How much do we need to know to recognise a process?

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The Central Question

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Question

For which sets $P \subset \mathbb{Z}$, *can we identify the process given its sample on the set* P, *that is,* $X_i; i \in P$?

Some notation: Cylinder Sets

Given a finite set $B \subset \mathbb{Z}$ and $w \in A^B$, we write

$$[w] := \{x \in A^{\mathbb{Z}} \ : \ x|_B = w\}.$$

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We will frequently use the correspondence between processes and infinite measure preserving transformations: The process will be denoted by $X_i; i \in \mathbb{Z}$ while the corresponding measure preserving action will be denoted by $(A^{\mathbb{Z}}, \mu, \sigma)$ where σ is the shift map.

What if we know everything?

Hopf's ratio ergodic theorem says that if $f, g \in L^1(\mu); g \geq 0$ then for almost every $x \in A^{\mathbb{Z}}$,

$$\lim_{n\to\infty} \frac{\sum_{i=1}^{n} f(\sigma^i(x))}{\sum_{i=1}^{n} g(\sigma^i(x))} = \frac{\int f \ d\mu}{\int g \ d\mu}.$$

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Thus if a sample of a process is given on $\mathbb{N}$ then (up to measure zero), we can apply Hopf's ratio ergodic theorem to find the ratio of $\mu([u])$ and $\mu([v])$ for all cylinder sets $[u], [v]$ enabling us to recognise the underlying process.

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Then given a sample of either process, we will not be able to identify it with probability 1/2.

These two examples motivate the following definition.

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A set $P \subset \mathbb{Z}$ is called a recognition set if there is a measurable function

$$f : A^P \to Meas(A^{\mathbb{Z}})$$

such that for all processes $X_i; i \in \mathbb{Z}$ corresponding to measure μ,

$$f(X_i; i \in P) = k\mu$$

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$\mathbb{N}$ is a recognition set while $2\mathbb{N}$ is not.

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While we have not found one, we do have a partial understanding.

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Theorem (Chandgotia, Weiss)

P is a recognition set for processes on probability spaces if and only if it is thick, that is, it contains intervals of arbitrary size.

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In particular, there are thick sets which do not have bounded gaps so there are recognition sets for processes on probability spaces which are not recognition sets (on spaces of infinite measure).

IP* sets

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This is a consequence of more general theorem which we now state. Given a sequence of positive integers $i_1, i_2, \ldots$, we write

$$IP(i_1, i_2, \ldots) := \{ \sum_{t \in \mathbb{N}} \epsilon_t i_t \ : \ \epsilon_t \text{ is 0 or 1} \}.$$

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A set $P \subset \mathbb{N}$ is called a Maharam set if for all conservative measure preserving actions, (X, μ, T) and sets $A \subset X$ of positive measure, there exists $n \in P$ such that

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Theorem (Chandgotia, Weiss)

A set $P \subset \mathbb{N}$ is a Maharam set if and only if it is IP. In particular it must have bounded gaps.*

A recognition set has to be a Maharam set and hence must have bounded gaps.

Examples: Removal of a sparse sequence

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$$\lim_{k\to\infty} \frac{f(T^{n_1}x) + f(T^{n_2}x) + \ldots + f(T^{n_k}x)}{f(Tx) + f(T^2x) + \ldots + f(T^{n_k}x)} \to 0.$$

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It follows that $\mathbb{N} \setminus \{n_k \ : \ k \in \mathbb{N}\}$ is a recognition set.

Question

Do all recognition sets have density one?

Summary

- We are interested in conservative, infinite, ergodic, invariant Radon measures on $\mathbb{N}^{\mathbb{Z}}$.
- A set $P \subset \mathbb{Z}$ is called recognition set if processes can be recognised by their samples restricted to P.
- Recognition sets in the natural numbers have bounded gaps.
- If n_k forms a sparse sequence then $\mathbb{N} \setminus \{n_k \ : \ k \in \mathbb{N}\}$ is a recognition set.

Questions:

- Is there a nice characterisation of recognition sets?
- Do they necessarily have density one?