L4: Concept generation

Motivation

Barriers to creative thought

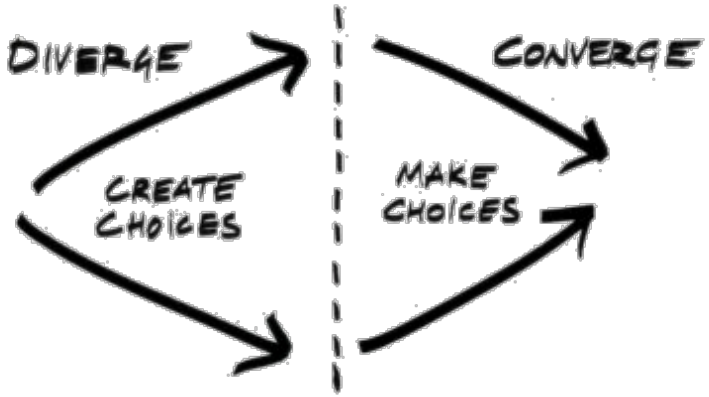
Strategies for enhancing creativity

Methods for concept generation

Techniques for concept evaluation

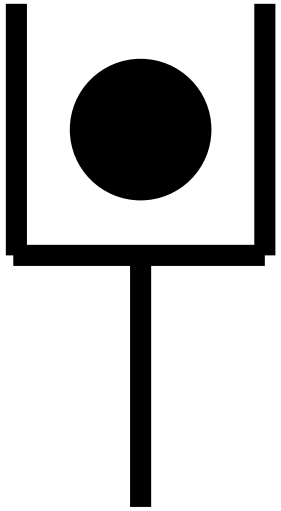
Motivation

Generating concept(s)

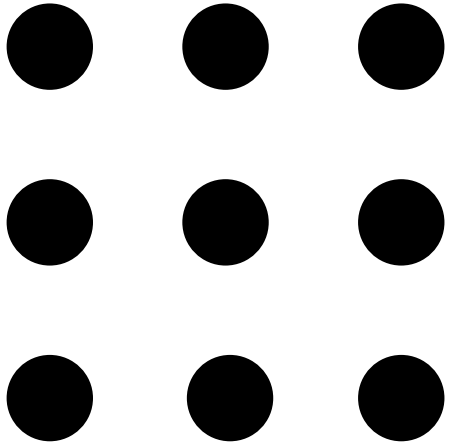


- As engineers, we often
  1) Start with a single solution to a problem, and then
  2) Pursue it as the only possibility
- Instead, we need to apply two key processes:
  - **Creativity**: to generate a variety of possible designs or novel concepts, and
  - **Judgment**: to evaluate these designs and select the best solution

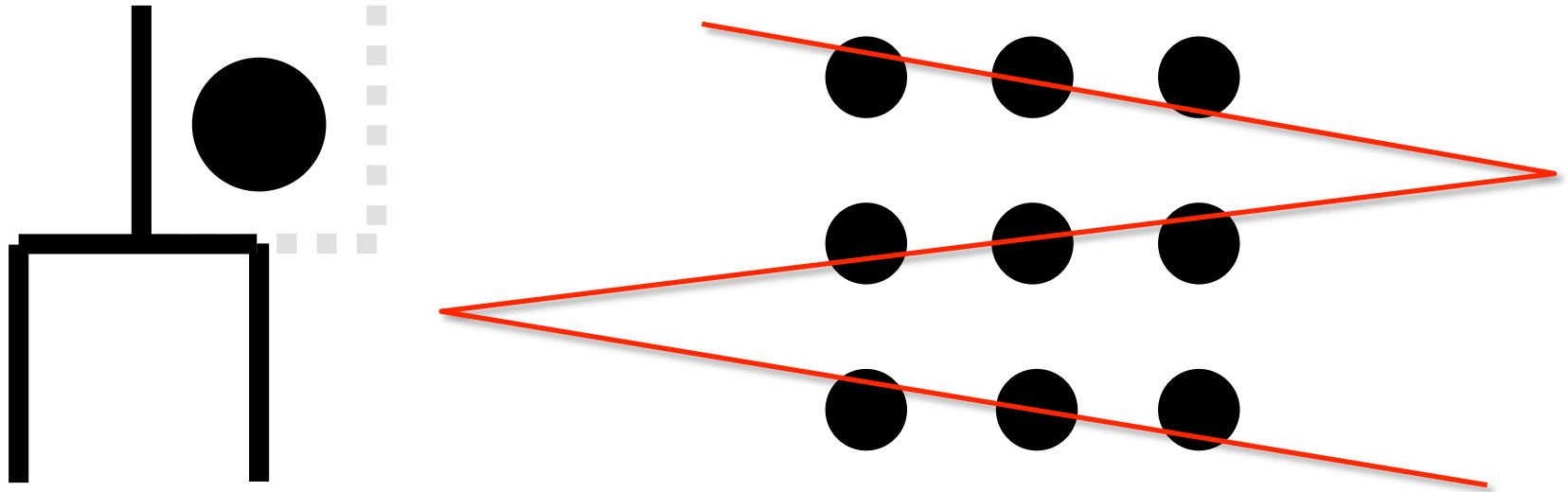
Creativity vs. innovation



Move two lines so that the coin is no longer in the spade



Draw three connected straight lines that pass through all nine dots



Barriers to creativity

Perceptual

- Those that prevent us from clearly seeing the problem for what it is
- Examples

Emotional barriers

- Fear of failure
  - People often have creative ideas but are afraid to share them since they may be criticized
  - As seen in the IDEO video: fail early and often in order to succeed
- Fear of chaos and disorganization
  - The creative process challenges engineers because it is messy, and not a "neat" scientific process
- Tendency to critically judge ideas, instead of building on them
- Incubation period: it takes time for creative ideas to appear
  - "I have my best ideas in the shower"

Environmental

- Poor teamwork: members distrusting or criticizing each other
- Autocratic management that resists new ideas
- Cultural biases: e.g., engineers generally distrust creativity

Intellectual and expressive

- The designer needs to understand the intellectual tools that are needed to solve problems
  - Mathematics is a universal language for solving problems
  - Digital design tools: truth tables, state diagrams
  - Electronics design: functional models (in a future lecture)
  - Software design: object-oriented, UML

Vertical vs. lateral thinking

Vertical (convergent) thinking

- The way engineers generally think: take a problem and proceed logically to the solution
- Typically linear: start at the highest level and successively refine its elements until the problem is solved

Lateral (divergent) thinking

- Term coined by Edward deBono
- Concerned with identifying many creative solutions, rather than developing a single solution to the problem
- Jumps around steps in a non-linear fashion, makes no attempt to discern right from wrong
- More apt to follow least likely paths, whereas vertical thinking follows the most likely path

Strategies to enhance creativity

- **Have a questioning attitude**
  - Be willing to challenge assumptions
  - Ask basic questions: "*why do we need to use a μP?*"
- **Practice being creative**
  - Creativity can be increased through conscious effort
  - e.g. identify your "pet peeves" and try to develop new solutions for them
- **Suspend judgment**
  - Seemingly outlandish ideas can lead to other concepts and solutions
  - Combine multiple of these ideas to form new ideas
- **Allow time**
  - The mind needs time to work on problems –the incubation period
- **Think like a beginner**
  - Novices do not have preconceived ideas about the solution to a problem
  - Experience is a double-edge sword
    - It helps is solve problems quickly by drawing on previous solutions, but
    - It can inhibit creativity

The SCAMPER technique

- **Substitute:** Can new elements be substituted for those that already exist in the system?
- **Combine**: can existing entities be combined in a novel way that has not been done before?
- **Adapt**: Can parts of the whole be adapted to operate differently
- **Modify**: Can part of all of a system be modified
- **Put to other use**: Are there other applicable domains where the system can be used
- **Eliminate**: Can parts of the whole be eliminated
- **Rearrange or Reverse**: Can elements of the system be rearranged to work better?

Concept generation

External searching

- Conduct literature search
- Search and review existing patents
- Benchmark similar products
- Interview experts

Internal searching

- Brainstorming
- Brainwriting
- Nominal group technique
- Concept tables

Brainstorming

- No evaluation or judgment of ideas permitted
- Encourage wild ideas
- Focus on quantity, not quality (can always toss later!)
- Build upon, combine, or modify the ideas of others (SCAMPER)
- Record all ideas

Brainwriting

- Team develops an common problem statement that is read out loud
- Each team member writes ideas down on a card and places it in the center of the table
- Other team members take cards from the pile and use other's ideas to generate new ones or build upon them
- Alternatively, members can each generate an idea, write it on a card, and then pass it to another team member, who builds upon the idea

Nominal group technique

- **Read problem statement**
  The facilitator reads the problem statement
- **Restate the problem**
  Each member restates the problem in their own words to ensure that all members understand it
- **Silently generate ideas**
  Each member silently generates ideas during a set period (5-15 min)
- **Collect ideas in a round-robin fashion**
  Each person presents one idea in turn until all ideas are exhausted
- **Summarize and rephrase ideas**
  Once the ideas are collected, the facilitator leads a discussion to clarify and rephrase the ideas
- **Vote**
  Each person casts a predetermined number of votes, and the votes are tallied

Concept table

- Decompose the problem into sub-functions
- Seek solutions for each sub-function
- Organize them in a table format
- Each solution is in the form of a single element from each column

Example concept table for a personal computing system

User Interface	Display	Connectivity & expansion	Power	Size
Keyboard	CRT	Serial & parallel	Battery	Hand-held, Fits in pocket
Touchpad	Flat Panel	USB	AC Power	Notebook size
Handwriting Recognition	Plasma	Wireless Ethernet	Solar Power	Wearable
Video	Heads-up display	Wired Ethernet	Fuel Cell	Credit card size
Voice	LCD	PCMCIA	Thermal transfer	Flexible in shape
		Modem / Telephone		

Concept evaluation

Strength & weakness analysis

- Identify and list strengths and weaknesses of each concept
- To make more analytical, assign subjective weights to strengths and weaknesses (plus and minus factors) and sum them
- The example below is for an experimental design project for testing a computer card

Method	Strengths	Weaknesses
Contact heating	- Simplest design - Could be used internally to computer	- Does not create uniform temperature - Hard to control temperature
Temperature chamber	- Uniform temperature - Greater control of temperature	- Must be external to computer - More difficult to design - Expensive

Analytical hierarchical process

1) Determine the selection criteria
2) Select the criteria weightings $\boldsymbol{\omega_j}$
   (*e.g. via pairwise comparisons*)
3) Identify and rate alternatives relative to the criteria ($\boldsymbol{\alpha_{ji}}$)
4) Compute the scores ($\boldsymbol{S_i} = \sum_{j=1}^{m} \omega_j \alpha_{ji}$)
5) Review the decision (*sanity check*)

		Design option 1	Design option 2	…	Design option n
Criteria 1	ω_1	α_{11}	α_{12}		α_{1n}
Criteria 2	ω_2	α_{21}	α_{22}		α_{2n}
⋮					
Criteria *m*	ω_m	α_{m1}	α_{m2}		α_{mn}
Score		S_1	S_2		S_n

Pugh concept selection

1) Select the comparison criteria
2) Determine weights for the criteria
3) Determine the concepts
4) Select baseline concept, initially believed best
5) Compare against other concepts (+1 better; 0 equal, -1 worse)
6) Compute weighted score for concepts, not including the baseline
7) Examine concepts (retain, update, drop)
8) Synthesize best elements of others where possible
9) Update table and iterate until best concept emerges

		Option 1 (Ref)	Option 2	Option 3	Option 4
Criteria 1	4	-	0	0	+1
Criteria 2	5	-	+1	-1	0
Criteria 3	2	-	-1	0	+1
Criteria 4	1	-	+1	+1	-1
Score		-	**4**	**-4**	**5**
Continue?		Combine	Yes	No	Combine