

**THE LIMITS OF CONTROL**  
or how I learned to stop worrying  
and love regulation

(DISCUSSION)

Systems Science Seminar  
November 5, 2010

# CONTROL

Achieving and/or maintaining a desired state (or set of states) of a **system** in an **environment** subject to some **criteria**.

“Regulation achieves a *goal* against a set of disturbances.”<sup>1</sup>

## Two main points in control/regulation

“only variety can destroy variety”<sup>1</sup>

“every good regulator of a system must be a model of that system”<sup>2</sup>

<sup>1</sup> Ashby, W. Ross (1958). “Requisite Variety and Its Implications for the Control of Complex Systems,” *Cybernetica*, **1**, 83.

<sup>2</sup> Conant, R.C., Ashby, W.R. (1970). “Every good regulator of a system must be a model of that system,” *International Journal of Systems Science*, **1**(2), 89-97.

# Ashby's formulation of REGULATION

pay-off (outcome) table

		responses	
		$r_1$	$r_2$
disturbances	$d_1$	$z_{11}$	$z_{12}$
	$d_2$	$z_{21}$	$z_{22}$

# Ashby's formulation of REGULATION

pay-off (outcome) table

		responses	
		$r_1$	$r_2$
disturbances	$d_1$	good	bad
	$d_2$	good	bad

# Ashby's formulation of REGULATION

pay-off (outcome) table

		responses	
		$r_1$	$r_2$
disturbances	$d_1$	good	bad
	$d_2$	bad	good

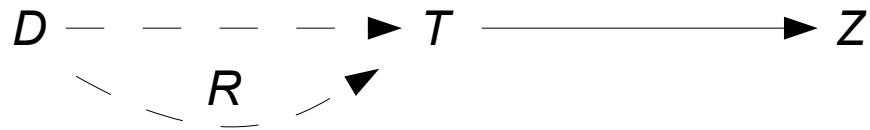
# Ashby's formulation of REGULATION

pay-off (outcome) table

		$R$		
		$r_1$	$r_2$	
$D$	$d_1$	$z_{11}$	$z_{12}$	← $T$
	$d_2$	$z_{21}$	$z_{22}$	

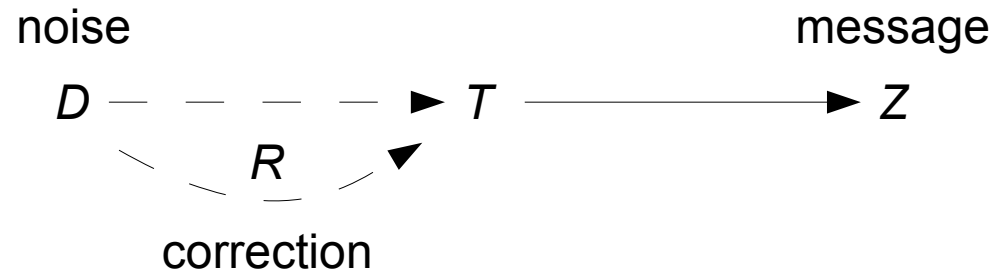
The “goal” of  $R$  is get the desired  $Z$  (a subset of  $T$ ) given any  $D$ .

# Ashby's *alternate* formulation of REGULATION



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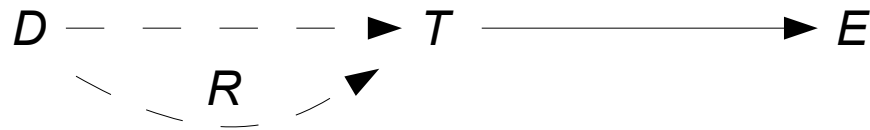
# Ashby's *alternate* formulation of REGULATION



The “goal” of  $R$  is to correct for  $D$  so the message  $Z$  is received.

# Ashby's *alternate* formulation of REGULATION

outcomes  $Z$  = variety in essential variables  $E$



The “goal” of  $R$  is maintain  $E$  within a specified range.

# Ashby's LAW OF REQUISITE VARIETY

introduce entropy  $H(x)$  as a measure of variety

$\{gbcggc\}$

has a variety of 3 letters

$\{bcaaCaBa\}$

has a variety of 5 shapes or 3 letters

typical to measure entropy in bits

Ashby's  
LAW OF REQUISITE VARIETY

$$H(E) \geq H(D) + H_d(R) - H(R)$$

$H_d(R) = 0$  when  $R$  is a determinate function of  $D$

$$H(E) \geq H(D) - H(R)$$

**the variety in the essential variables**  
will be greater than or equal to  
**the variety in the disturbances**  
minus  
**the variety in the regulators**

## Conant and Ashby's GOOD REGULATOR

**“Every good regulator of a system  
must be a model of that system.”**

$H_d(R) \rightarrow 0$  as  $R$  gets better (more determinate)  
for  $H_d(R) = 0$  we need a perfect model

**{*bcaaCaBa*}**

Ashby's  
LAW OF REQUISITE VARIETY  
sustainability example

$E = \{people\ live\ well,\ nature\ is\ not\ run\ down\}$

$$H(E) \geq H(D) - H(R)$$

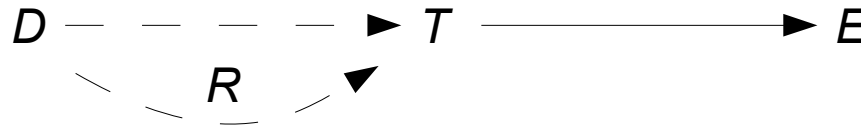
**options**

- 1) *do nothing* – essential variables are controlled by disturbances
- 2) *lower standards* – allow more variety in  $E$
- 3) *increase regulation* – new laws, renewable resources
- 4) *discover disturbance patterns* – learning structure (constraints) of disturbances reduces variety in  $D$  and *can* lead to the creation of better models

# CONTROL PROBLEMS

other examples

$$H(E) \geq H(D) - H(R)$$



What are the essential variables?

What are the disturbances?

What are the possible regulators?

How well can we model the system?

# SOCIAL SYSTEM CONTROL PROBLEMS

other examples

traffic controls

(speed bumps, crosswalks, signals)

taxes, tax breaks, tariffs, subsidies

federal regulation

(health care, housing, financial system)

war on drugs

others?