Digital Communication Systems
ECS 452

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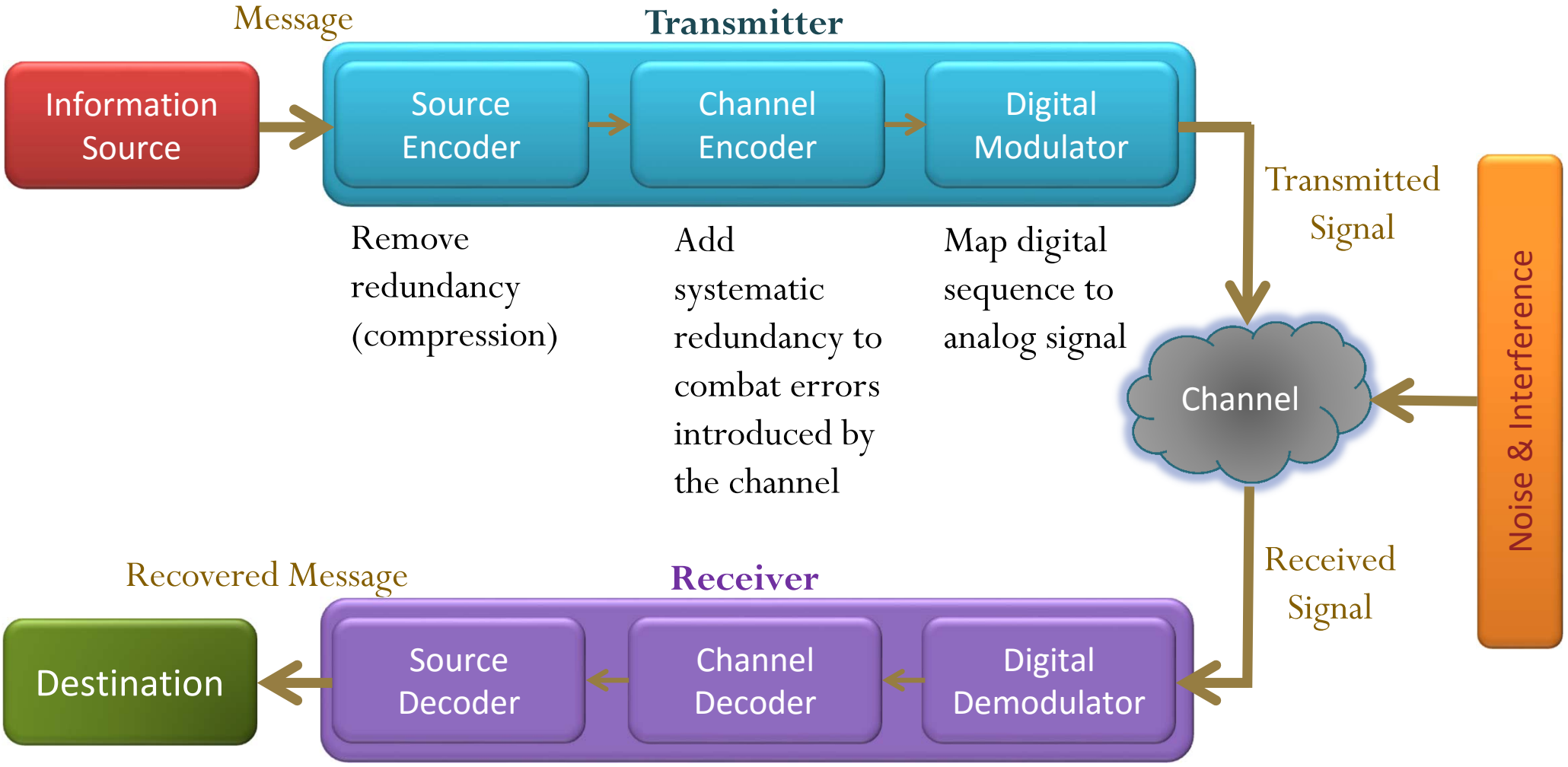
6. Digital Modulation

Office Hours:

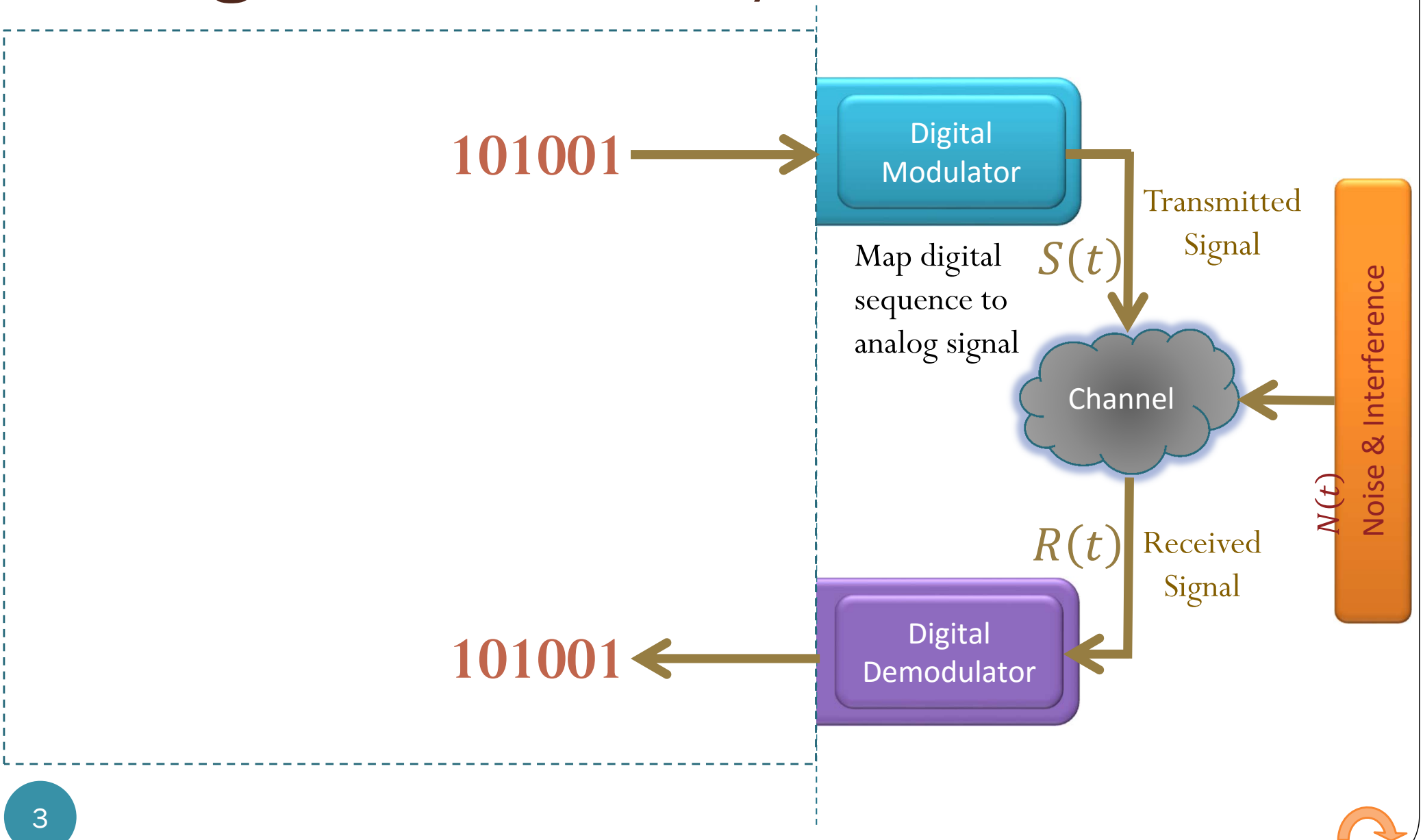
BKD, 4th floor of Sirindhralai building

Monday	**14:00-16:00**
Thursday	**10:30-11:30**
Friday	**12:00-13:00**

Elements of digital commu. sys.



Digital Modulation/Demodulation



Energy and Power

- Consider a signal $g(t)$.
- Total (normalized) **energy**:

Parseval's Theorem

$$E_g = \int_{-\infty}^{\infty} |g(t)|^2 dt = \lim_{T\to\infty} \int_{-T}^{T} |g(t)|^2 dt = \int_{-\infty}^{\infty} |G(f)|^2 df.$$

$$\Psi_g(f) = |G(f)|^2$$

ESD: Energy Spectral Density

- Average (normalized) **power**:

$$P_g = \left\langle |g(t)|^2 \right\rangle = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} |g(t)|^2 dt = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} |g(t)|^2 dt.$$

Modulator and Waveform Channel

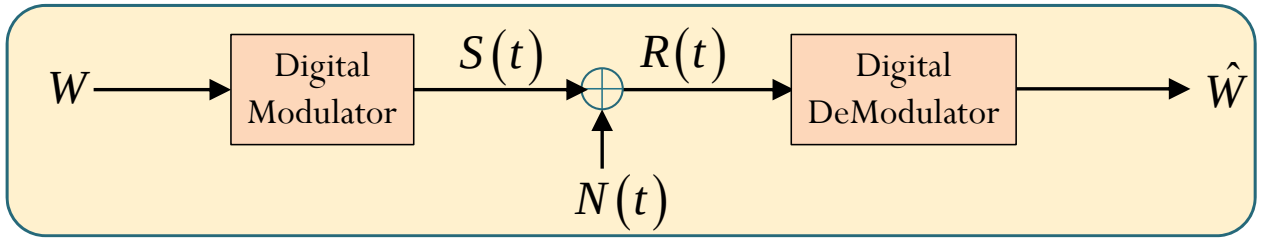
Goal: Want to transmit the message (index) $W \in \{1, 2, 3, \ldots, M\}$

Prior Probabilities: $p_i = P[W = i]$

M-ary Scheme

M =2: Binary
M = 3: Ternary
M = 4: Quaternary

Waveform Channel:



M possible messages requires
M possibilities for $S(t)$:

$$\{s_1(t), s_2(t), \ldots, s_M(t)\}$$

$$R(t) = S(t) + N(t)$$

Additive White Noise (Independent of $S(t)$)

Transmitted waveform

Received waveform

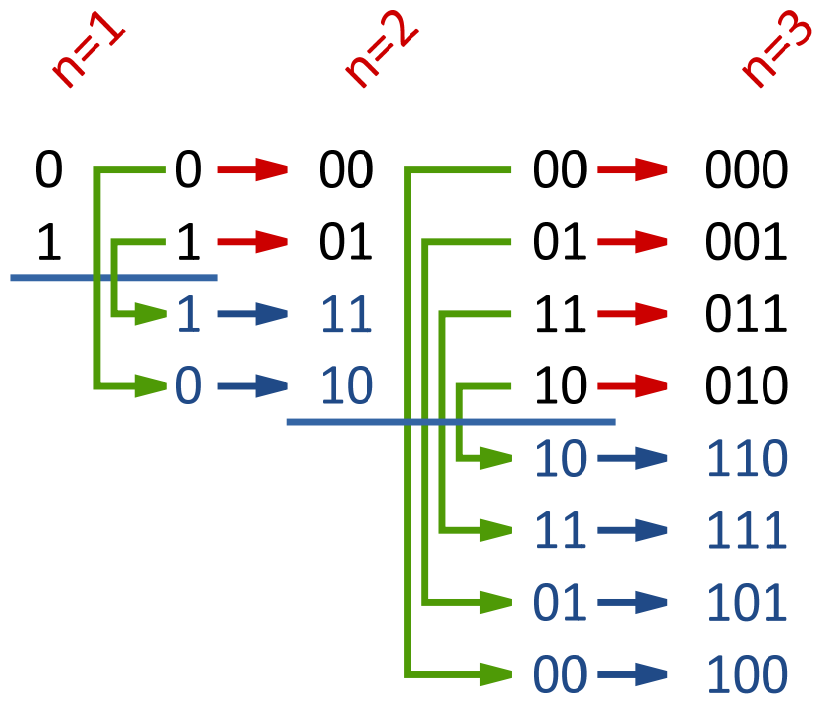
Transmission of the message $W = i$ is done by inputting the corresponding waveform $s_i(t)$ into the channel.

Prior Probabilities: $p_i = P[W = i] = P[S(t) = s_i(t)]$

Energy: $E_i = \langle s_i(t), s_i(t) \rangle$ $\quad E_s = \sum_{i=1}^{M} p_i E_i = (\log_2 M) E_b$

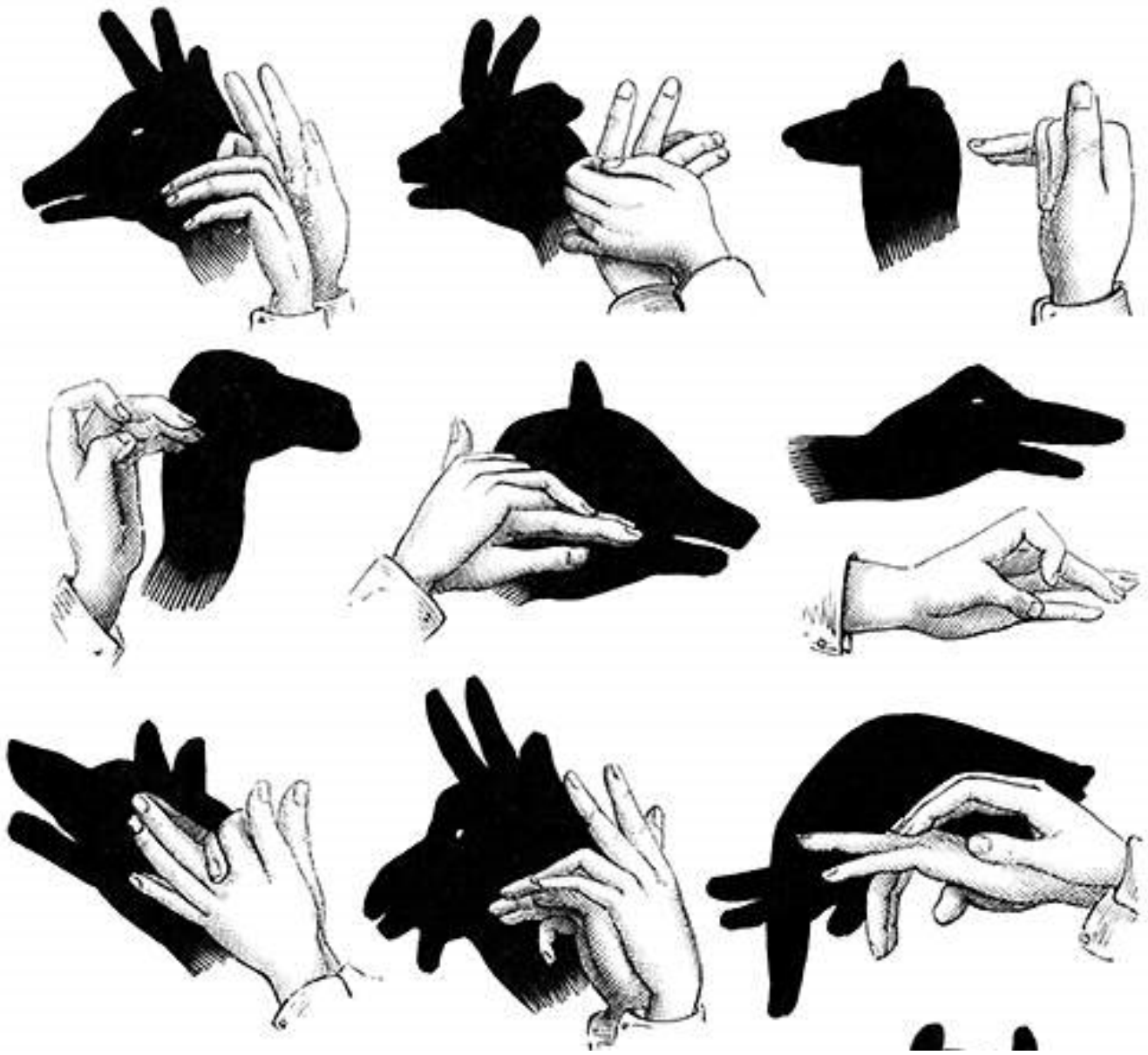
Gray Code

- Reflect-and-prefix method for 1-D Gray code construction
- Gray code list for n bits can be generated recursively from the list for $n-1$ bits by
  - reflecting the list (i.e. listing the entries in reverse order),
  - concatenating the original list with the reversed list,
  - prefixing the entries in the original list with a binary 0, and then prefixing the entries in the reflected list with a binary 1.



[http://en.wikipedia.org/wiki/Gray_code#mediaviewer/File:Binary-reflected_Gray_code_construction.svg]

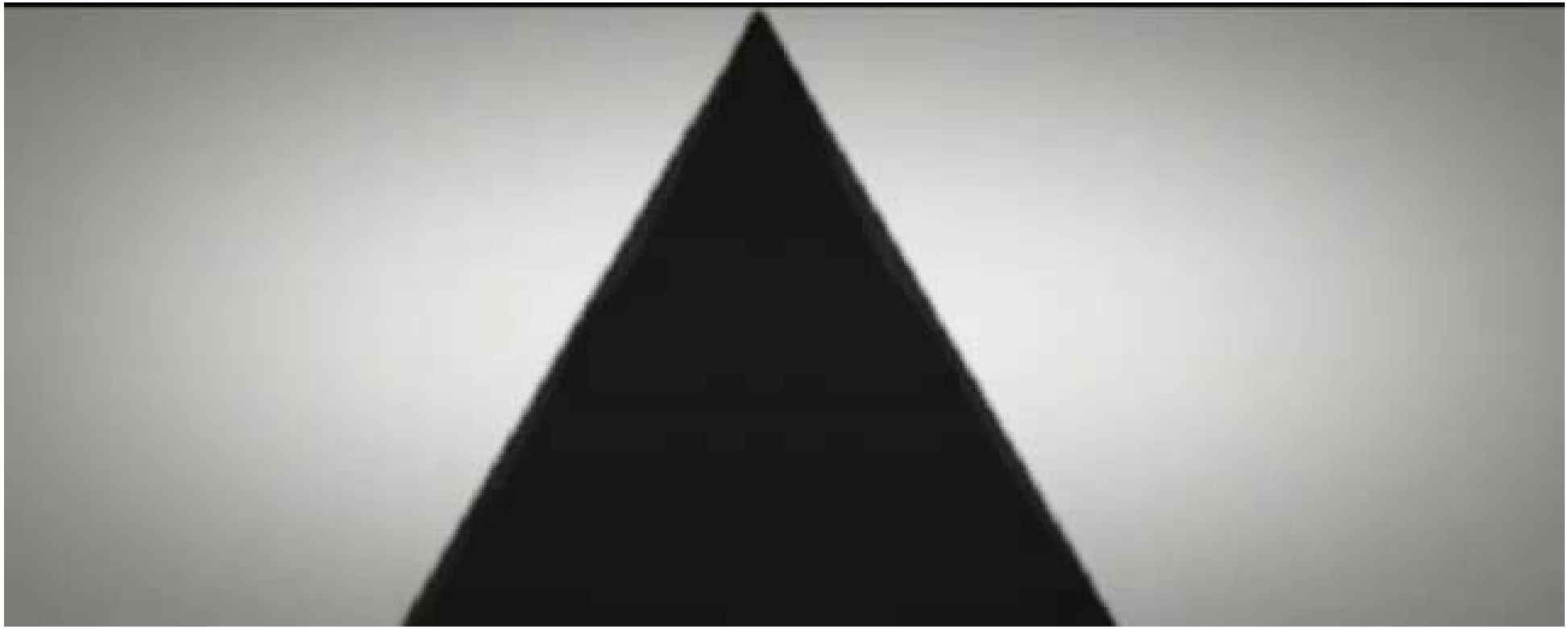
Projection: Hand Shadow



Projection: Shadow Art

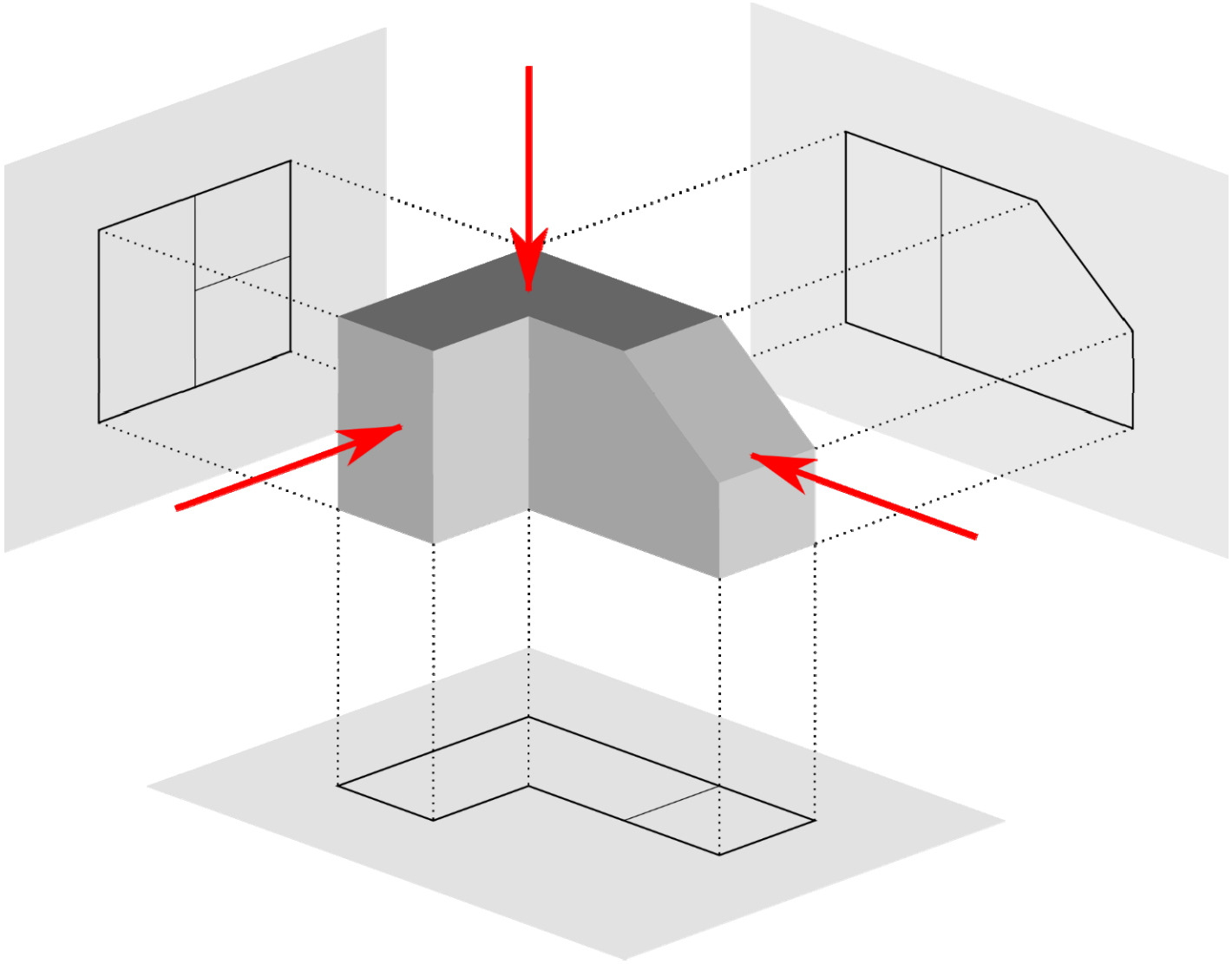
[http://thesuiteworld.com/wp-content/uploads/2011/07/Shadows-thesuiteworld.jpg]

Projection: Hand Shadow



[https://www.youtube.com/watch?v=VpC9HSYMwdY]

Projection: Engineering drawing



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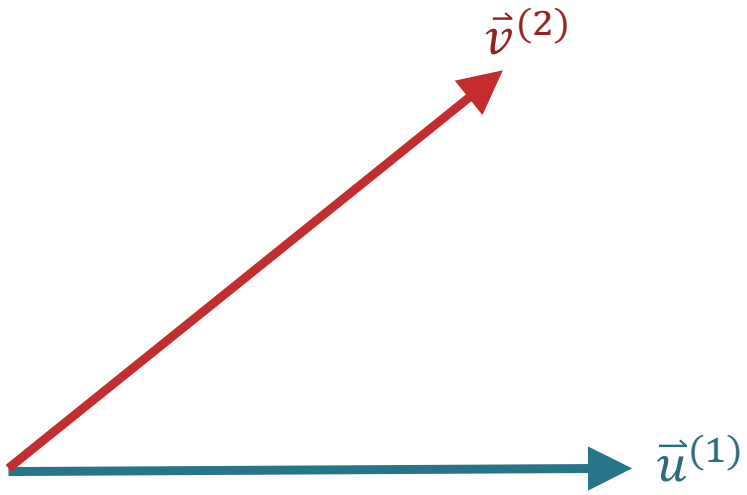

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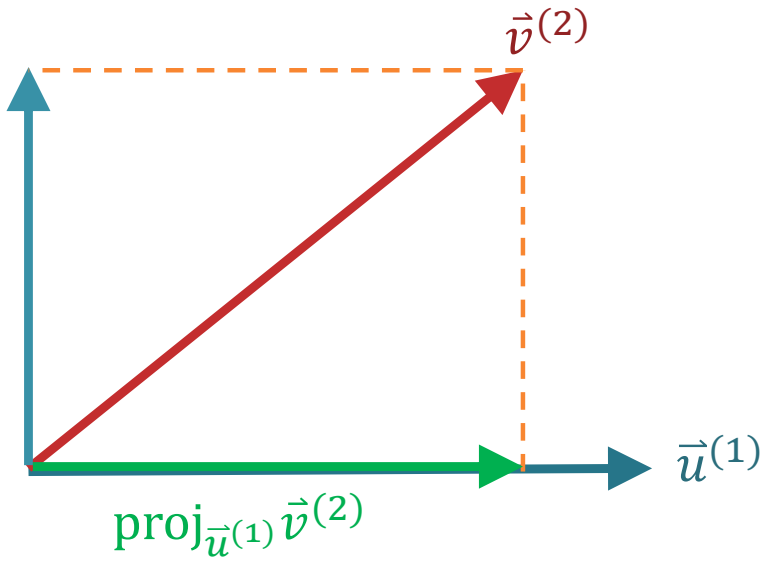
$$\vec{u}^{(2)} = \vec{v}^{(2)} - \text{proj}_{\vec{u}^{(1)}} \vec{v}^{(2)}$$



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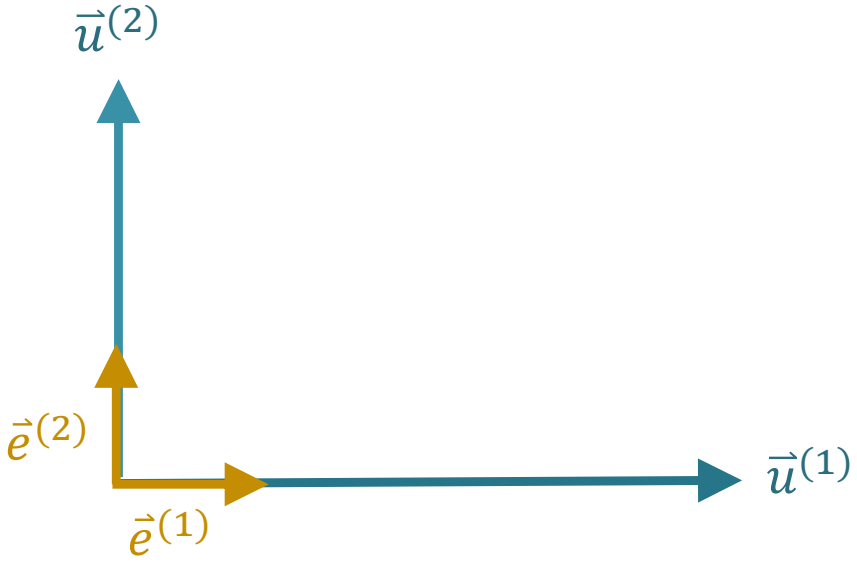

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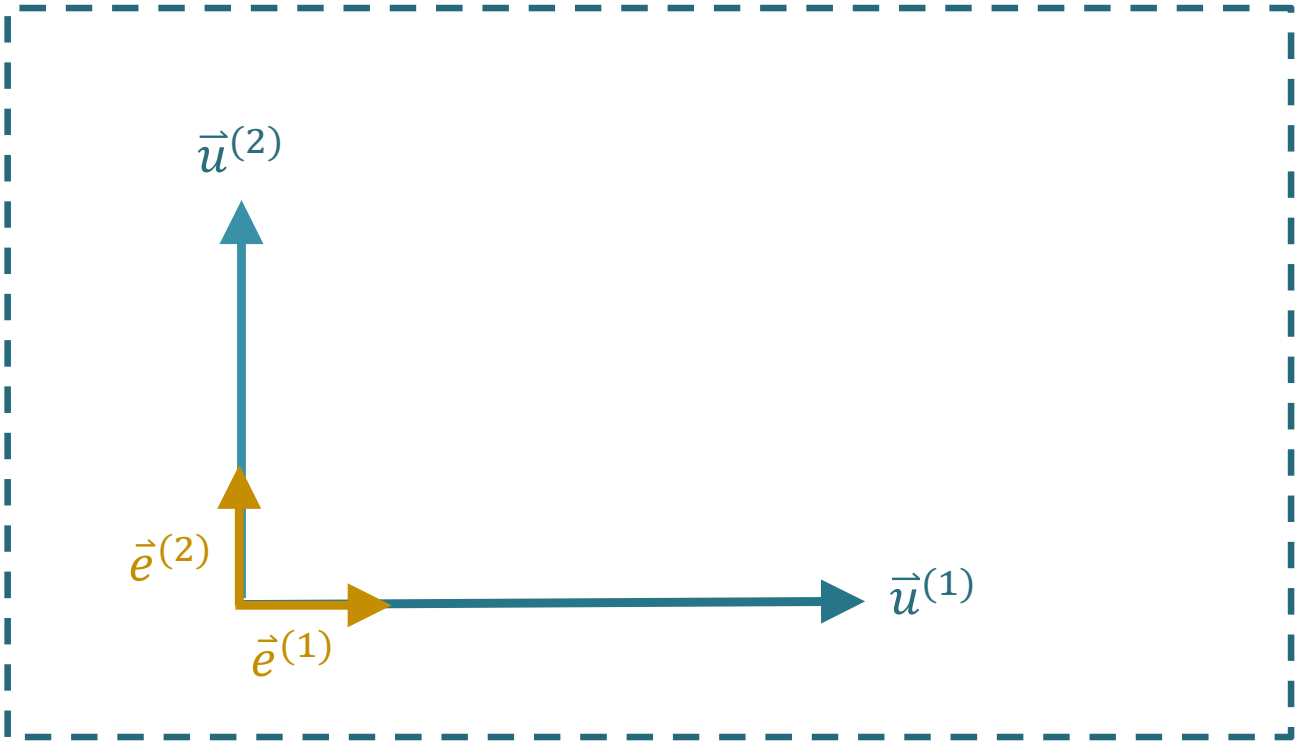

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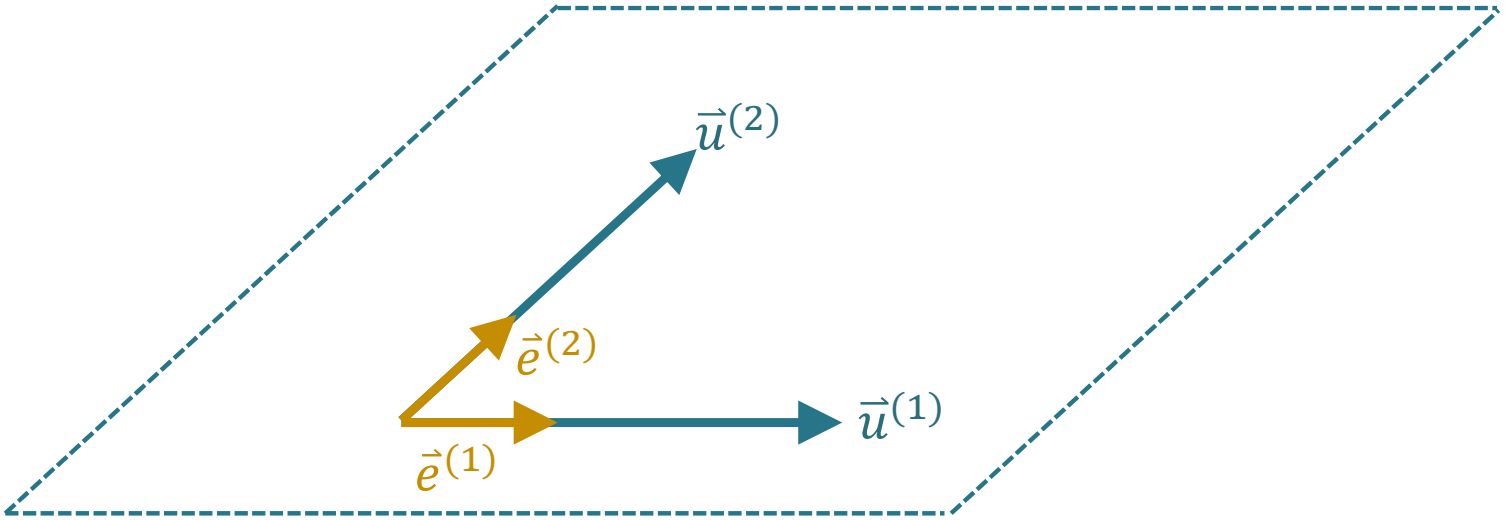

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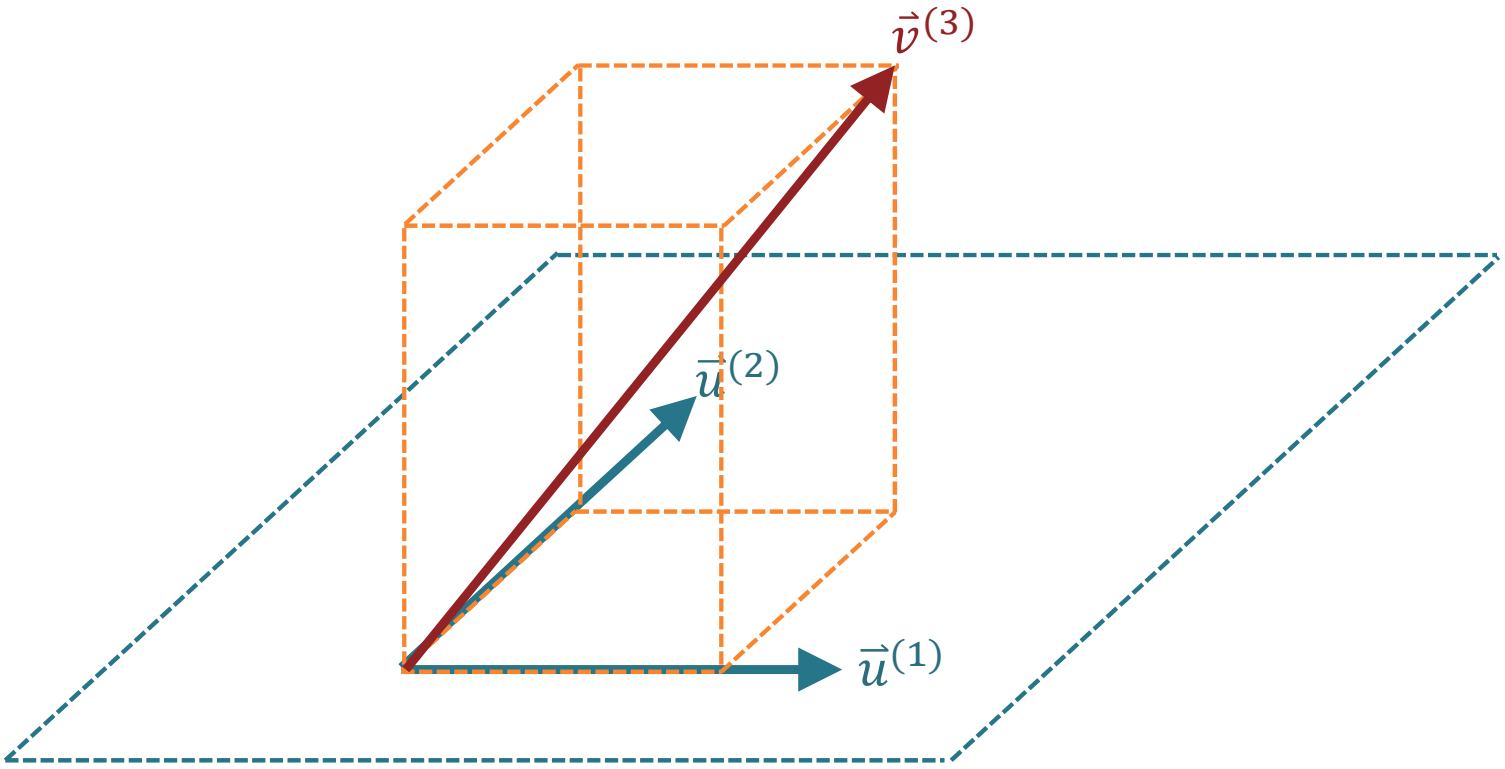

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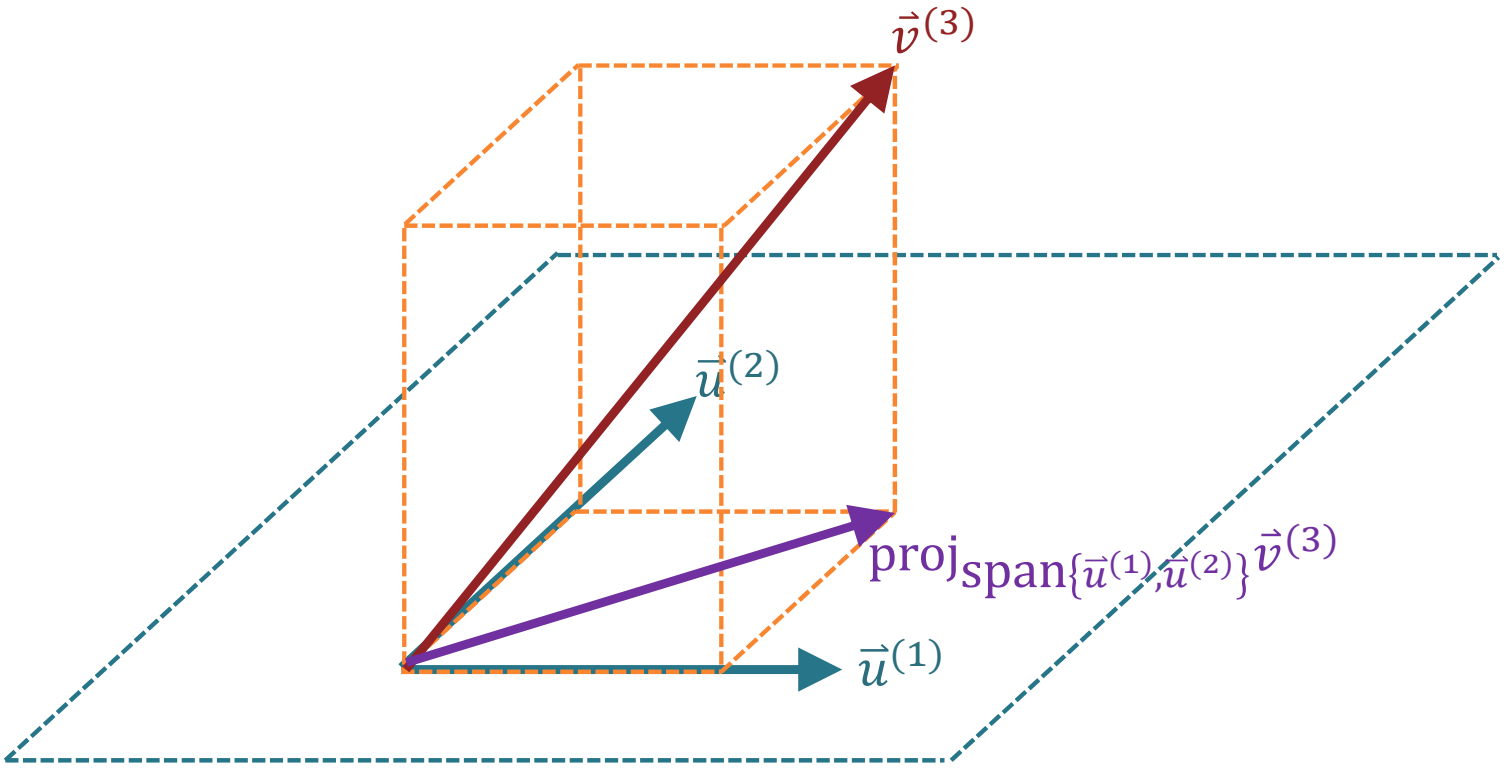

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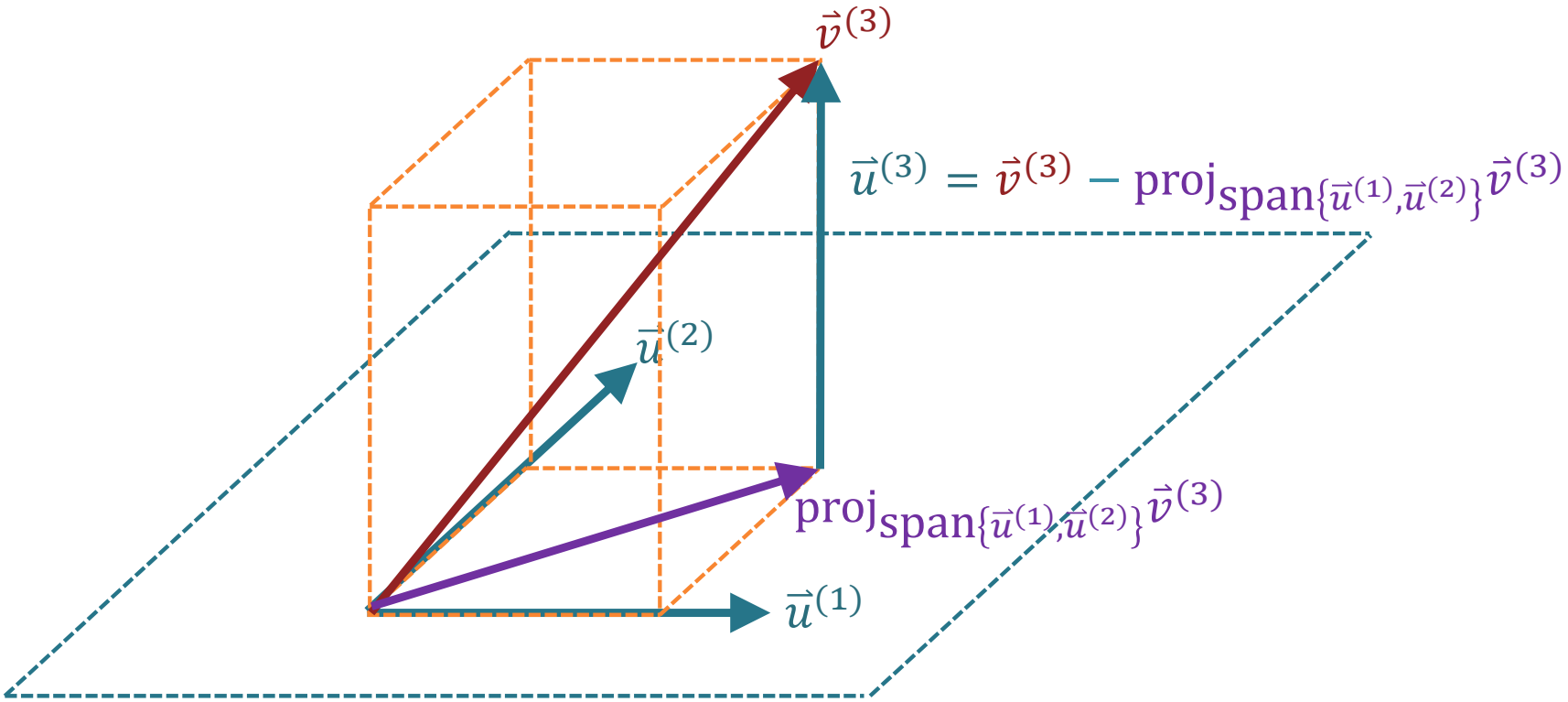
$\vec{v}^{(3)}$
$\vec{u}^{(3)} = \vec{v}^{(3)} - \text{proj}_{\text{span}\{\vec{u}^{(1)},\vec{u}^{(2)}\}}\vec{v}^{(3)}$
$\vec{u}^{(2)}$
$\text{proj}_{\text{span}\{\vec{u}^{(1)},\vec{u}^{(2)}\}}\vec{v}^{(3)}$
$\vec{u}^{(1)}$

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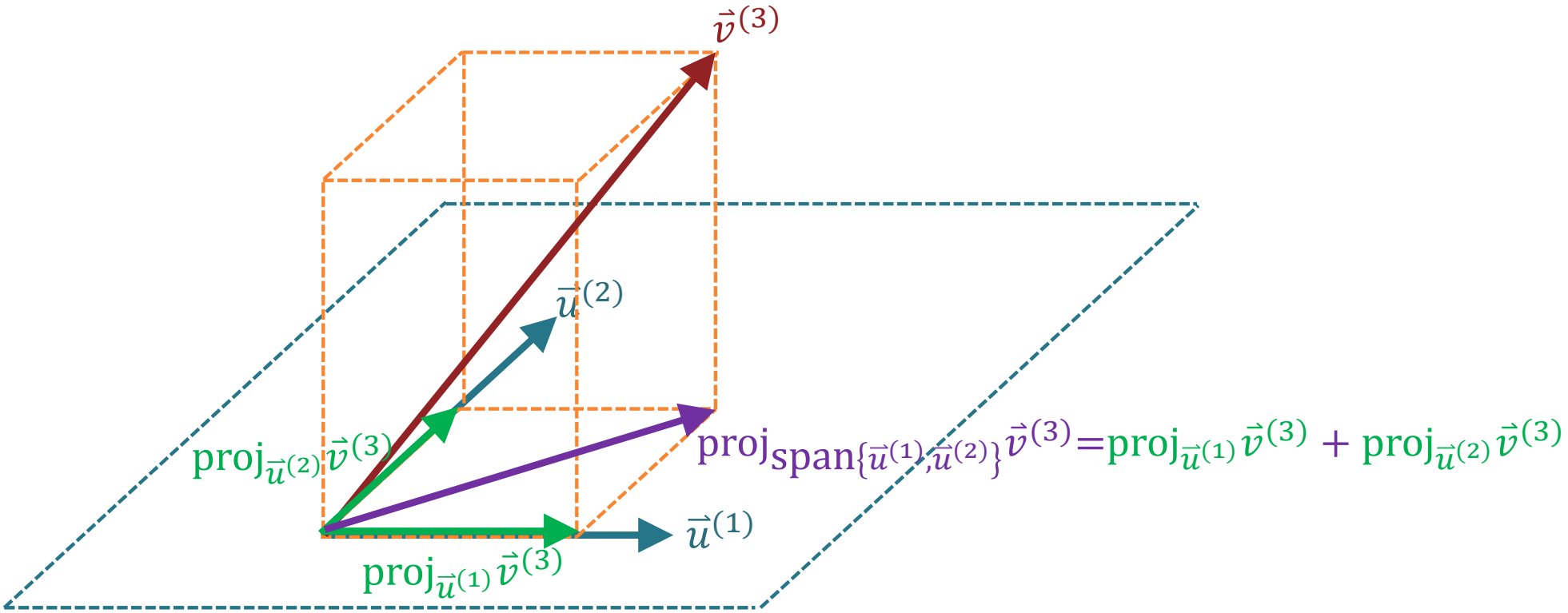
$\vec{v}^{(3)}$
$\vec{u}^{(2)}$
$\text{proj}_{\vec{u}^{(2)}}\vec{v}^{(3)}$
$\text{proj}_{\text{span}\{\vec{u}^{(1)},\vec{u}^{(2)}\}}\vec{v}^{(3)}=\text{proj}_{\vec{u}^{(1)}}\vec{v}^{(3)}+\text{proj}_{\vec{u}^{(2)}}\vec{v}^{(3)}$
$\vec{u}^{(1)}$
$\text{proj}_{\vec{u}^{(1)}}\vec{v}^{(3)}$

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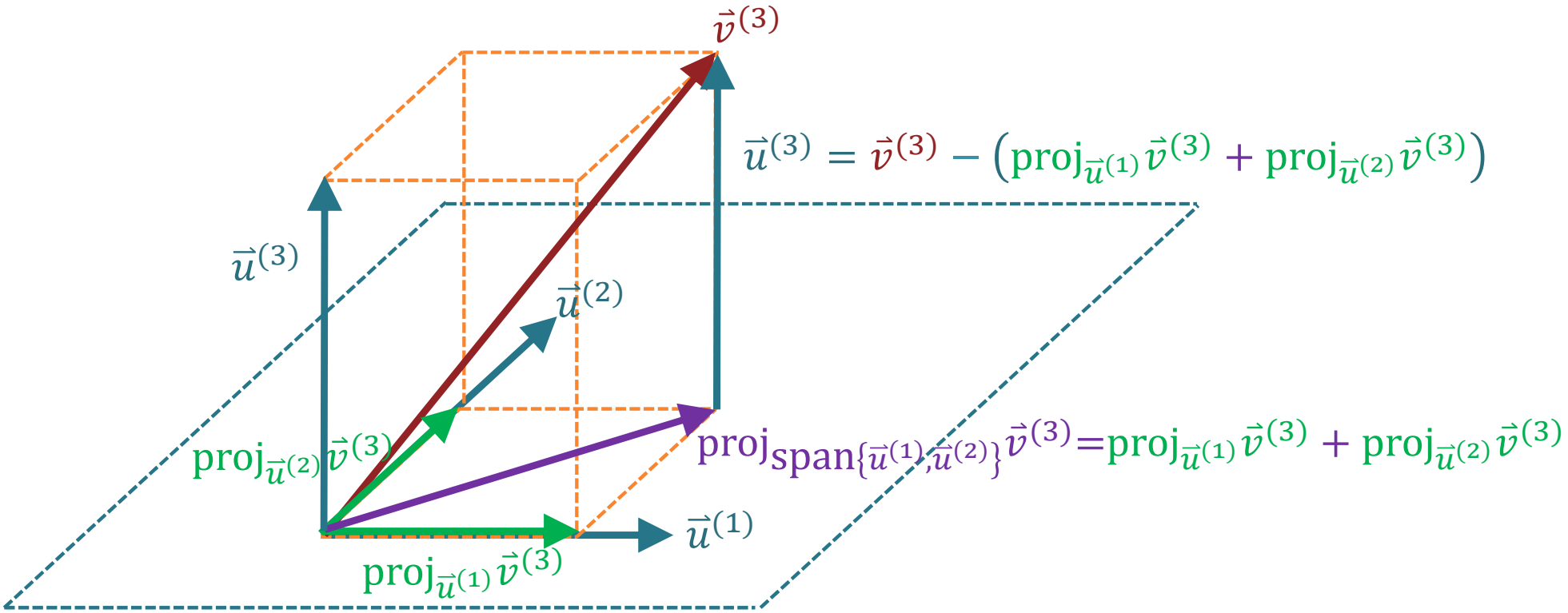
$\vec{v}^{(3)}$
$\vec{u}^{(3)} = \vec{v}^{(3)} - \left(\text{proj}_{\vec{u}^{(1)}}\vec{v}^{(3)} + \text{proj}_{\vec{u}^{(2)}}\vec{v}^{(3)}\right)$
$\vec{u}^{(3)}$
$\vec{u}^{(2)}$
$\text{proj}_{\vec{u}^{(2)}}\vec{v}^{(3)}$
$\text{proj}_{\text{span}\{\vec{u}^{(1)},\vec{u}^{(2)}\}}\vec{v}^{(3)} = \text{proj}_{\vec{u}^{(1)}}\vec{v}^{(3)} + \text{proj}_{\vec{u}^{(2)}}\vec{v}^{(3)}$
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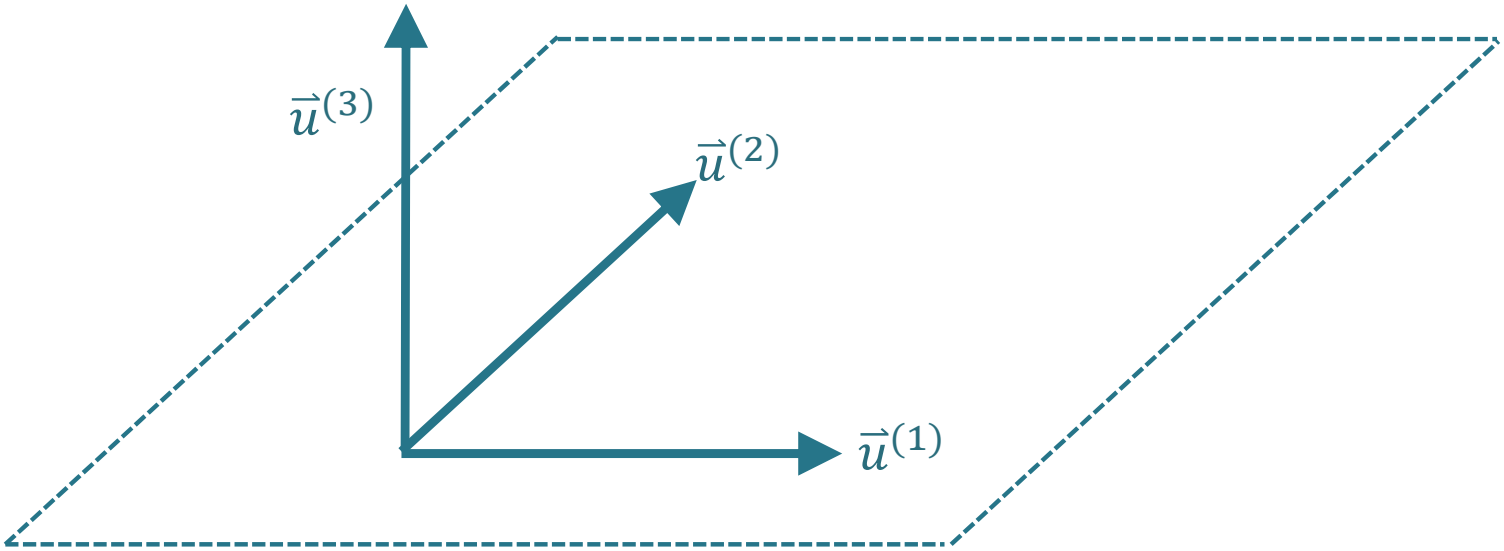

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