ISDN2400 Physical Prototyping

Testing

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Today's lecture

- Introduction to testing
- Student guest lecture – Yang Wei (Adam)
- TA instruction – Using the pool for testing
- Walk to the pool

Iterative prototyping

- So far, we discussed design and development tools
- Prototypes are build to test hypotheses

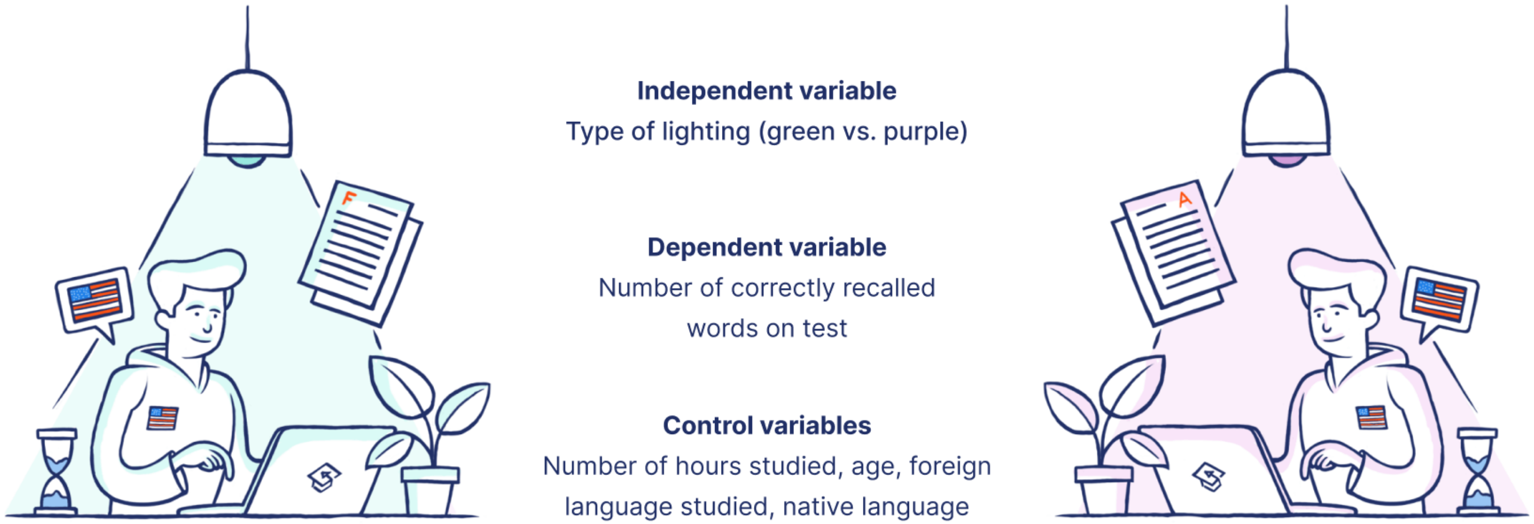
www.pacific-research.com/iterative-product-development/

Defining a testing hypothesis

- Hypothesis: idea or explanation that you test through experimentation with the prototype
  - Helps clarifying what you aim to achieve with the prototype
  - Helps clarifying how to build and test the prototype
- Is the following statement a good hypothesis?
  - "*The robot fish will swim better with different fins*"
  - Not clear what 'better' means (speed, maneuverability, stability)
  - Not clear what 'different' means (surface area, color, weight)
- Define dependent and independent variables

Dependent and independent variables

- Independent variable
  - Variable that is changed
- Dependent variable
  - Variable that is affected by the change
- Control variable
  - Variable that is held constant
  - Controlled because it could influence the outcomes



www.scribbr.com/methodology/control-variable/

Defining a testing hypothesis

- Hypothesis: *"Increasing the surface area of the caudal fin will lead to an increase in forward speed"*
  - Independent variable: Fin surface area
  - Dependent variable: Swimming speed
  - Even better: predict how the dependent and independent variable are related

The effect of an increased caudal fin surface area on the swimming speed can be estimated as follows. The hydrodynamic drag can be expressed as:

$$F_D = \frac{1}{2}\rho S v^2 C_D \quad (1)$$

where ρ is the density of the fluid, v is the speed, S is the reference area, and C_D is the drag coefficient. When swimming at a constant speed, the drag force and the thrust force (F_t) are in equilibrium ($F_D = F_t$). As the density of the fluid and drag coefficient are constant over the two experiments, it follows that:

$$F_t = v^2 c \quad (2)$$

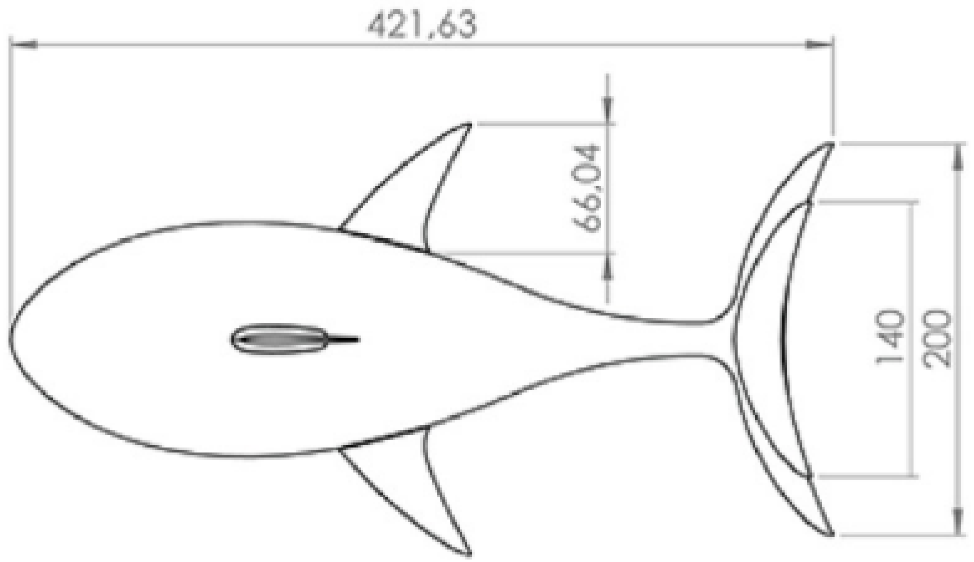
where c is a constant replacing all constants from Eq. 1. As the thrust force increases linearly with the surface area of the caudal fins, the expected swimming speed of the fish with the large caudal fin (v_l) can be expressed as a function of the swimming speed of the fish with the smaller caudal fin (v_s) and the surface areas of both caudal fins:

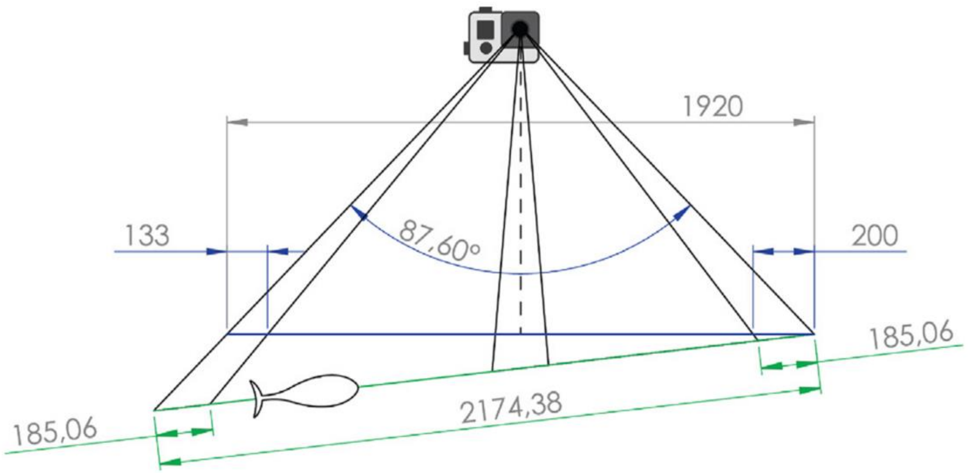
$$v_l = \sqrt{\frac{A_l \; v_s^2}{A_s}} \quad (3)$$

It should be noted that changing the size and shape of the caudal fin is likely to lead to changes in the angle of attack. This effect is not taken into account for the estimation above.

Defining prototype and test setup design

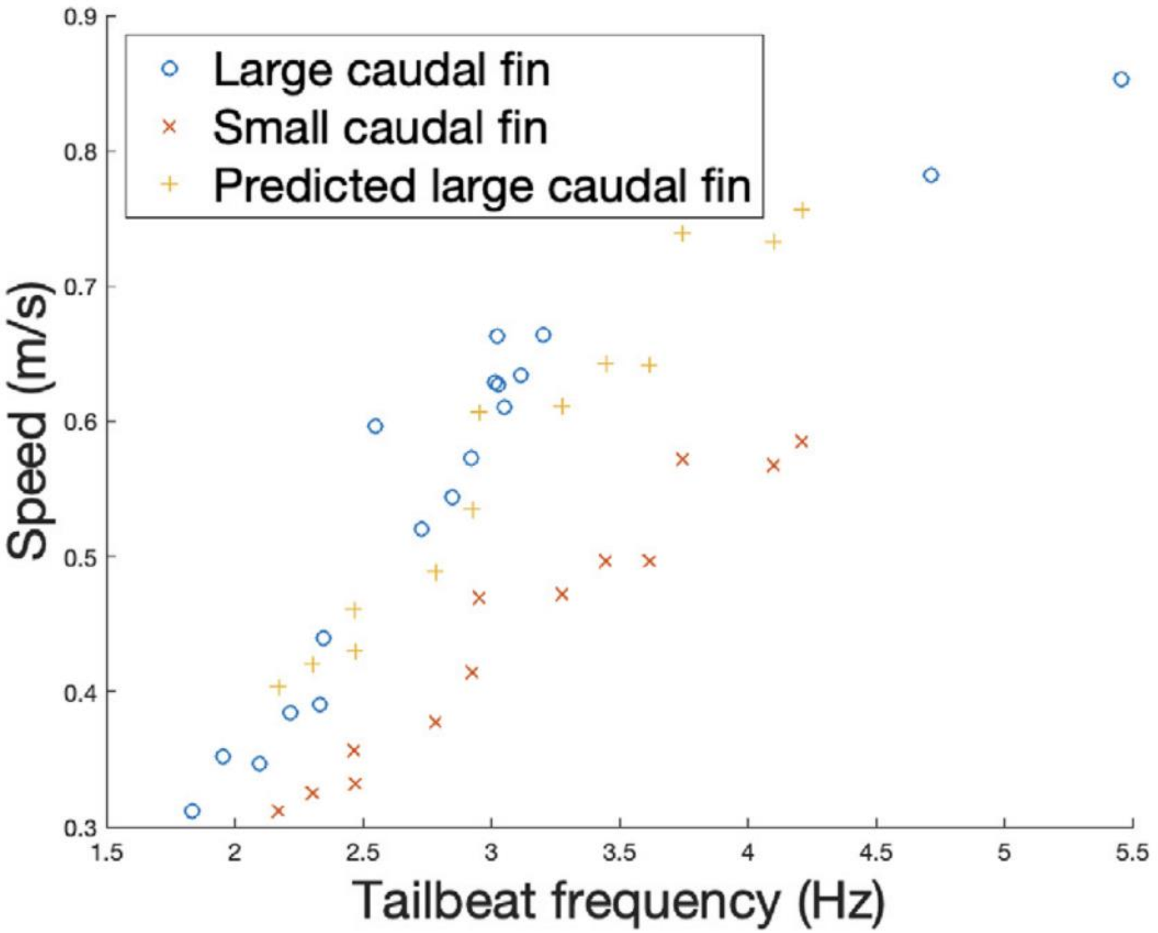
- How to build the fish:
  - Two caudal fins with surface area X and Y (independent variable)
  - Keep the motor, the shape of the fish body, and the shape of the caudal fin constant (control variables)
- How to test the fish:
  - Measure the time in which the fish swims a specific distance (dependent variable)
  - Keep the water tank, travelled distance, and starting speed constant (control variables)





Verifying the hypothesis

- Can the null hypothesis (no effect) be rejected and the alternative hypothesis accepted?



Multiple independent variables

- Each independent variable can interact with the others in complex ways
- How many experiments do you need to test the stability?
  - With or without dorsal fin
  - With or without pectoral fins
  - 5 levels of passive tail stiffness
  - 3 different head shapes
  - Etc..

- $2 \times 2 \times 5 \times 3 = 60$ different prototype configurations
  - Too many to test!

- Prototyping is about making smart choices:
  - Which variables are unlikely to interact with each other and could be tested in isolation?
  - Perform an exploratory study first where each variable has only two levels

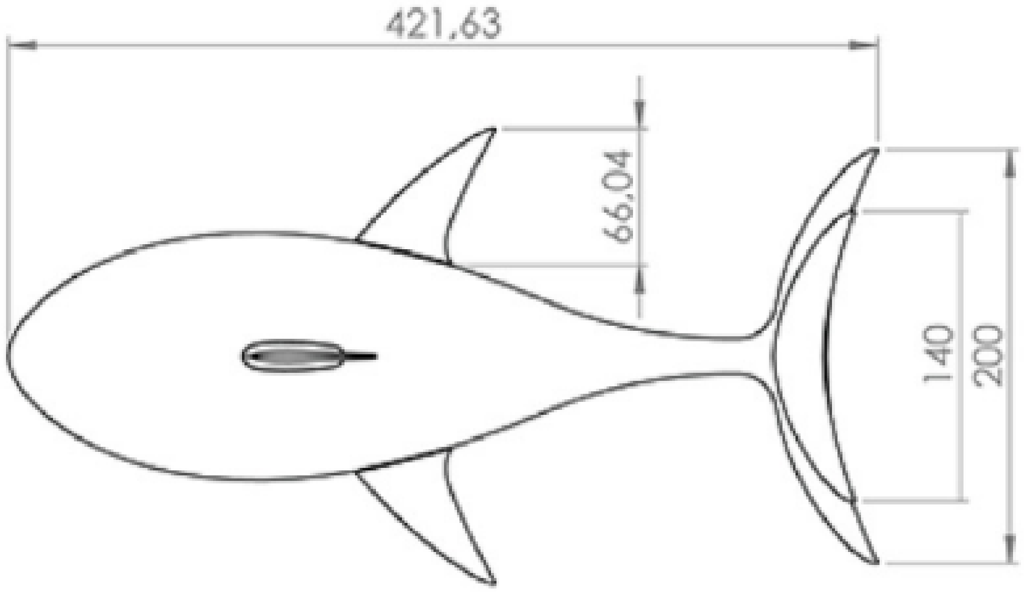
Competition

- Place the fish in the water with the caudal fin touching the swimming pool wall
- Time will start when the fish is released
- Time is stopped when the head of the fish touches the opposing swimming pool wall
- The fish body, tail and fins need to be fully submerged in the water throughout the entire swim for the time to count
- Speed is measured in body lengths travelled per second
- Highest average speed wins

Example calculation

- Body length = 421,63 mm
  - Measured from tip of the head to end of the caudal fin
- Swimming pool length = 4 m
- Time to cross the pool = 5.2 s
- $\frac{4 - 0.42163}{0.42163 \times 5.2} = 1.632\ BL/s$

- **Last year's record: 1.215 BL/s**



Questions?