Comparative Study of Intensity of Echo and Source Sound

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Abstract

Echo is the repetition of sound due to reflection. This repetition sound will be distinct from the original sound. This paper attempt to compare the intensity of source sound and intensity of echo sound. In this experiment ten Nepali isolated words are spoken three times by ten males and ten females at same age group 20 to 25 years and the echo sound produces by the reflection of sound from the properly selected hill. This study helps to investigate the nature of absorption coefficient of reflecting surface and surrounding. The recorded echo and source sound digitize and analyze by Praat software at sampling frequency 16KHz. Linear predictive coding (LPC) spectra were obtained for each word and instantaneous values of minimum, maximum and average intensity were measured for echo and source sounds. Threshold value of intensity of sound is zero (0 dB). For male speakers minimum, maximum, average intensity of source sound and echo sound varies from 57.78 to 67.31dB, 63.76 to 83.24 dB, 60.77 to 74.45 dB and 53.62 to 58.33 dB, 56.30 to 66.94dB, 54.96 to 62.64 dB, respectively. In case of female speakers minimum, maximum, average intensity of source sound and echo sound varies from 63.83 to 71.35, 67.62 to 89.39dB, 66.47 to 78.29 dB and 57.80 to 61.60 dB, 60.21 to 70.23dB, 59.01 to 65.92dB, respectively. The ratios of the average intensity of echo to source sound varies from 0.79 to 0.88 for male speakers and 0.80 to 0.89 for female speakers.

Introduction

The echo is a reflection of sound waves from surfaces that bounce back towards the source and creating a repeated auditory effect. In order to understand the principles of echo sound, it is essential in various field like acoustics, architecture, and communication. This literature has reviewed to explore the science behind sound echoes, its applications, and the factors affecting its perception (Rindel, 2000). The concept of echoes has been known since ancient times. Ancient Greek and Roman writers, such as Aristotle and Vitruvius, documented their observations of sound reflections. They noticed that echoes were more pronounced in open spaces and mountains, where sound waves could bounce off surfaces more effectively. Sound waves travel through a medium, such as air, until they encounter a surface. When the sound waves hit the surface, some of its energy is absorbed, but the rest is reflected back. The reflected sound wave combines with the original sound wave, creating the perception of an echo. The intensity and delay of the echo depend on the distance between the sound source and the reflecting surface (Rossing *et al.*, 2002).

The main condition for an echo to be audible is that the time interval between the original sound and the reflected sound should be at least 0.1 seconds. This delay is necessary for the human ear to distinguish the reflected sound as a separate repetition rather than a continuation of the original sound. If the time interval is shorter, the reflected sound is perceived as a mere continuation of the original sound, known as reverberation (Blesser & Salter, 2009).

The conditions for perceiving an echo involve a minimum time delay between the original sound and the reflected sound, based on the speed of sound in the medium. The reflecting surface's characteristics, such as smoothness and hardness, also influence the quality and clarity of the echo (Egan, 2007). Echoes can be heard in small spaces with hard walls, like wells, or where there are lots of hard surfaces all around. That is why echoes can be heard in a canyon, cave, or mountain range. But sounds are not always reflected. If they meet a soft surface, such as a cushion, they will be absorbed and will not bounce back (Lehmann & Blauert, 2008).

The absorption coefficient of sound, is a measure of how much sound energy is absorbed by a material when sound waves pass through it. It quantifies the ability of a material to attenuate or reduce the intensity of sound. A coefficient of 0 (zero) indicates perfect reflection, meaning the material reflects all the sound energy incident upon it, while a coefficient of 1 or 100% indicates perfect absorption, where all the sound energy is absorbed and none is reflected. The human auditory system is highly sensitive to echoes. When the delay between the original sound and the echo is relatively short (around 50 milliseconds), the human brain perceives them as a single sound (Toole, 2008). As our understanding of acoustics and sound propagation continues to advance, we can expect further developments in utilizing sound echoes to enhance our lives in both practical and aesthetic ways (Vorländer, 2008). The studies on psychological and cognitive effects have shed light on how echoes influence human perception, speech comprehension, and emotional responses, highlighting the importance of controlling echoes in specific environments to optimize communication and comfort (Williams, 2012).

Doppler ultrasound also used to quantitative measurements of echo contrast concentration in flow systems. Doppler intensity can effectively measure relative echo contrast, it falls short for absolute quantification due to the complexities of microbubble behavior (Schwarz *et al.*, 1993). A new method for measuring noise at echo integrator outputs offers practical advantages over receiver output measurements, enabling easier comparison with fish backscattering strength (SV). This includes a conversion equation to determine equivalent noise spectrum levels, facilitating comparisons across different echo sounding systems. Applied to the dual beam system on the research vessel Kaiyo-maru, it verified a 5 dB difference in noise SV aligned with theoretical predictions (Takao & Furusawa, 1995). The validation of an ODEON-simulated reverberation room was conducted through empirical measurements of reverberation time, emphasizing the critical impact of material property selection and sound diffusion irregularities on simulation accuracy.

Accurate modeling is essential due to inherent uncertainties in acoustic inputs and room geometry (Artur & Marcelina, 2022). To compared the traditional sound intensity measurement using dual pressure microphones with a new method that integrates an acoustic particle velocity transducer with a pressure microphone. It highlights the critical phase calibration issues at frequencies below 500 Hz when the measurement surface is near the sound source. Moving the measurement surface away from the source mitigates these errors, and calibration can be effectively conducted in an anechoic room (Jacobsen & Hans-Elias, 2005).

Bats also actively adjust their pulse intensity to maintain a consistent echo intensity from targets as they navigate (Shizuko *et al.*, 2007). Flying horseshoe bats adjust their sonar broadcasts to maintain constant frequency and amplitude of returning echoes, compensating for Doppler shifts and target proximity, which enhances their precision in target range estimation during landings. This dual compensation facilitates effective navigation, even when approaching non-fluttering objects (Shizuko *et al.*, 2008). Detection distance for insects like Drosophila typically ranges from about 50 cm to occasionally up to 1 meter by using echo sound. In a study with particular bats, low-frequency thermal noise (0.1–15 kHz) did not hinder their ability to catch Drosophila, allowing them to gain weight as in silence. In contrast, high-frequency noise (20–100 kHz) discouraged insect catching. Which suggests that bats primarily rely on echolocation rather than passive listening to detect small, quiet insects (Donald, 1960).

Like instrument Obstetric MRI, intensity level of echo sound used to diagnosis in health sector. By compared ultrasound echo intensity (EI) with high-resolution T1-weighted MRI to estimate intramuscular fat in four muscle groups (Glover *et al.*, 1995; Young, 2015).

Mathematical Analysis

Sound intensity is defined as the sound energy per second per unit area. The unit of sound intensity is watt-m^{-2}. The most common approach to sound intensity measurement is to use the decibel scale. Intensity of sound is given by following formula (Kinsler *et al.*,2000).

(1)

where threshold of hearing intensity $I_0 = 10^{-12} watt\ m^{-2}$

The aim of this work is the analyze the intensity of source sound and echo sound of male and female and compare intensity of source sound with echo sound across the gender. For such a measurement, the recorded sound of source and echo for male and female were analyzed by the Praat software. During calculation we keep absorption coefficient constant. Also, we keep resistance due to air and other obstacles constant.

Methodology

(a) Study area

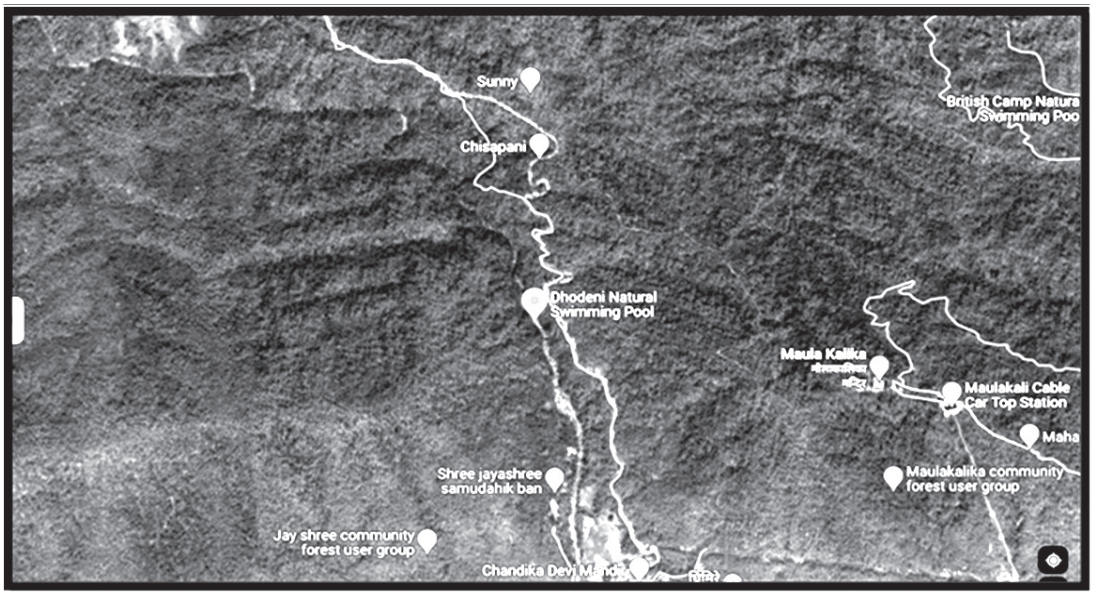

Fig. 1. Location of Field Study Area

The study was carried out on Dhodeni natural swimming pool site which is located in Gaindakot.

(b) Subject

Altogether 10 boys and 10 girls having age 20 to 25 years, were selected for the research on the criteria that they had Nepalese language as their mother tongue, able to read Nepali and normal speech, language and hearing function.

(c) Test material

The main theme of the study was to find out the Comparative Study of Intensity of Echo and Source Sound. We have taken into consideration of 10 Nepali isolated words Git, Dada, Chap, Chit, Khat, Kaka, Khet, Mama, Papa, Khag. So, we analyze 10 words and three times for each speaker.

(d) Procedure

Primary data was collected using sound recorder. When we shout word (token isolated Nepali selected words) loudly on the hill then we will hear our voice twice, one is our original voice and another one is echo**. The echo produced on the top of the hill is because there will no object around the hill which can absorb the sound energy from us and the surface reflects our own voice.** Intensities was calculated by using sound analysis PRAAT software.

Results and Discussion

In case of maximum, the maximum intensity of source sound varies from 63.76 to 83.24 dB and 67.62 to 89.39dB for male and female speakers respectively and shown in table 1 and 2. In the case of echo sound, the intensity varies from 56.30 to 66.94dB and 60.21 to 70.23dB for male and female speakers respectively.

In case of minimum the source sound intensity varies from 57.78 to 67.31dB and 63.83 to

71.35 dB for male and female speakers respectively whereas for echo sound, the intensity varies from 53.62 to 58.33 dB and 57.80 to 61.60 dB for male and female speakers and shown in table 1 and 2 respectively.

In case of average, the average intensity of source sound varies from 60.77 to 74.45 dB and 66.47 to 78.29 dB for male and female speakers respectively. In the case of echo sound, the intensity varies from 54.96 to 62.64 dB and 59.01 to 65.92dB for male and female speakers respectively. The ratios of the average intensity of echo sound to the average intensity of source sound varies from 0.79 to 0.88 for male speakers and in case of female speakers which varies from 0.80 to 0.89. From the fig 2 and fig.3 it found that the intensity of the source sound is greater than the intensity of the echo sound in every case of male and female speakers.

Table 1. Minimum, maximum and average intensity of source and echo sounds and ratio of sound and ratio of average intensity of echo to source sound for male speakers.

words	Intensity of source sound of male (dB)			Intensity of echo sound of male (dB)			Ratio of the average intensity
	Minimum	Maximum	Average	Minimum	Maximum	Average	
Git	65.32	82.24	73.78	57.61	65.91	61.76	0.84
Dada	67.31	77.02	72.17	56.37	61.34	58.86	0.82
Chap	59.21	83.54	71.38	58.33	66.94	62.64	0.88
Chit	69.06	79.84	74.45	57.19	60.09	58.64	0.79
Khat	67.18	77.03	72.11	55.74	59.23	57.49	0.80
Kaka	66.27	75.11	70.69	56.40	60.83	58.62	0.83
Khet	65.97	76.95	71.46	57.50	60.10	58.80	0.82
Mama	66.38	75.17	70.78	54.21	57.48	55.85	0.79
Papa	64.91	75.94	70.43	53.71	57.70	55.71	0.79
khag	57.78	63.76	60.77	53.62	56.30	54.96	0.90

Table 2. Minimum, maximum and average intensity of source and echo sounds and ratio of sound and ratio of average intensity of echo to source sound for female speakers.

words	Intensity of source sound of female (dB)			Intensity of echo sound of female (dB)			Ratio of the average intensity
	Minimum	Maximum	Average	Minimum	Maximum	Average	
Git	68.05	88.52	78.29	59.65	69.55	64.60	0.85
Dada	71.35	80.77	76.06	59.23	64.53	61.88	0.81
Chap	63.83	89.39	76.61	61.60	70.23	65.92	0.86
Chit	71.26	83.84	77.55	60.32	65.29	62.81	0.81
Khat	69.38	81.53	75.46	60.51	64.55	62.53	0.83
Kaka	70.28	80.65	75.47	60.33	66.25	63.29	0.84
Khet	71.15	79.54	75.35	59.62	67.41	63.52	0.84
Mama	70.34	80.14	75.24	58.92	61.23	60.08	0.80
Papa	68.23	79.34	73.79	60.33	**64.32**	62.33	0.84
khag	65.32	67.62	66.47	57.80	60.21	59.01	0.89

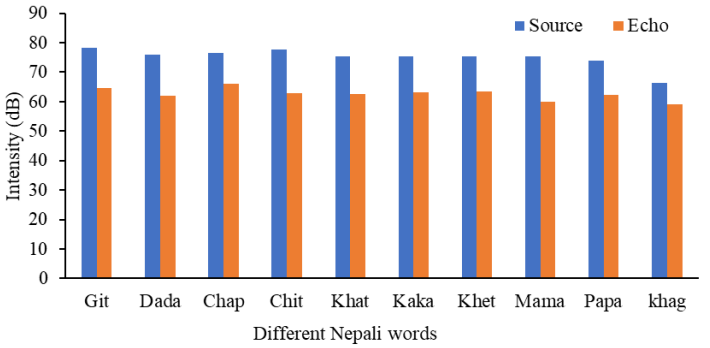

Fig. 2. Variation of intensity of source and echo sound of different Nepali words for male speakers.

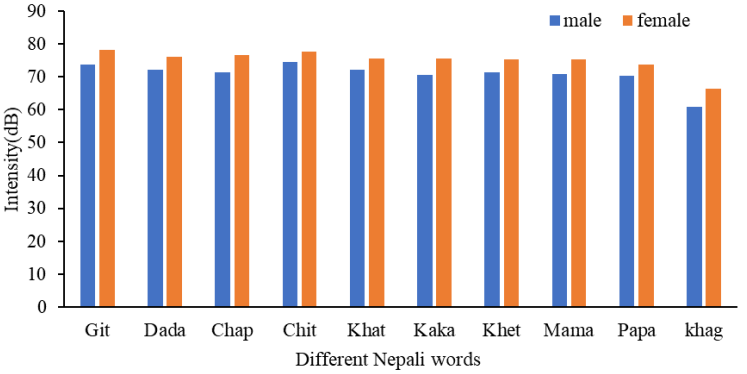

Fig. 3. Variation of intensity of source and echo sound of different Nepali words for Female speakers.

Conclusion

The main objective of the study was to compare the intensity of source sound and the intensity of echo sound. The data was collected from the hill. For the echo sound rocky hill was a reflecting surface. The data was collected by using the recording device and analyzed by using the software.

The average intensity of source sound varies from 60.77 to 74.45 dB and 66.47 to 78.29 dB for male and female speakers respectively. Similarly, for echo sound, average intensity varies from 54.96 to 62.64 dB and 59.01 to 65.92dB for male and female speakers. The ratios of the average intensity of echo to source sound varies from 0.79 to 0.88 and 0.80 to 0.89 for male and female speakers respectively. As the ratio of intensity of source sound to echo sound is < 1, the intensity of source sound is greater than echo sound. That indicate that there is loss in sound energy in echo sound.

At last, it concludes that in case of minimum, maximum and average intensity of source sound greater than intensity of echo sound for male and female speakers. So, it is clear that the ratio of the intensity of echo sound to the intensity of source sound is nearly equal if the source of the sound, reflecting surface, distance between the source of sound and reflecting surface, and direction of sound is the same.

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