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The Synthesis of Soundscape using Genetic Algorithm and Popular Songs

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ABSTRACT

This paper proposes the concept of soundscape synthesis based on improving existing soundscapes with optimization through Genetic Algorithm. As a goal function for optimization the parameter of some soundscape called Total Distraction Coefficient (which depends on loudness, sharpness and loudness growth rate) is chosen by which one can synthesize an improved soundscape. To verify the proposed concept two representative (and familiar to most urban residents) soundscapes are further analysed and compared (namely, a children's park and an expressway). Using Genetic Algorithm (with previously known Total Distraction Coefficient) two new soundscapes are synthesized from each soundscape- one with higher and one with optimum Total Distraction Coefficient (i.e. the soundscapes supposed to be perceived as "worse" and "better" than the starting one, respectively). The obtained soundscapes can serve as a basis for further subjective testing.

Keywords: Soundscape Synthesis, Genetic Algorithm, Total Distraction Coefficient, Subjective Perception

1. INTRODUCTION

Nowadays, each individual is exposed to noise on a daily basis. Noise pollution is often overlooked when compared to other different environmental pollutions (e.g. air pollution, water pollution, soil pollution etc.). However, same as the all aforementioned pollutions, noise exposure has an accumulating character, meaning that the harmful effect of noise is detected only after a long period of time (1). Long exposure to noise pollution can be displayed as a bad mood, fatigue, insomnia, headache and loss of concentration, which causes reduced work ability and ultimately permanent hearing impairment (2-4). Bearing in mind the ever increasing problem of noise pollution the concept of soundscape was introduced in order to amend and supplement the assessment of noise and its effects on humans (5, 6). Soundscape studies offer a more intuitive and interdisciplinary approach to noise and its numerous consequences. This particular field of research is becoming very propulsive and everyday more and more scientists with different areas of expertize are being included while trying to make their contribution in terms of improving the overall quality of life especially in urban areas (e.g. acoustic engineers, urban planners, psychologists, architects, doctors etc.). Their common goal is to link objective and subjective acoustic parameters, to plan future urban infrastructures keeping in mind the existing soundscapes (e.g. building while not deteriorating the sound environments) and to create and implement new solutions that will design, preserve and improve acoustic environments (7, 8). Thus, we can conclude that nowadays more and more soundscape studies are oriented towards human health, well-being and overall quality of life (9).

Bearing in mind all of the aforementioned, in our previous research we have proposed a simple acoustical model, which allows one to quantify how much typical urban acoustic environments are subjectively perceived in terms of affecting the listeners’ concentration. For that purpose, we have

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recorded several different soundscapes which were then reproduced to listeners in laboratory conditions. It was found that the linear model is adequate for calculating the parameter which we named respectively Total Distraction Coefficient (TDC). For instance, the lowest TDC was obtained for the soundscape of stream (10).

The motivation for this research is to use the Genetic Algorithm (GA) as an instrument which will optimize the parameter Total Distraction Coefficient (TDC) and furthermore allow us to synthesize improved versions of existing soundscapes. The obtained soundscapes were then tested and compared in terms of subjective perception.

2. EXPERIMENT: THE TOTAL DISTRACTION COEFFICIENT (*TDC*) OPTIMIZATION

In our previous research (10) we have obtained a mathematical expression for the numerical parameter which we term Total Distraction Coefficient (TDC):

$$TDC = 0.1 \cdot L_{DIF} + 0.02 \cdot LGD_{DIF} + 0.44 \cdot S_{DIF} \quad (1)$$

where L_{DIF}, LGD_{DIF} and S_{DIF} are ratios of difference value and the mean value of the three considered objective acoustic parameters themselves namely loudness, loudness growth, and sharpness (e.g. loudness difference was calculated $L_{DIF}=\Delta N_5/N_{mean}$). This numerical value is envisaged as a characteristic value of the soundscape and can serve as an objective parameter or a measure for evaluation of soundscapes. Linear regression and linear model have been selected after calculating both linear and nonlinear models. It was found that nonlinear models do not give significantly better dependence on the results of the three aforementioned acoustic parameters. This claim is verified by the fact that the standard error was significantly higher in nonlinear models. Thus, linear model can be considered as adequate enough for determination of the distraction coefficient.

For this particular study we have selected two soundscapes which are familiar to most urban residents: a children's park and an expressway (shown in Figure 1). The calculated deviation factors (objective measures) and *Total Distraction Coefficient* (TDC) for the considered soundscapes are shown in Table 1.

Figure 1 – The selected locations for further analysis

Table 1 – The calculated deviation factors and *Total Distraction Coefficient* for the considered soundscapes

Soundscape type	L_{DIF}	LGD_{DIF}	S_{DIF}	TDC
Children's park	1.48	3.9	0.27	0.343
Expressway	0.83	3.45	0.28	0.28

In addition, our previous studies have shown that the soundscape of a stream has the lowest *Total*

Distraction Coefficient TDC = 0.184 (10). Therefore, this experiment is designed in order to achieve the same *TDC* for the children's park and expressway by using the Genetic Algorithm (GA).

2.1 The Genetic Algorithm (GA)

The Genetic algorithm (GA) is an adaptive empirical search algorithm based on the evolutionary ideas of natural selection and genetics (11). As such it represents an intelligent exploitation of a random search used to solve optimization problems. Although randomized, GA is by no means random, instead they exploit information to direct the search into the region of better performance within the certain search area. The basic techniques of the GA are designed in order to emulate processes in natural systems necessary for evolution, especially those which follow the principles of Charles Darwin i.e. "survival of the fittest".

Genetic algorithm starts with an initial set of random solutions called population and each individual in the population is called candidate units.

The basic structure of the Genetic Algorithm (shown in Figure 2) is:

1. Setting a random initial population *P* that is made from x_i candidate units, where $i = 1, 2, \dots, N$;
2. Determining the Fitness Value of all candidate units from the population *P*;
3. Selecting the best candidate units from the population *P* according to the predefined Fitness Value (the number of best candidate units which enter a new iteration of GA can be defined according to the study hypothesis);
4. Creating a new population i.e. best candidate units and new units created by using genetic operators:
   a. Crossover *P2 = Crossover (P1)*
   b. Mutation *P2' = Mutation (P1')*;
5. Determining the Fitness Value of all candidate units in a new population *P2*;
6. Returning to step 3 until the break condition is achieved.

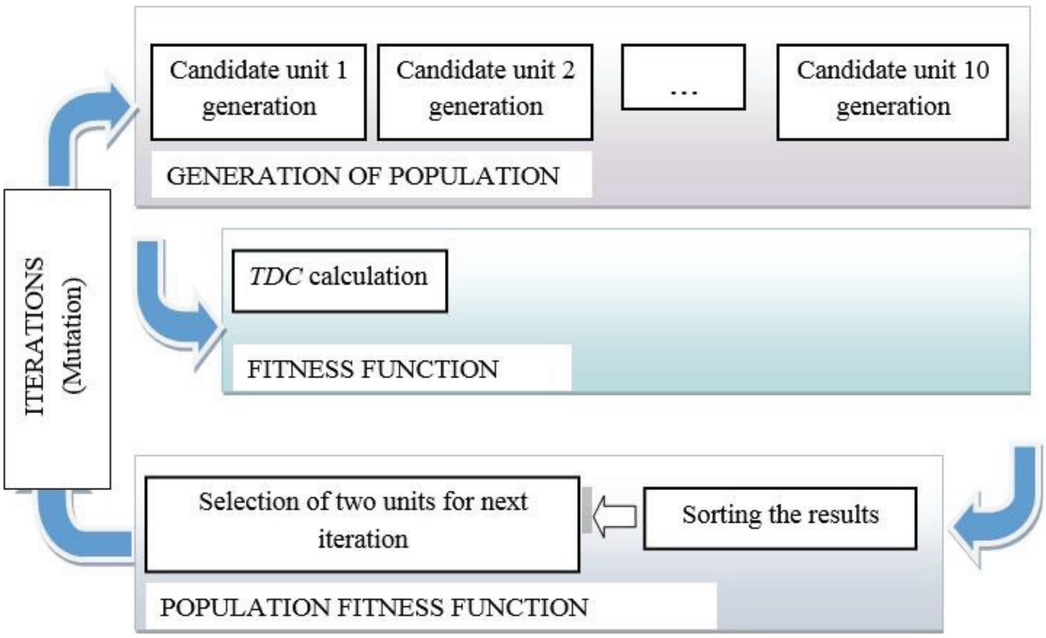

Figure 2 – Genetic Algorithm flowchart

In this particular study, we have defined for Genetic Algorithm the *TDC* (Fitness Value) to be exactly 0.18 (the obtained *TDC* from our previous research for the soundscape characterized as the most pleasant and calming one i.e. stream). The size of population is ten and in each iteration the GA preserves the two best candidate units while generating eight new ones. In order to create new candidate units according to Eq.1 we needed to change the ranges of following parameters: the loudness difference range from 0.5 to 1.5, the loudness growth difference range from 3 to 6 and the sharpness difference range from 0.1 to 0.3. The ranges for all three acoustic parameters are changed with a step of 0.05. The mentioned ranges and step were chosen based on our findings in previous research on a larger number of acoustic environments.

2.2 The optimized solutions for calculating Total Distraction Coefficient

After performing fifty iterations, the Genetic Algorithm has provided nine possible optimized solutions for calculating Total Distraction Coefficient (shown in Table 2). We have decided to further investigate the second solution (marked yellow in Table 2) which provided the largest alteration primarily for the loudness ratio value (L_{DIF}) and in addition for the ratio of loudness growth difference value (LGD_{DIF}).

Table 2 – Optimized solutions for calculating Total Distraction Coefficient

ID	L_{DIF}	LGD_{DIF}	S_{DIF}
1	0.55	4.25	0.10
2	0.80	3.00	0.10
3	0.50	3.40	0.15
4	0.75	3.25	0.10
5	0.50	4.50	0.10
6	0.55	3.15	0.15
7	0.60	4.00	0.10
8	0.65	3.75	0.10
9	0.70	3.50	0.10

3. SYNTHESIS OF NEW SOUNDSCAPES

In order to achieve the optimized Total Distraction Coefficient for the aforementioned soundscapes we have tried to use acoustical methods such as compression and filtering of higher frequencies. However, in our opinion this is very unpractical in real case scenarios i.e. performing audio compression and filtering of higher frequencies in in-situ conditions. Therefore, we have decided to use different popular songs in the process of new soundscapes' synthesis.

3.1 The selection of songs

The selection of used songs was not done completely randomly. At this stage of research we have decided to use some of the "classics" and on the other hand songs that are extremely popular i.e. songs that are often played on radio stations. Furthermore, we chose two genres in particular rock and pop songs and for each genre a song which is perceived as happy or optimistic and a song perceived as sad or depressing. The selection of songs is shown in Table 3.

Table 3 – Selection of songs

CLASSICS		
	HAPPY/OPTIMISTIC	SAD/DEPRESSING
ROCK	Queen *"Bohemian Rhapsody"*	Guns N' Roses *"November Rain"*
POP	John Lennon *"Imagine"*	Jeff Buckley *"Hallelujah"*
MODERN		
	HAPPY/OPTIMISTIC	SAD/DEPRESSING
POP	Beyoncé *"Crazy in Love"*	Miley Cyrus *"Nothing Breaks like a Heart"*

In addition, for each individual song prior to mixing it with soundscapes we have calculated Total Distraction Coefficient (shown in Table 4.). The mean sound pressure level used for calculation of loudness parameters and TDC was 50 dB(A).

Table 4 – Total Distraction Coefficient for the chosen songs

SONG	L_{DIF}	LGD_{DIF}	S_{DIF}	TDC
Queen *"Bohemian Rhapsody"*	0.9	3.2	0.33	0.30
Guns N' Roses *"November Rain"*	0.47	2.1	0.18	0.17
John Lennon *"Imagine"*	0.5	1.82	0.38	0.25
Jeff Buckley *"Hallelujah"*	1.2	3.5	1.02	0.64
Beyoncé *"Crazy in Love"*	0.37	1.79	0.24	0.18
Miley Cyrus *"Nothing Breaks like a Heart"*	0.41	3.1	0.21	0.20

Finally, in order to proceed with the experiment we have eliminated the extremes (two lowest and two highest TDCs) and the mixing was done with two songs marked yellow in Table 4 (i.e. John Lennon "Imagine" – song 1 and Miley Cyrus "Nothing Breaks like a Heart" – song 2).

3.2 The process of mixing the selected soundscapes with chosen songs

The process of mixing soundscapes with the two chosen songs was done in the following way. Each soundscape was mixed with three versions of each song (shown in Table 5.). The 100% of a song's mean level corresponds to a 100% of soundscape's mean level in the steady part of the soundscape (equivalent continuous sound pressure level corresponds to 50 dB(A)). The 50 seconds long examples of soundscape signals mixed with songs signal versus time are shown in Figures 3 and 4. Figures 3a and 4a show loudness of the soundscape and the mixed signal, while figures 3b and 4b show normalised level of soundscapes and songs signals. If we analyse the results shown in Table 5. It can be concluded that by raising the percentage of a song in the mixed signal, the Total Distraction Coefficient becomes closer to the calculated Total Distraction Coefficient of a song. If we go back to the results obtained from Genetic Algorithm in terms of the desired TDC (i.e. Fitness Value 0.18) we can observe that the best result was achieved for the combination of children's park and Miley Cyrus song "Nothing breaks like a heart" with a 100% loudness. In order to proceed with the experiment, we have eliminated the extremes (two lowest and two highest TDCs) and the mixing was done with two songs marked yellow in Table 4.

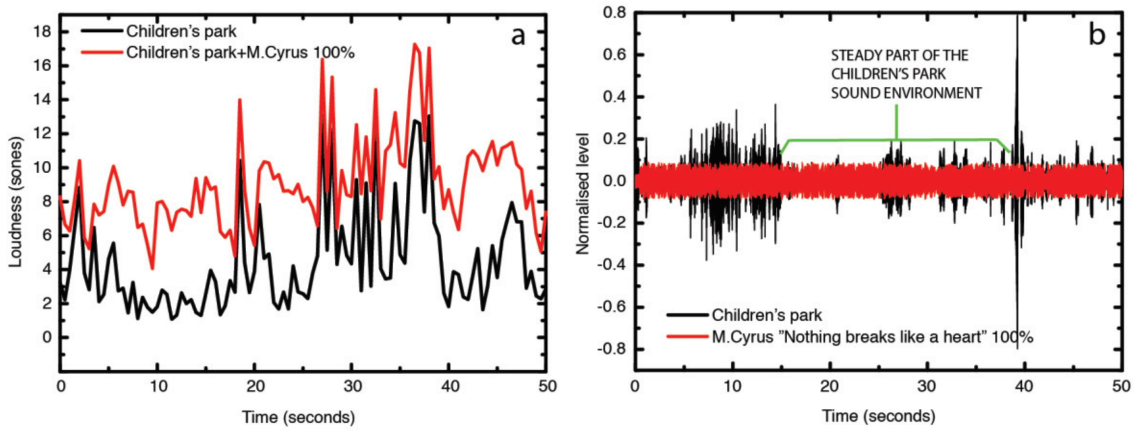

Figure 3 – An example of mixing: children's park with 100% Miley Cyrus "Nothing Breaks like a Heart"; a) loudness of mixed signals versus time, b) normalised level versus time of each signal

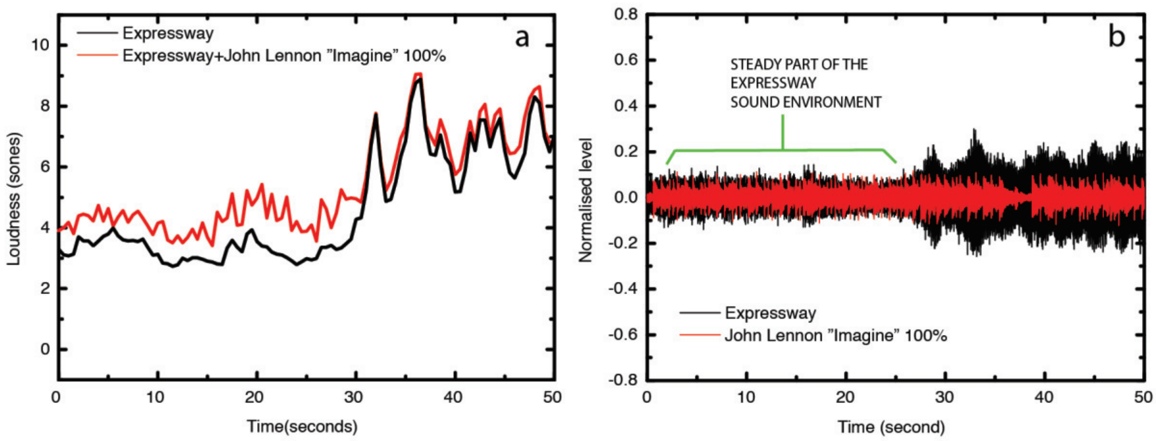

Figure 4 – An example of mixing: expressway with 100% John Lennon "Imagine"; a) loudness of mixed signals versus time, b) normalised level versus time of each signal

Table 5 – Total Distraction Coefficient for the soundscapes mixed with chosen songs

	L_{dif}	LGD_{dif}	S_{dif}	TDC		L_{dif}	LGD_{dif}	S_{dif}	TDC
CHILDREN'S PARK	1.5	3.9	0.3	**0.36**	EXPRESSWAY	0.98	3.8	0.28	**0.30**
+Lennon 40%	1.3	3.8	0.29	0.33	+Lennon 40%	1	3.8	0.28	0.30
+Lennon 80%	0.88	3.8	0.29	0.29	+Lennon 80%	0.86	2.86	0.3	0.28
+Lennon 100%	0.67	3.5	0.31	0.27	+Lennon 100%	0.74	2.1	0.29	0.24
+Miley 40%	1.24	4.3	0.24	0.32	+Miley 40%	0.97	3.9	0.25	0.29
+Miley 80%	0.6	3.7	0.18	0.21	+Miley 80%	0.73	2.6	0.23	0.23
+Miley100%	**0.42**	**2.93**	**0.17**	**0.18**	+Miley 100%	0.52	2.55	0.23	0.20

4. CONCLUSIONS

This paper deals with the concept of soundscape synthesis based on improving the existing soundscapes with optimization of Total Distraction Coefficient calculations using the Genetic Algorithm. Total Distraction Coefficient depends on loudness, sharpness and loudness growth rate.

Our previous studies have shown that the soundscape of a stream has the lowest Total Distraction Coefficient *TDC = 0.184*, therefore, this experiment is envisaged in order to achieve the same *TDC* for the children's park and expressway. In our experiments we have obtained the desired TDC for the aforementioned soundscapes using acoustical tools such as compression and filtering of higher frequencies. However, in our opinion these methods are extremely unpractical to apply in real case scenarios in the field of soundscape. When speaking about indoor soundscapes, filtering of higher frequencies can actually be achieved using specific acoustic absorptive materials and collaborating with architects regarding the layout of e.g. open-space offices.

For outdoor soundscape our idea was to test different songs in terms of calculating their *TDC*. Regarding the choice of songs, we have decided to use some of the "classics" songs together with the songs that are often played on radio stations. After calculations we have decided to eliminate the extremes and use two songs i.e. John Lennon's "Imagine" (*TDC = 0.2536*) and Miley Cyrus's "Nothing Breaks like a Heart" (*TDC = 0.1954*). Each soundscape was mixed with three versions of each song (40%, 80% and 100% of song's level) where a 100% of a song's mean level corresponds to a 100% of soundscape's mean level in a steady part of a soundscape (i.e. 50 dB(A)). The tests have shown that by increasing the percentage of a song's level the overall *TDC* becomes closer to the *TDC* of a song.

The best result with respect to the desired *TDC* was obtained for the case of children's park mixed with "100% loud" Miley Cyrus's song "Nothing Breaks like a Heart".

In order to confirm our findings, the next stage of research will be focused on conducting extensive listening tests on urban residents. Furthermore, the obtained formula for calculating the Total Distraction Coefficient will need to be expanded and a correction factor which takes into account the human perception will be applied. In addition, we plan to extend the base of songs used for synthesizing the soundscapes.

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