

Feasibility Study on Intra-Grid Location Estimation Using Power ENF Signals

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Abstract—The Electric Network Frequency (ENF) is a signature of power distribution networks that can be captured by multimedia recordings made in areas where there is electrical activity. This has led to an emergence of several forensic applications based on the use of the ENF signature. Examples of such applications include estimating or verifying the time-of-recording of a media signal and inferring the power grid associated with the location in which the media signal was recorded. In this paper, we carry out a feasibility study to examine the possibility of using embedded ENF traces to pinpoint the location-of-recording of a signal within a power grid. In this study, we demonstrate that it is possible to pinpoint the location-of-recording to a certain geographical resolution using power signal recordings containing strong ENF traces. To this purpose, a high-passed version of an ENF signal is extracted and it is demonstrated that the correlation between two such signals, extracted from recordings made in different geographical locations within the same grid, decreases as the distance between the recording locations increases. We harness this property of correlation in the ENF signals to propose trilateration based localization methods, which pinpoint the unknown location of a recording while using some known recording locations as anchor locations. We also discuss the challenges that need to be overcome in order to extend this work to using ENF traces in noisier audio/video recordings for such fine localization purposes.

Index Terms—Electric Network Frequency, Information Forensics, Fine Location-of-recording Estimation

I. INTRODUCTION

The Electric Network Frequency is the frequency of power distribution networks. It has a nominal value of 60Hz in the United States and Canada, and 50Hz in most other parts of the world. The ENF does not stay at this nominal value, but rather fluctuates around it due to load changes in the power grid. The changing value of the instantaneous ENF over time is known as the *ENF signal*.

An important characteristic of ENF signals, which makes them relevant to multimedia forensics, is that the ENF variations can be captured in media recordings made in places where there is electrical activity. In audio recordings, this is mainly due to electromagnetic influences and the power acoustic hum [1], [2]. In video recordings, this can be attributed to near-invisible flickering of electric lighting [3].

The ENF signals can be extracted from *power recordings* measured using a 1-D signal sampler and recorder, such as

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a digital audio recorder, connected to a power outlet using a step-down transformer and a voltage divider circuit [4]. The recorded signal is divided into frames and a frequency estimation algorithm is applied to each frame to determine its dominant frequency in the band near to nominal ENF value [5] [6]. The ENF traces present in such power recordings typically has a very high signal-to-noise ratio (SNR), making the extracted ENF signal a high quality reference for the ENF variations. It has been shown that the ENF variations extracted from audio/video recordings match with the ENF variations from power recordings made simultaneously and within the same power grid [3].

The similarity in the observations between ENF signals extracted from simultaneously recorded signals has motivated one of the early proposed ENF-based forensics applications: using the ENF traces to authenticate or identify the time-of-recording of a signal [1]. Other proposed ENF-based applications include detection of tampering/modification in a media signal [7]–[10] [11], multimedia synchronization [12], [13], characterizing the video camera producing an ENF-containing video [14], and determining the location-of-recording among different grids [15], [16]. Being able to tell the grid-location of recording of a media signal containing ENF traces across grids naturally leads to the question of whether we can pinpoint the location of recording of the media signal within a grid, i.e., an intra-grid localization. An answer in the affirmative could potentially lead to many applications, especially in defense and security.

At the intra-grid level, most existing works have assumed that ENF signals across different locations in an interconnected power grid are the same at a given time. However, minor variations are likely to be present in the frequency fluctuations at different locations. This can be attributed to local changes in the load and the finite propagation speed of the effects that such load changes would have on other parts of the grid [17]. In the past, research has been conducted on building a robust reference ENF database for forensics matching by estimating big system disturbances in concurrent multiple recordings at different geographical locations, and using the recordings without any frequency glitch to record ENF at corresponding time [18]. Recently concurrent to the review of this journal paper, a machine learning based classifier approach was used to statistically learn the signal patterns unique to a given location, and determine the location out of the possible locations present in the training set [19]. However, this classification based method is not designed to infer any location outside those in the training set, and would require gathering new data and retraining the classifier for each new

