Analysis of Purposive Systems (2)

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Contents

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Background

Four Blunders

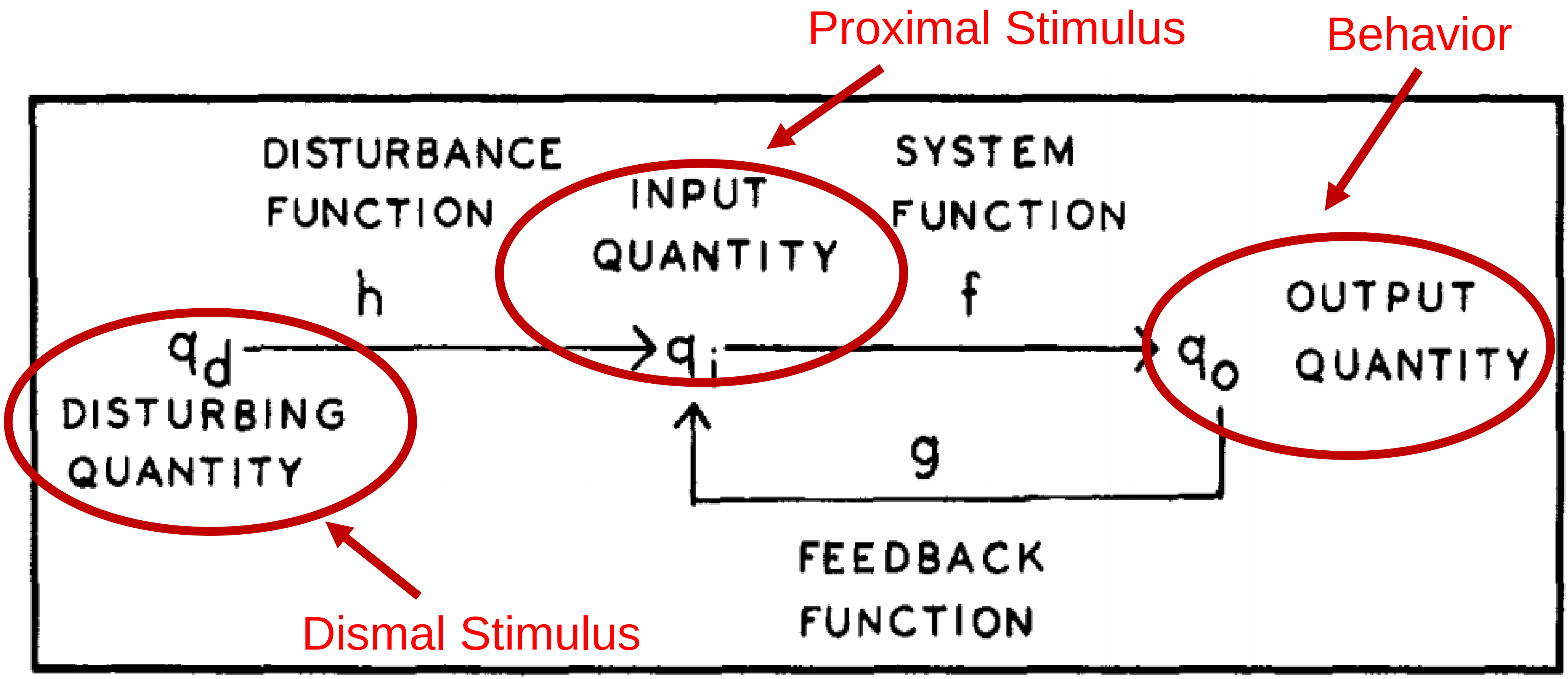
- Machine Analogy Blunder
- Objectification Blunder
- Input Blunder
- Man-Machine Blunder

Proxmal & Dismal Stimulus

- Proximal Stimulus
  - Physical stimulation that is measured by sensory apparatus
  - Ex) His eyes sensed the orange on the table

- Dismal Stimulus
  - The state of objects in the world that were the cause of proximal stimulus
  - Ex) Orange on the table itself

Quasi-Static Analysis Revisited



Equations among quantities

- Behavior is influenced by Proximal Stimulus

$$q_o = f(q_i),\ f \text{ being a general algebraic function.} \quad (1)$$

- Proximal Stimulus is also influenced by Behavior and Distal Stimulus

$$q_i = g(q_o) + h(q_d). \quad (2)$$

Equations among quantities (Contd.,)

- New value: **q_i*** (Not defined yet)

- **q_i** can be induced as following from **q_d** and **q_i***

$$q_i = q_i^* + h(q_d)/(1 - UV),$$
$$\text{where } UV \neq 1. \quad (8)$$

- **U**: change of output per unit change of input
- **V**: change of input per unit change of output
- **UV**: *loop-gain*, which is used as a classifying factor for models

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Classifying System-Environment Relationships

Type Z: Zero Loop Gain

- **UV** = 0
- Why **UV** is zero?
  - if **U** = 0, there is no behavior system (Input does not change the Output)
  - So, **V** should be 0 instead of **U** (**g** = 0)
- Proximal stimulus is only determined by dismal stimulus
  - **No feedback to input from behavior**
- Behavior is also only determined by **f**, **h**, and dismal stimulus

$$q_o = f(q_i) = f[h(q_d)].$$

Type Z: Zero Loop Gain (Contd.,)

- Classical cause-effect model of behavior
  - Cause – dismal stimulus
  - Effect – behavior
- This model seems to be correct on our common sense
- But in reality, it is impossible for the outputs from organisms not to influence on its proximal stimulus
  - Feedbacks are clearly present in most circumstances

Type P: Positive Loop Gain

- **UV** > 0
- Only stable when 0 < **UV** < 1
  - When **UV** >=1
    - Oscillation
    - Increase exponentially
    - Head for positive or negative infinite values
- “Enhances” or “Amplifies” responses (1/(1-**UV**) > 1)
  - Positive feedback

Type P: Positive Loop Gain (Contd.,)

- **UV** range is too small!
  - Sensing apparatuses are quite sensitive
  - Ex) Human nose can detect molecules with so small density
- **UV** also varies with the magnitude of disturbance
- Too easy to get *unstable* under the best of circumstances!
- Not likely for the real organisms

Type N: Negative Loop Gain

- **UV** < 0
- Negative feedback
- The eligible model for living organisms
  - Stable for all UV values
  - **UV** can become very big
    - Fits to the fact that organisms are usually sensitive

Type N: Negative Loop Gain (Contd.,)

- ideal N system: An N system where **UV** is very big (Very responsive)
  - **UV**/(1-**UV**) -> -1
  - (1/(1-**UV**)) -> 0
- It leads to two new equations below

$$g(q_o) = q_i^* - h(q_d) \qquad (7a)$$

$$q_i = q_i^*. \qquad (8a)$$

Type N: Negative Loop Gain (Contd.,)

- Those two equations show the "Cancellation of disturbances"
- 7a: The Changes of the output cancels the effect of disturbance

$$g(q_o) = q_i^* - h(q_d) \qquad (7a)$$

- 8a: Due to 7a, input remains same even after the disturbance

$$q_i = q_i^*. \qquad (8a)$$

Type N: Negative Loop Gain (Contd.,)

- Before, negative feedback systems are thought that they “control” their outputs directly by adjusting the input from the feedback
- However, in Type N it can be interpreted like the below
  - Disturbance tries to change the input
  - Output is made to compensate for those disturbances
  - Input stays the same, because of the cancellation effect made by output
- Output is
  - less related to “how the input changes the output”, **f**
  - More directly related to “how the output effects the input”, **g**

$$q_o = g^{-1}[q_i^* - h(q_d)].$$

The fixed-ratio experiment

- Experiment Setting
  - An animal provides food for itself on a schedule by pulling a lever
  - A pallet of food is given by every N-lever pressing
  - Some amounts of food can be added as a disturbance
- Quantities
  - **q_i** = the rate of the food the animal gets
  - **q_o** = the rate of lever pressing
  - **q_d** = the rate of the food the animal can get without lever pressing
- The relationships between quantities
  - **g** = 1/**N**
  - **q_i** = **q_o/N** + **q_d**
  - **q_o = q_i**

The fixed-ratio experiment (Contd.,)

- When no disturbance (additional food) is added, the animal gets the food by **q_i*** rate by pressing levers in **q_o*** rates
- When **q_d** disturbance is added, the animal slows down the lever-pressing rate to maintain **q_i** same
- When the additional food incoming rate becomes same as **q_i***, the animal stops lever pressing

$$q_o = n(q_i^* - q_d). \qquad (12)$$

- The result is supported by the scientific observation (Teitelbaum, 1966)

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A Time-State Analysis with Dynamic Constraints

Traditional Z-System Approaches

- Based on open-loop & cause-effect approach

- Treats any feedback effects being separately
  - One after another

- It seems working qualitatively, but it fails to work quantitatively!

Linear Time-State Analysis

- The system equation will be

$$q_{o(t+1)} = F(q_i - q_i^*)_t, \qquad (13)$$

- The environment equation will be

$$q_{i(t)} = Gq_{o(t)} + Hq_d. \qquad (14)$$

- This model is not proper
  - Only stable when -1 < FG < 1
  - Cannot act like an ideal N system

Linear Time-State Analysis (Contd.,)

- Introducing new variable, **K**
  - **K** indicates the fraction of moving from the old **q_o** to the new **q_o**

$$q_{o(t+1)} = q_{o(t)} + K[F(q_{i(t)} - q_i^*) - q_{o(t)}]. \quad (15)$$

- From Equation 15, it leads to

$$q_{o(t+1)} = q_{o(t)}(1 + KFG - K) + KF(Hq_d - q_i^*). \quad (16)$$

Linear Time-State Analysis

- Equation 16 converges when **(1 + KFG – K)** becomes 0

$$K_{\mathrm{opt}} = 1/(1 - FG). \tag{17}$$

- Replacing **K** as **K_opt** in Equation 16 produces

$$q_{0(\mathrm{ss})} = \left(\frac{FG}{1 - FG}\right)\left(\frac{Hq_{\mathrm{d}}}{G} - \frac{q_{\mathrm{i}}{}^{*}}{G}\right). \tag{19}$$

- In ideal N system, **FG**/(1 – **FG**) becomes -1, producing

$$\boxed{Gq_{\mathrm{o(ss)}} = q_{\mathrm{i}}{}^{*} - Hq_{\mathrm{d}}. \qquad (20)}$$

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Applying the model to real cases

Overwatch

- A hyper-FPS game developed by Blizzard
- Players want to shoot each other, eventually knocking out the opponent
- The game is well-made and quite competitive

Overwatch(Contd.,)

Genji

Hanzo

A Scenario in Overwatch

- Two players are playing Hanzo & Genji
  - We call those players **H** and **G**
- **H** was aiming at **G** accurately, but **G** moved suddenly
- **H** tries to aim at **G** before he shoots **G**
- From **H**'s perspective
  - Proximal input (**q_i**) is visual angle of **G** got via retina of **H**
  - Dismal input (**q_d**) is the movement of **G**
  - Output (**q_o**) is aiming angle of **H**

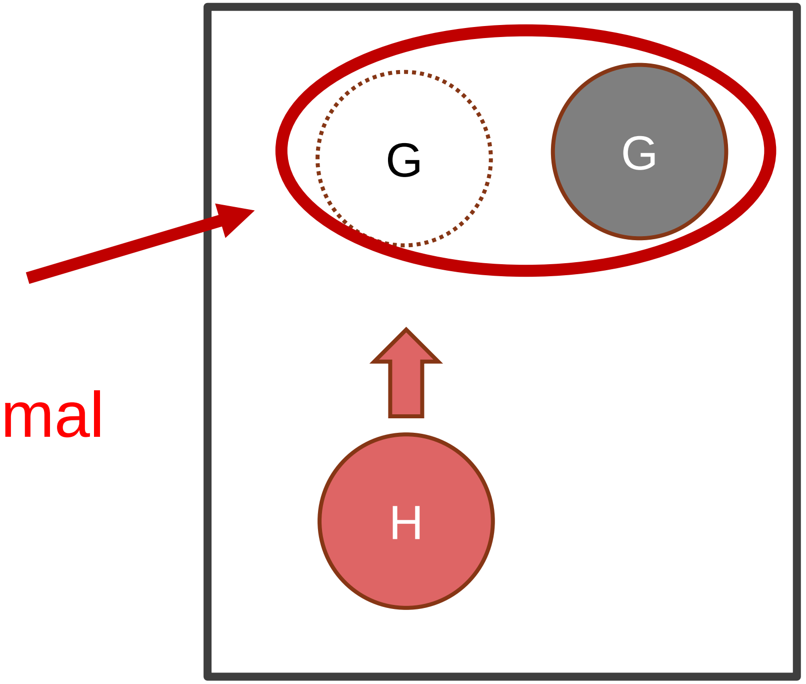
Overwatch Aiming

State of aiming the opponent accurately (**q_i***)

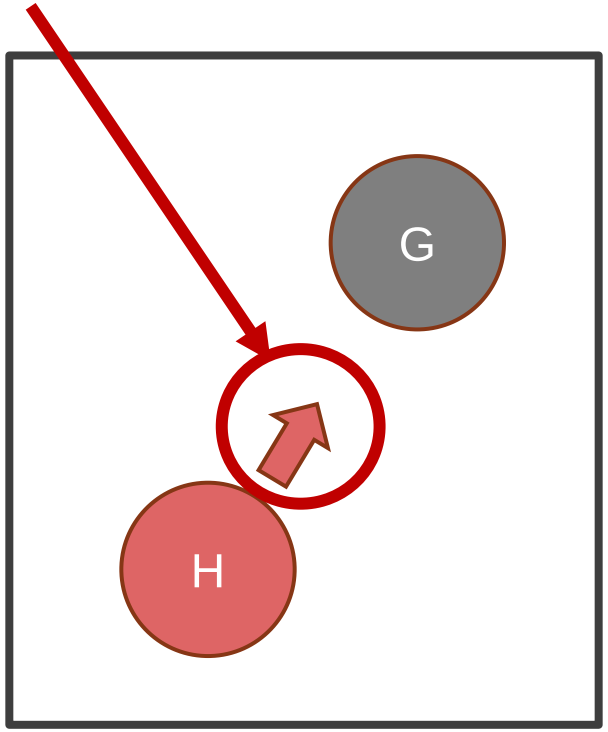
Z-System Explanation

- Cause & Effect Explanation
  - Cause – The movement of **G**
  - Effect – Changes in **H**’s aiming angle

G moves its location! (Dismal stimulus)



H changes its aiming angle



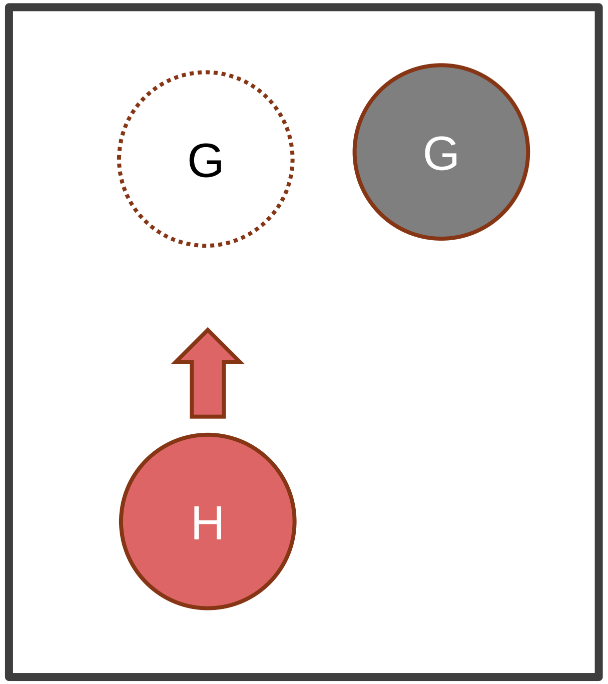
Problems of Z-System explanation

- Aiming is not always precise
  - What if **H**'s aiming is not precise?
  - When the aiming is not precise, **H** will see the different image of **G**
    - function **g()** is not zero, in reality!

- Cannot explain the proximal stimulus in the meantime
  - Because **H** is moving his aim angle**,** the intermediate visual angle of **G** is surely affected by **H**'s aim angle (behavior)!

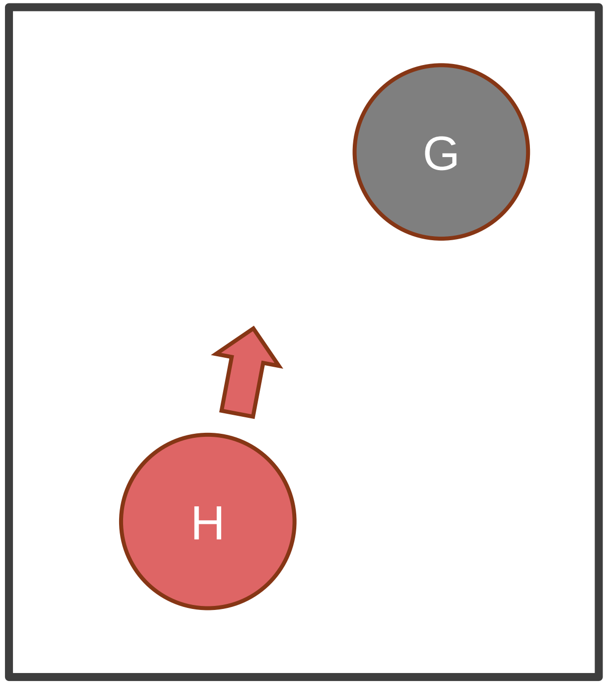
N-System Explanation

- Proximal Input (**q_i**) has been changed by outer disturbances



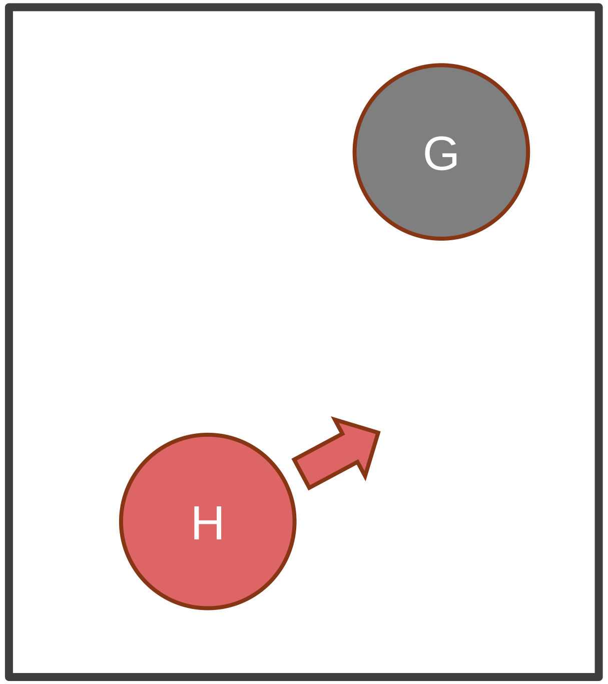
N-System Explanation (Contd.,)

- Output (**q_o**) is being taken to compensate for the input change
  - Feedback is consistently being given to **q_i**
  - **K** is introduced this intermediate state



N-System Explanation (Contd.,)

- If the output is not accurate, **q_i** gets feedback from it, and **H** tries to adjust the output to compensate for the mistake



N-System Explanation (Contd.,)

- The output is aiming at the accurate position and the input restored to the initial condition