method based on the detailed analyze of the physical environment using COMSOL and different ANC algorithm using MATLAB to roughly decide the best possible arrangement of the system setup. Genetic algorithms are adopted to find the optimal arrangement among unlimited spatial choices.

Active Noise Cancellation Algorithm

► Filter-x Least Mean Squares (FXLMS) algorithm is the best choice to balance between computational complexity and control performance.

► As shown in Figure below, reference signal is picked up by reference microphone, and error signals are picked by error microphone array. Reference signal and error signal are fed into control system. By using an estimation of cancellation path, control filter weights $W(z)$ can be calculated throught LMS. Then control signal $y(n)$ is got by passing reference signal $x(n)$ through control filter $W(z)$. The Core equation of filter-x LMS algorithm is presented below:

$$X_d = \sum_{i=1}^{N} X(i) * \hat{C}(N-i)$$
$$W = W + \mu * X_d * En$$
$$Y = W * X$$

where X is the input signal sequence, X_d is the result of input signal filtered by measured cancellation path $\hat{C}$. W is control filter coefficients sequence and Y is output signal sequence.
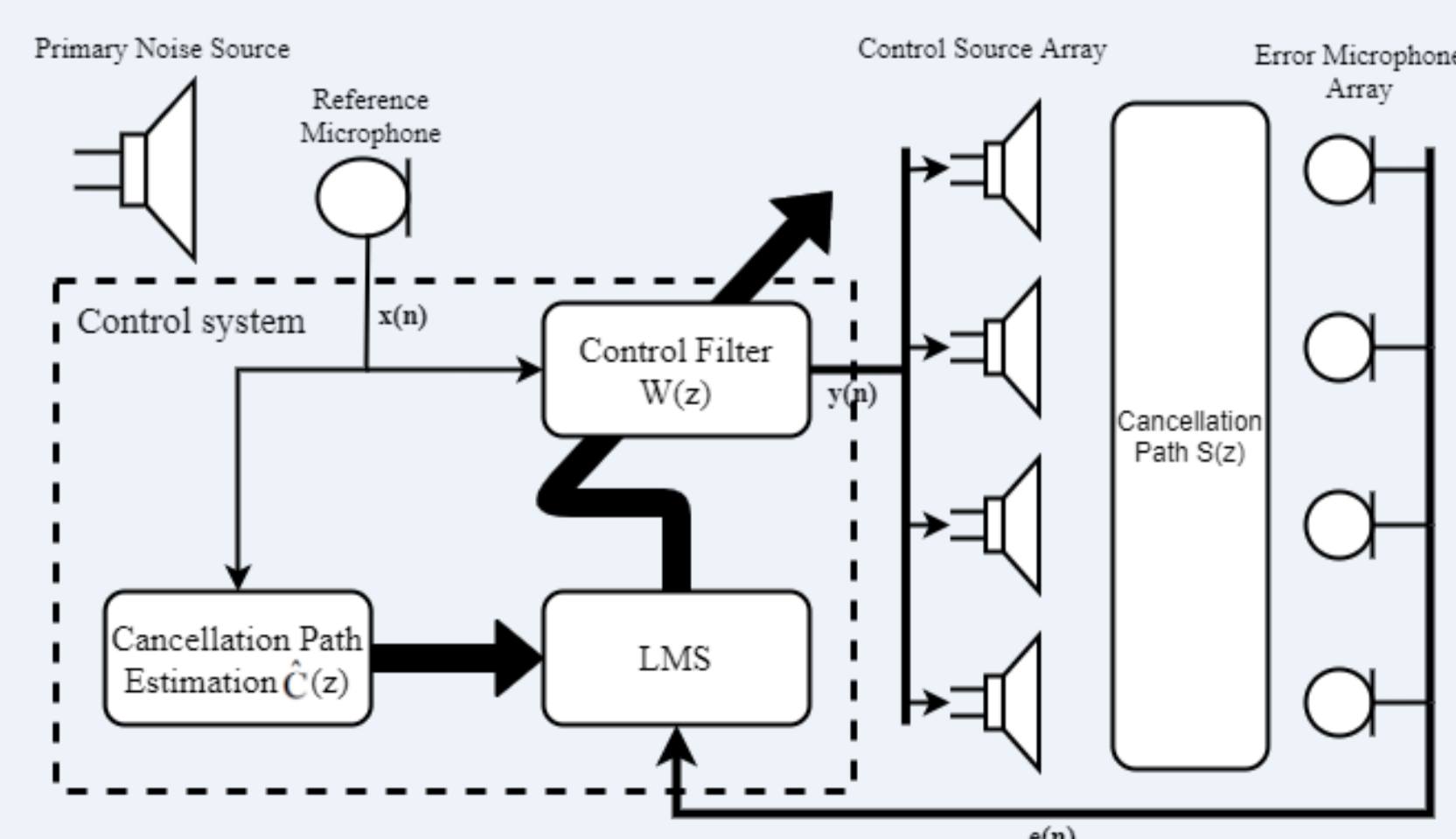

Figure: Diagram of ANC system

Analysis of Optimal System Arrangement using COMSOL & MATLAB
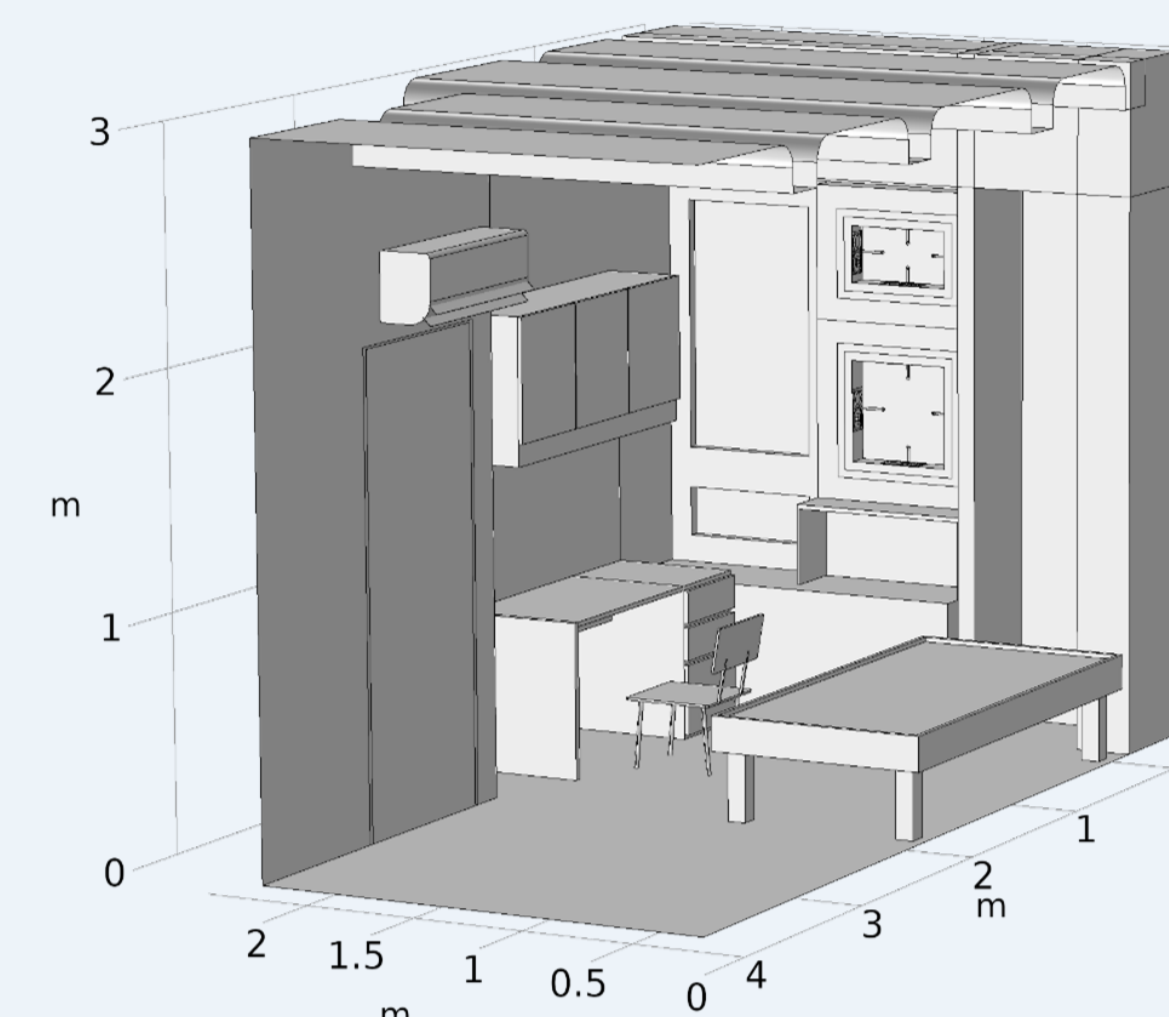

Figure: COMSOL Model for Apartment Room

► Our ANC window system is installed and tested in a dormitory room in Hall 5 of NTU. To built a precise model for the room, first, detailed spatial information about real experiment environment is to be measured accurately. Then a detailed COMSOL model for real experiment environment can be built according to geometry parameters measured in real environment.

► To describe the effects of furniture, wall, and window on the sound energy distribution precisely, materials of furniture, wall and window are considered into simulation. The unique structure of ceiling in the apartment is also precisely introduced into COMSOL model as shown in figure above.
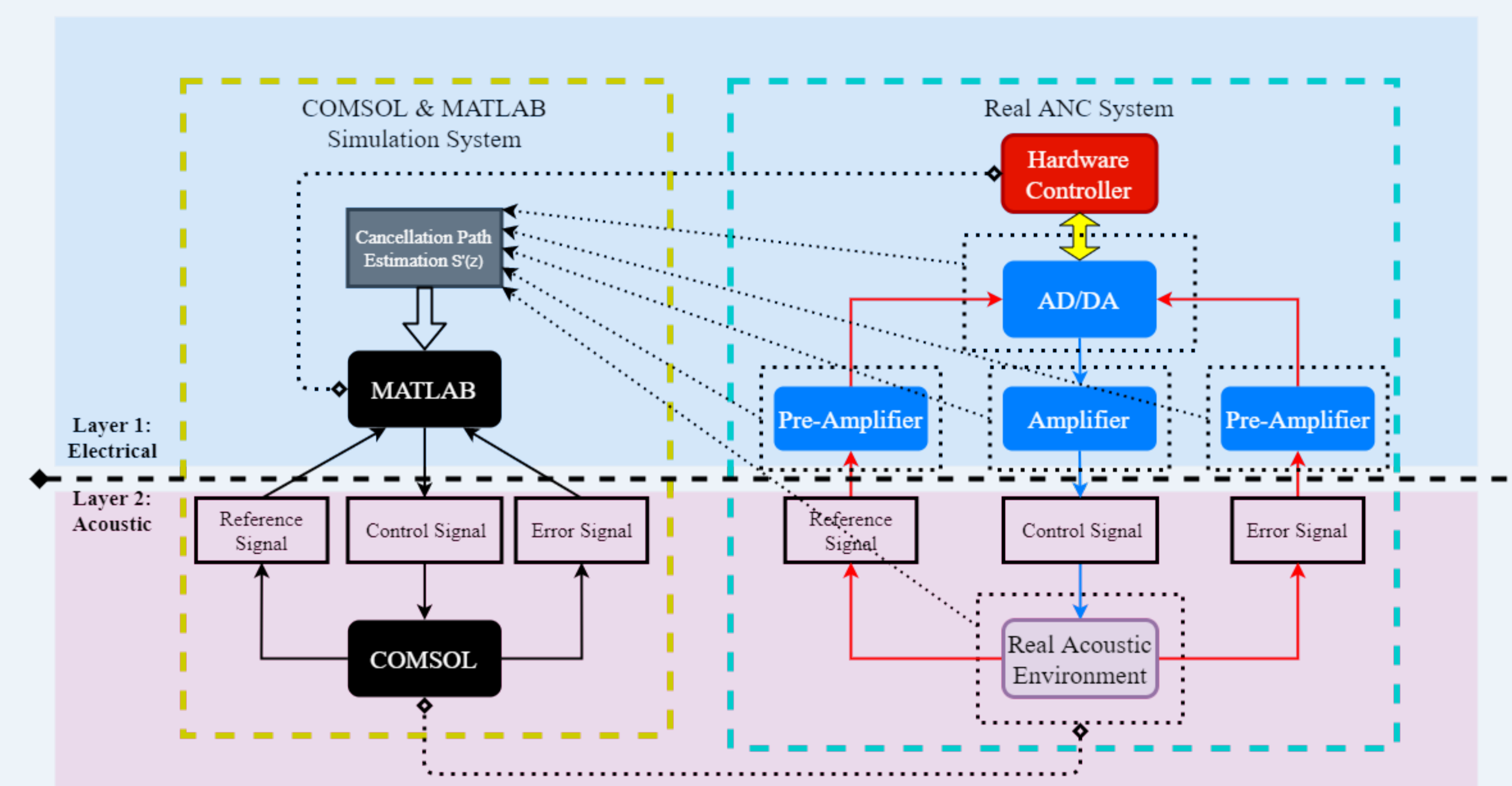
Combined Simulation of COMSOL and MATLAB

Figure: Block Diagram of COMSOL & MATLAB Combined Simulation System

► As shown in Figure above, the real ANC system is mapped into COMSOL MATLAB simulation system. Hardware controller used in real experiment is simulated by MATLAB. Real cancellation path including AD/DA, amplifers is measured and used in MATLAB to represent these components in real system. COMSOL is applied to simulate real acoustic environment.

► To test proposed ANC algorithm in simulated experiment system, reference signal and error signal are read from COMSOL simulation results, and secondary source speaker signal is fed back to the COMSOL model to perform update of control weights in simulation.

Using Genetic Algorithm to find optimal arrangement

► Based on COMSOL MATLAB Combined Simulation System, performance of different system arrangements can be evaluated according to reduction in sound pressure level of signal picked by error microphone. However, it is still difficult to use trial and error in simulation to find the optimal arrangement which gives best performance since there are too many possible positions for reference, error microphones and secondary source speakers.

► Genetic algorithm is used to search through all possible positions and find optimal arrangement. As shown in the figure below, all combinations of secondary source speakers, reference and error microphones are treated as particle space in genetic algorithm. The best reduction in sound pressure level of every particle, which represents one arrangement, is referred as the fitness value of the arrangement. Generally, particles in proposed genetic algorithm are combination of positions of error microphones and secondary source speakers, while the whole ANC system functions as fitness function. With genetic algorithm, optimal solution can be found faster compared to trial and error.

► Candidates of genetic algorithm which is going to be applied are Covariance matrix adaptation evolution strategy (CMA-ES), Comprehensive Learning Particle Swarm Optimization (CLPSO), and Particle Swarm Optimization with Momentum (mPSO).
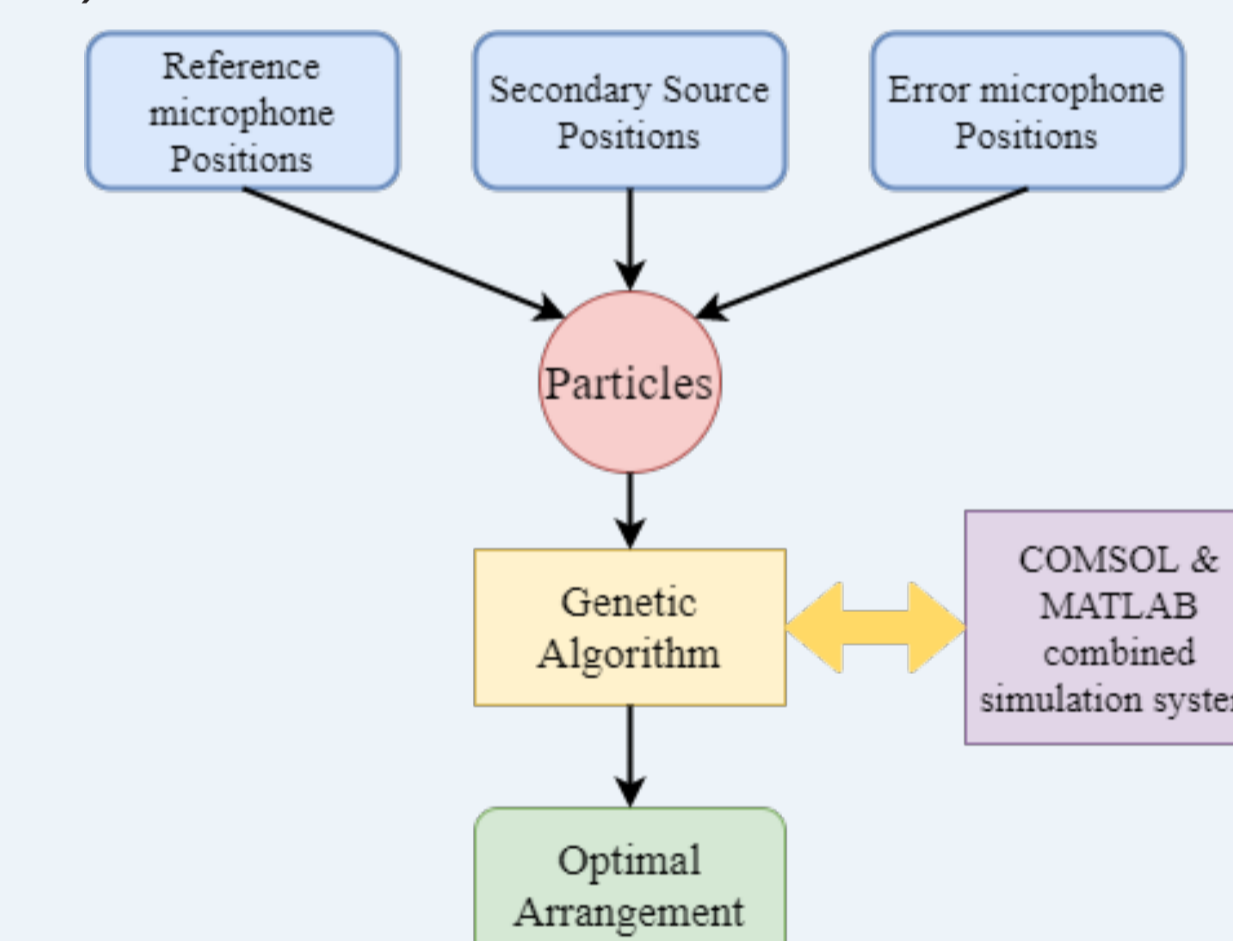

Figure: Block Diagram of simulation system with Genetic algorithm

Summary

► In near future, with the urbanization of cities, it is inevitable that urban noise sources will become more and more close to people's daily life. I hope my work can evoke people's interest in disturbance of urban noise and hearing protection of residents.

References

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