COMPLEXITY ANALYSIS ON NORMAL AND ABNORMAL ELECTROGASTROGRAMS USING TSALLIS ENTROPY

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INTRODUCTION

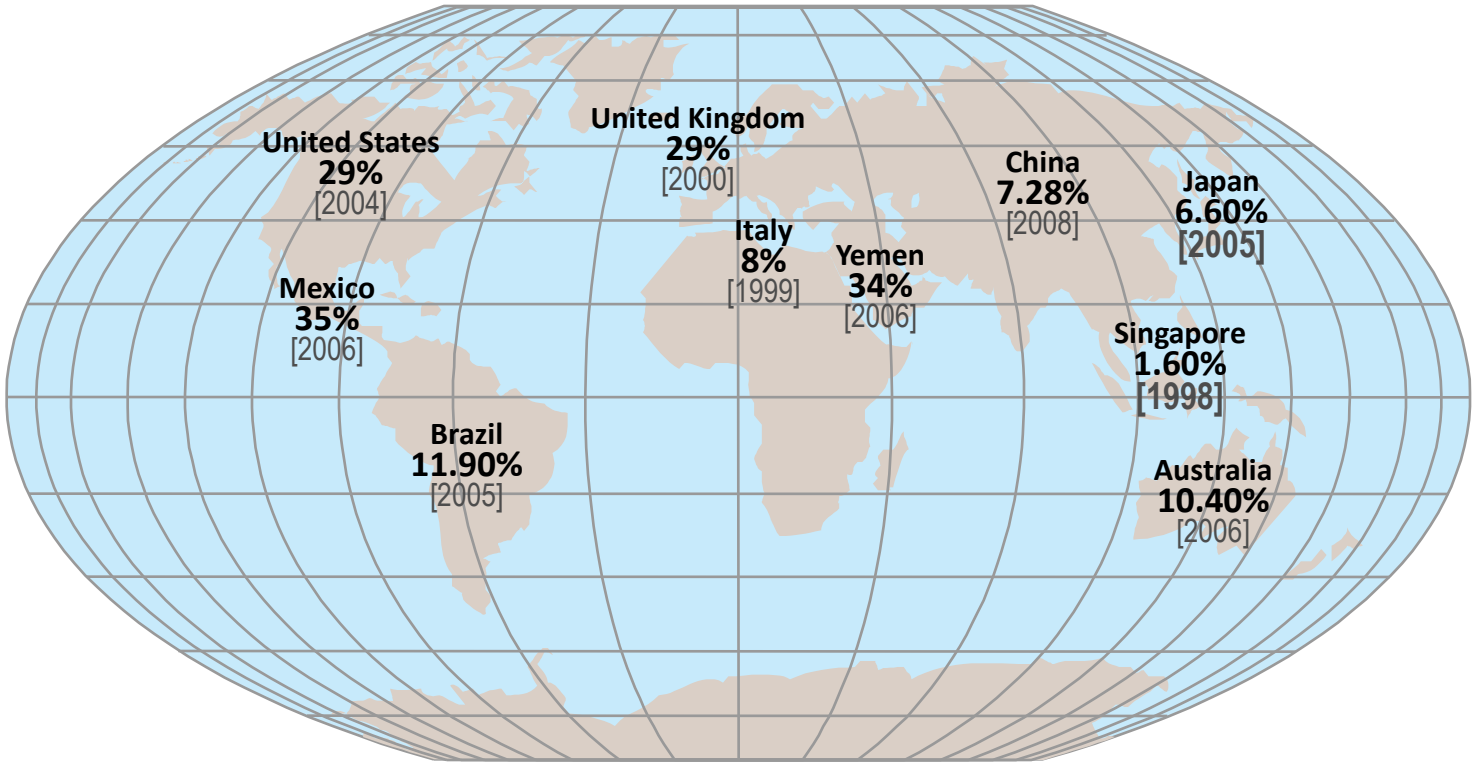
DIGESTIVE SYSTEM

- The gastrointestinal tract (GI) or digestive tract is made up of:
  - Esophagus
  - Stomach
  - Large and Small intestines
  - Liver
  - Pancreas
  - Gallbladder etc.
- Process of digestion has several stages
  - Food is broken into smaller parts and the nutrients are absorbed.

INTRODUCTION

- Digestive diseases - disorders of the digestive tract
  - Symptoms: bleeding, bloating, diarrhea, constipation, heartburn, nausea, vomiting etc.
- Digestive diseases significantly affect millions of people worldwide resulting in decreased quality of life.
- Diagnosis techniques - endoscopy, ultrasound scanning, electrogastrography (EEG) etc.
- In most cases, the diagnosis of the digestive diseases is invasive and a complex task.

GEOGRAPHIC PREVALANCE OF GASTROESOPHAGEAL REFLUX DISEASE



DIGESTIVE DISEASES STATISTICS - UNITED STATES

Gastrointestinal Infections	Prevalance	20 percent of the population (2004)
	Ambulatory care visits	8.9 million (2009)
	Hospitalizations	4.7 million (2010)
	Mortality	1,653 deaths (2010)
Gastroesophageal Reflux Disease	Prevalance	Foodborne illness: 76 million people(1998)
	Ambulatory care visits	2.3 million (2004)
	Hospitalizations	487,000 (2010)
	Mortality	11,022 deaths (2011)
Peptic Ulcer Disease	Prevalance	15.5 million people (2011)
	Ambulatory care visits	669,000 (2006-2007)
	Hospitalizations	358,000 (2010)
	Mortality	2,981 deaths (2011)

Source: digestive.niddk.nih.gov

ELECTROGASTROGRAPHY

- Electrogastrography (EGG) - an efficient and noninvasive alternative for diagnosis of digestive disorders.
- Electrogastrograms - electrical signals generated by the muscles of the stomach.
- Measurement of EGG signals - several electrodes are placed onto the abdomen over the stomach.
  - The electrodes sense the electrical signals originating from the stomach muscles.
- Features of the EGG signals of normal individuals differ when compared to the features of the signals obtained from patients with abnormalities.
  - By analyzing such features, several digestive disorders can be diagnosed.

ENTROPY

- Entropy is a measure of the disorder associated with a system and hence is a measure of complexity of the system.
- In medical diagnostics, entropy has proved to be an efficient feature for discriminating the normal and abnormal states of biological systems.
- Various entropic measures:
  - Tsallis entropy
  - Renyi entropy
  - Shannon's entropy
  - Approximate entropy
  - Fuzzy entropy etc.

A BRIEF SURVEY OF LITERATURE

- Gopu *et al*. (2008) have acquired and analyzed the Electrogastrograms for Digestive System Disorders such as Dyspepsia, Stomach Ulcer, Nausea etc. Further, the authors have discussed the dissimilarity in frequency and amplitude of Electrogastrograms.

- Riezzo *et al*. (2013) have discussed the recording and processing methodology of the Electrogastrograms. Further, the authors have presented clinical applications of Electrogastrograms such as detection of digestive abnormalities in adults and children.

A BRIEF SURVEY OF LITERATURE

- Al-nuaimi *et al.* (2015) have proposed the most promising information theoretic methods for quantifying changes in the EEG using Tsallis entropy.

- De Bock *et al.* (2010) have utilized the Tsallis entropy of EEG signals for early detection of Alzheimer's disease. Further, the authors have concluded Tsallis entropy based EEG analysis was a highly promising potential diagnostic tool for mild cognitive impairment and early dementia.

MOTIVATION

- The gastrointestinal disease accounts for a large number of deaths in several parts of the world. Gastrointestinal infection has been an emerging problem in various parts of India such as Sikkim, Darjeeling etc.
- Total 65 (65%) cases of gastrointestinal disease were found in 100 individuals out of which 24 were males and 41 were females.

(Gajamer *et al., Journal of community health* (2014): 767-774)

- Nowadays, endoscope procedure is followed to investigate the problems in the digestive system disorders, which is a tedious, expensive and invasive method.
- Hence, an efficient and noninvasive technique for diagnosis of digestive disorders is required.

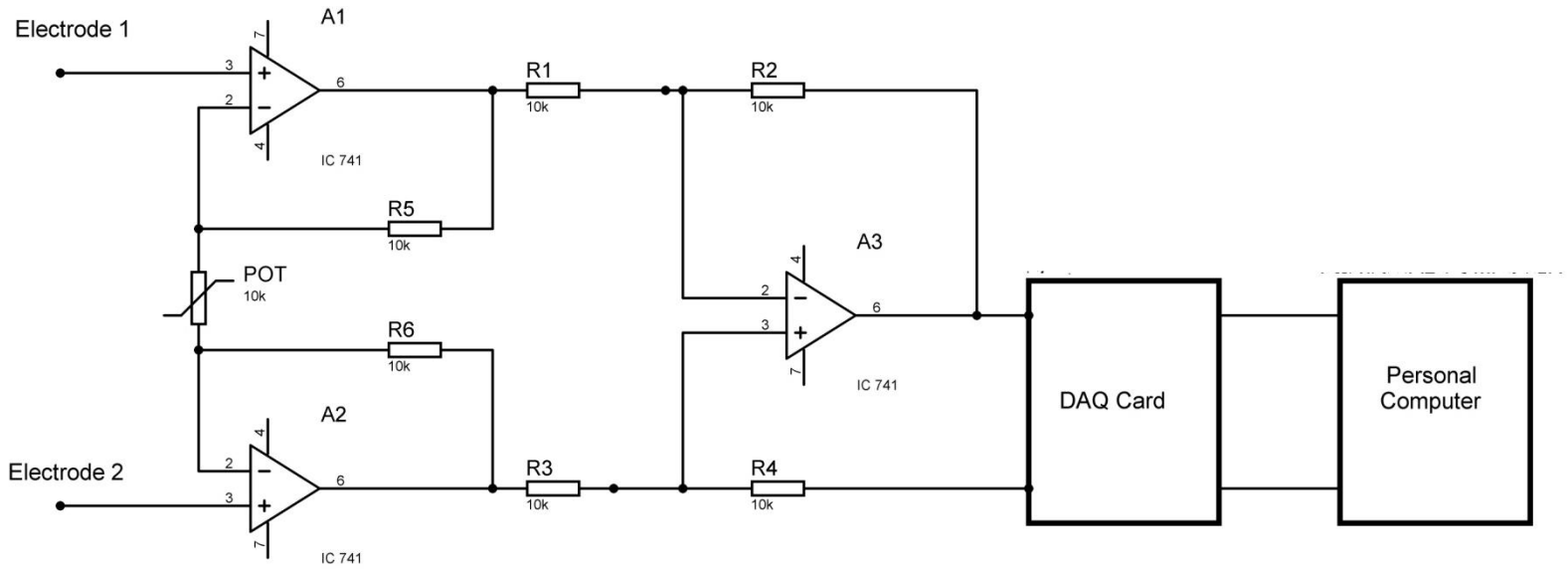
(Gopu *et al.,* IEEE 2008)

OBJECTIVE

- To analyze normal and abnormal Electrogastrograms in cases of various digestive disorders such as diarrhea, vomiting and stomach ulcer, using Tsallis and Renyi entropy.

METHODOLOGY

DESIGN OF EGG ACQUISITION SYSTEM



- Acquiring EGG signals: Amplifier - instrumentation amplifier
- Two cutaneous electrodes - one reference electrode and one measurement electrode.
- EGG signals - acquired and logged using the data acquisition system with LabVIEW (V14.0.1).

ELECTRODE PLACEMENT

- The electrodes are placed on the stomach, according to the measurement protocol with a distance of 7cm between the electrodes.

Parkman *et al.,* Neurogastroenterology & Motility 2003.

EGG SIGNAL ACQUISITION

- The EGG signals have been acquired from normal and abnormal subjects having different digestive abnormalities such as diarrhea, vomiting and stomach ulcer, from a local hospital (Sree Balaji Medical College and Hospital, Chennai, Tamil Nadu, India).

ESTIMATION OF TSALLIS ENTROPY

- Tsallis entropy (H_R) is defined as:

$$H_R = \frac{1}{\alpha - 1}\left(1 - \sum_{i=1}^{n} p_i^{\alpha}\right)$$

p_i is the given set of probabilities

α is a real number

- Increasing the value of α results in more contribution of high probabilities than low probabilities for the entropy values.
- Tsallis entropy is one of the most promising information theoretic methods for biosignal analysis.

(Gajowniczek *et al.*, 2015)

ESTIMATION OF RENYI ENTROPY

- Renyi entropy (*H(a)*) is defined as:

$$H(a) = \frac{1}{1-a} log_2 \left(\sum_{i=1}^{n} p_i^a \right)$$

p_i is the probability that a random variable takes a given value out of *n* values

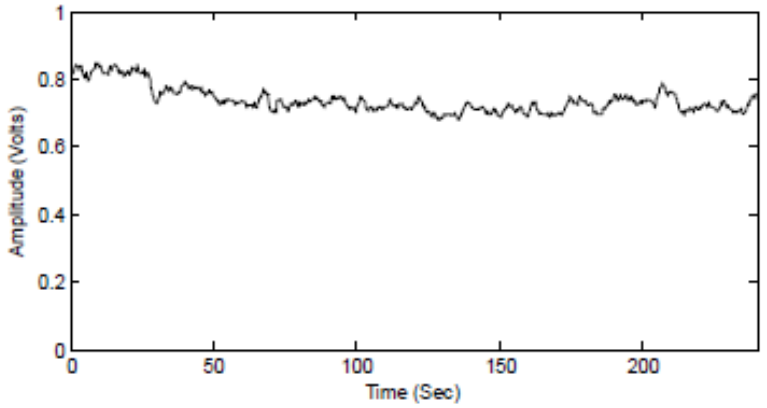
α is the order of the entropy measure

- As α increases, the entropy values become more sensitive to higher probabilities and less sensitive to lower probabilities.
- Renyi entropy is an effective measure of complexity of the signal.

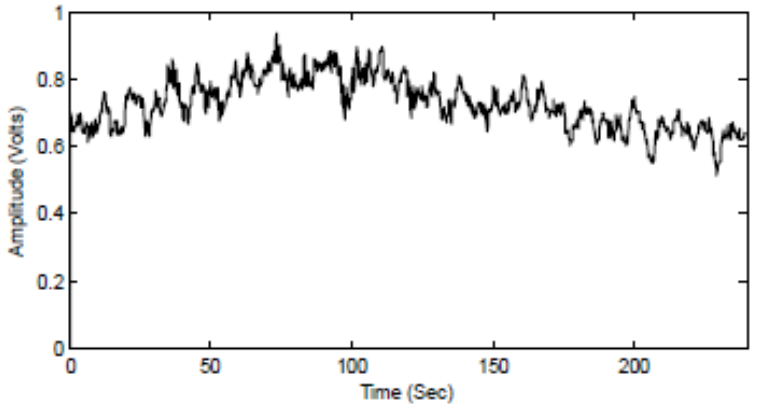
(Cornforth *et al.*, 2014)

RESULTS AND DISCUSSION

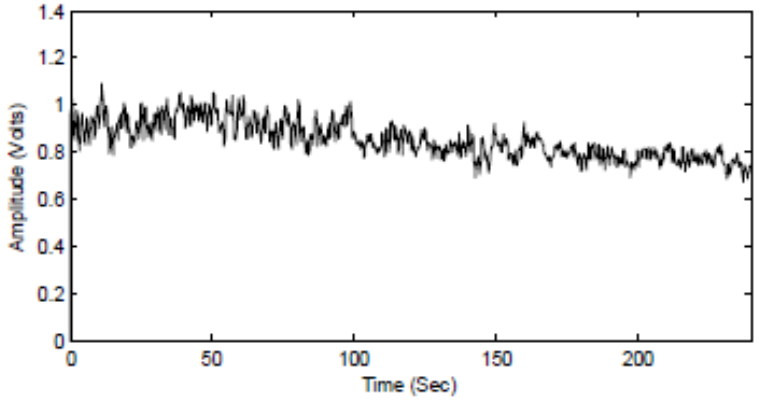
RECORDED EGG SIGNALS



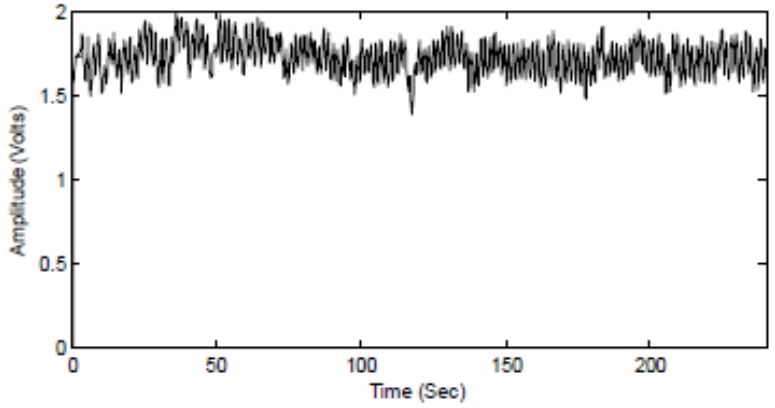
(a)



(b)



(c)

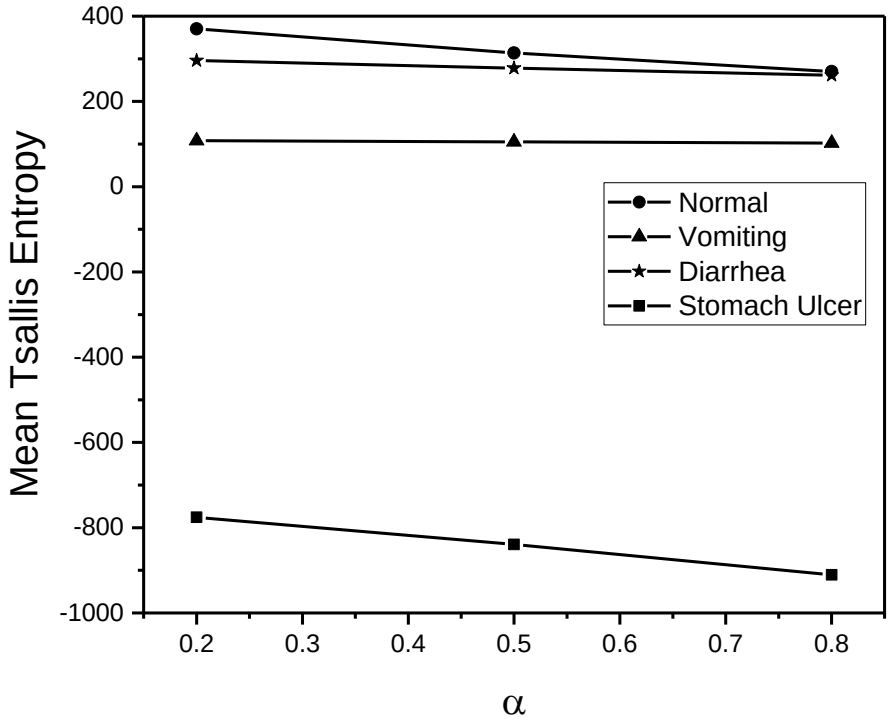


(d)

Typical EGG signal recorded from (a) normal and abnormal individuals suffering from (**b**) diarrhea, (**c**) vomiting and (**d**) stomach ulcer.

Several variations in the EGG signals are observed in normal and abnormal cases.

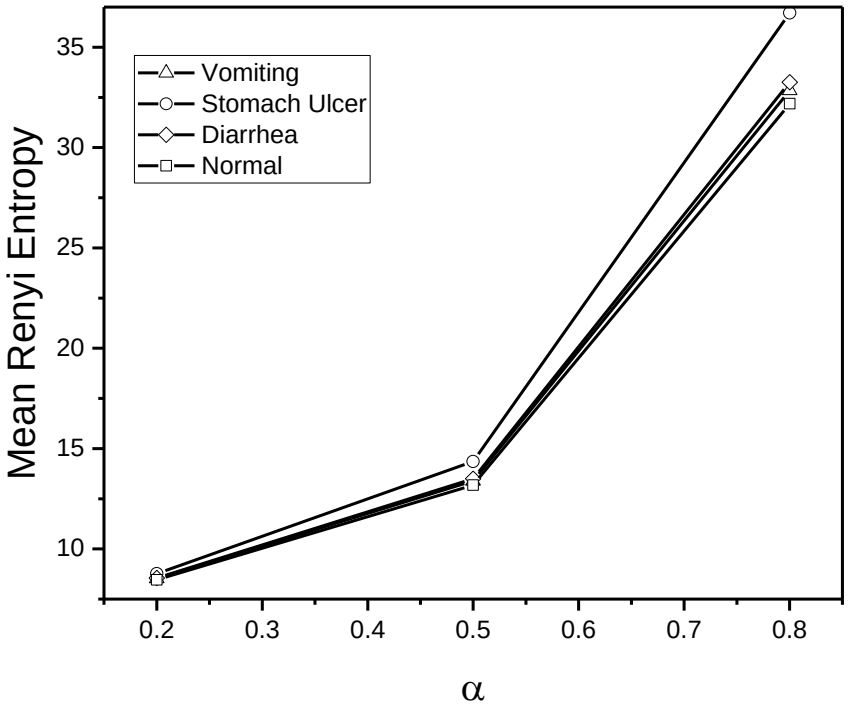
ANALYSIS OF EGG SIGNALS USING TSALLIS ENTROPY



Mean Tsallis Entropy (MTE) of normal and abnormal EGG signals, shown as a function of α.

- The mean Tsallis entropy decreases with increase in α.
- The mean Tsallis entropy values of normal individual is higher when compared to the entropy values of individuals having abnormalities, at different α values.

ANALYSIS OF EGG SIGNALS USING RENYI ENTROPY



Mean Renyi Entropy (MRE) of normal and abnormal EGG signals, shown as a function of α.

- The mean Renyi entropy increases with increase in α.
- The mean Renyi entropy values of normal individual is low compared to the Renyi entropy values of individuals having abnormalities for different α values.

Subject	Normalized Mean Tsallis Entropy (NMTE)			Normalized Mean Renyi Entropy (NMRE)		
	α=0.2	α=0.5	α=0.8	α=0.2	α=0.5	α=0.8
Normal	1	1	1	0	0	0
Diarrhea	0.9352	0.9689	0.9866	0.9866	0.9664	0.9464
Vomiting	0.7711	0.8199	0.9921	0.9921	0.9757	0.9611
Stomach ulcer	0	0	0	1	1	1

- The Tsallis entropy value for normal individuals is highest at $\alpha = 0.2$ and the entropy value for individuals having stomach ulcer is lowest at $\alpha = 0.8$.

- The Renyi entropy value for normal individuals is lowest at $\alpha = 0.2$ and the entropy value for individuals having stomach ulcer is highest at $\alpha = 0.8$.

SUMMARY AND CONCLUSIONS

- Electrogastrography
  - noninvasive technique to record the electrical activity of the digestive system.
  - features obtained from these signals are useful for diagnosis and staging of several digestive diseases.
- Entropy - measure of the disorder associated with a system and hence is a measure of the information content, uncertainty and complexity of the system.
- In this work, the EGG signals have been obtained from normal and abnormal subjects having different digestive abnormalities such as diarrhea, vomiting and stomach ulcer, from a local hospital.
- Tsallis entropy and Renyi entropy of the acquired signals have been estimated and the entropy of normal and abnormal EGG signals is analyzed.

SUMMARY AND CONCLUSIONS

- Results demonstrate that the Mean Tsallis Entropy of the EGG signals obtained from normal individuals is high when compared to the individuals having diarrhea, vomiting and stomach ulcer.

- The Mean Renyi Entropy of the EGG signals obtained from normal individuals is low when compared to the individuals having digestive disorders.

- This work appears to be of high clinical relevance, since feature extraction from EGG signals is highly useful for noninvasive diagnosis of various digestive abnormalities.

ACKNOWLEDGEMENT

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Thank You