Real-time ECG Monitoring using Compressive Sensing on a Heterogeneous Multicore Edge-Device
Djelouat et al. MDM 2019

Compressive Sensing-based IoT applications: A review
Djelouat et al. SJAN 2018

Sparse MRI: The application of compressive sensing for rapid MR imaging
Lustig et al. Wiley 2007

def: Compressed Sensing (Sparse Sampling): a signal processing technique for efficiently acquiring and reconstructing a (sparse) signal by finding solutions to underdetermined linear systems

Regular sampling

Compressive sensing (CS)

Time domain

Frequency domain
communication with regular sampling and CS

\[
\text{Source} \rightarrow \text{Sampling} \rightarrow \text{Channel} \rightarrow \text{Recovery}
\]

\[
y = x, \text{ for } n \text{ odd}
\]

\[
y = x, \text{ for } n \text{ even}
\]

Why it is possible?

When sampling an arbitrary bandwidth-limited signal

\[
\text{band-limited} \rightarrow \text{Nyquist frequency} \rightarrow \text{Nyquist rate} \leq \text{Sample rate}
\]

\[
\frac{1}{2} f_s > B \implies f_s > 2B
\]

Nyquist rate is the minimal rate that guarantees no aliasing.

Aliasing will occur when

\[
f_s = 2B
\]

Viewing in the frequency domain

When \( f_s = 2B \)

When \( f_0 < 2B \)
when \( f_s \) is sufficiently large, compressive sensing exploits sparsity to allow \( f_s < 2B \)

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Let \( x \) be the original sparse signal and \( D \) be the compression matrix. Compressive sensing computes

\[
\begin{bmatrix}
D
\end{bmatrix}
\begin{bmatrix}
x
\end{bmatrix} \rightarrow \text{underdetermined system}
\]

\[
\begin{bmatrix}
y_1 \\
y_2 \\
\vdots \\
y_m
\end{bmatrix} = \begin{bmatrix}
a_{11} & a_{12} & \cdots & a_{1n} \\
a_{21} & a_{22} & \cdots & a_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
a_{m1} & a_{m2} & \cdots & a_{mn}
\end{bmatrix} \begin{bmatrix}
x_1 \\
x_2 \\
\vdots \\
x_n
\end{bmatrix}
\]

The receiver, with \( y \), tries to compute \( x \) with

\[
\min \| y - Dx \|_2^2 + \| x \|_1
\]

\( x = [x_1, x_2, \ldots, x_n] \), \( \| x \|_1 = |x_1| + |x_2| + \cdots + |x_n| \)

\( l_1 \) norm enforces sparsity

(1) \( l_2, \text{norm} \) \( \| x \|_2 \)

(2) \( l_1, \text{norm} \) \( \| x \|_1 \)
recover a sparse version for $x$.

In realworld, most bio signal is sparse

heartbeat CEC

breathing
Application: ECS compression

Electrocardiogram

Compression

Compressive Sensing

CS Recovery

Received signal

L1 - norm minimization

Compressed and transmitted same time by sensors

Received signal

Reconstructed Electrocardiogram by CS

Medical imaging compression