Toward a prescriptive semantic basis for change- type ilities

By
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Toward a Theory of Ilities

What are the semantic fields that span the general set of ilities?
e.g. “change-type”, “architecture-type”, “new ability-type”

Ultimate Goal: develop the basis/bases to be a prescriptive instrument(s) for spanning the semantic fields whose union encompass all “ilities”
Goals for the Research

Wouldn’t it be great to have this on your desk?

One of the key objectives for this work is to stimulate a new conversation on a theory of ilities
A Linguistic Approach to Ilities

Linguistic meaning vs. speaker meaning

Literal vs. nonliteral

“ULA says the network augments 'more robust and flexible' execution of Command and Control, Communications Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR)…”

To Axe, there is a "clear" need for the K-MAX because operations in the country are "highly dependent on flexible, reliable and secure logistics…”

“Defense Secretary Panetta: "The US joint force will be smaller and it will be leaner. But it will be more agile, more flexible, ready to deploy quickly, innovative and technologically advanced."

… “the Defense Department and the Office of the Director of National Intelligence pledged to foster an industrial base that is 'robust, competitive, flexible, healthy, and delivers reliable space capabilities on time and on budget.'"

- Linguistics is the scientific study of human natural language, including semantics
- Semantics is the study of “meaning” and is a promising area for clarifying the “ilities”
- Meaning arises from interplay of “use” (i.e. speech) and “prescription” (i.e. dictionaries)
- Technical and political leaders are using “ilities” so we need to understand them well enough to ensure systems predictably display these properties

Semantic field

“a group of words with related meanings, for example kinship terms or color terms”

Akmajian et al 2001, p. 587

Semantic Challenges for Ilities

• Fundamental “ambiguity” in terms
  — Many of these terms are use colloquially and therefore inherit meaning
  — Polysemy – “The property of [a term] having multiple meanings that are semantically related”
    o Flexibility (able to be changed) and flexibility (able to satisfy multiple needs)
  — Synonymy – “The property of multiple terms having similar meaning”
    o Flexibility (able to be changed) and changeability (able to be changed or change itself)

• Problem partly stems from considering one ility at a time
  e.g. flexibility:

• Some work done on sets
  e.g. changeability:

If challenge can be addressed by looking at sets of ilities, how do we select members of the set?
These are just a handful of sources; What is the basis for their inclusion in each proposed set? How are these illitities related to one another? How can illitities be traded off?
Descriptive and Prescriptive Approaches

Frequency of ilities mentioned in journal articles and Google hits (de Weck, Roos, Magee 2011, p. 67)

Frequency of ilities mentioned in literature across time (de Weck, Roos, Magee 2011, p. 69)

Ility term co-occurrence in the literature with implied dependence (de Weck, Roos, Magee 2011, p. 83)


Ilities as Responses to Uncertainties

Uncertainties

- Threat/Hazard Opportunity
- Constraint
- Perturbation
- Limitation
- Resulting Impact

Responses

- Design Decision
- Change Enabler
- Path Inhibitor
- Resistance Mechanism
- Resulting Ilities

Perturbations and limitations impact value

Changes and resistances maintain value

Suppose we want to maintain value (i.e., no-change in outcome parameter value)

There are four high level ility responses

- Robustness
- Survivability
- Versatility/Insensitivity
- Changeability

Having a basis allows us to quickly derive responses
Theoretical Framework Motivating a Semantic Basis

- Extracted concepts from wide review of literature and theoretical frameworks
- Avoiding imposed definitions; focused on potential degrees of freedom implied within an array of “change-type” ility definitions
- Results in a “mix and match” set of bases from which to propose “definitions” that can be labelled with ility terms

### 10D Basis

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Name</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Perturbation</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>2</td>
<td>Context</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>3</td>
<td>Phase (Change Mechanism)</td>
<td>Ross and Rhodes 2011</td>
</tr>
<tr>
<td>4</td>
<td>Change Agent</td>
<td>Ross, Rhodes, Hastings 2008</td>
</tr>
<tr>
<td>5</td>
<td>Change Effect</td>
<td>Ross, Rhodes, Hastings 2008</td>
</tr>
<tr>
<td>6</td>
<td>Parameter (Change Effect)</td>
<td>Ross, Rhodes, Hastings 2008</td>
</tr>
<tr>
<td>7</td>
<td>End States (Change Mechanism)</td>
<td>Ross and Rhodes 2011</td>
</tr>
<tr>
<td>8</td>
<td>Aspect</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>9</td>
<td>Abstraction</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>10</td>
<td>Valuable</td>
<td>Ross and Rhodes 2011</td>
</tr>
</tbody>
</table>

### 14D Basis

Generalizing the Change-related Statement: A Prescriptive Basis

(From Ross, Rhodes, and Hastings 2008)

The system shall be ___________________________ in ___________________________ for less than ___________________________.

Prescriptive Semantic Basis for Change-related Ilities

In response to “cause” in “context”, desire “agent” to make some “change” in “system” that is “valuable”

<table>
<thead>
<tr>
<th>Cause</th>
<th>Context</th>
<th>System</th>
<th>Agent</th>
<th>Change</th>
<th>Valuable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why</td>
<td>Where</td>
<td>What</td>
<td>Change Type</td>
<td>Effect (Scale)</td>
<td>Effect (Amount)</td>
</tr>
<tr>
<td>perturbation</td>
<td>specificity</td>
<td>abstraction</td>
<td>aspect</td>
<td>LC phase</td>
<td>executes</td>
</tr>
<tr>
<td>disturbance</td>
<td>circumstantial</td>
<td>architecture</td>
<td>form</td>
<td>pre-ops</td>
<td>internal</td>
</tr>
<tr>
<td>shift</td>
<td>general</td>
<td>design</td>
<td>function</td>
<td>ops</td>
<td>external</td>
</tr>
<tr>
<td>none</td>
<td>any</td>
<td>system</td>
<td>operations</td>
<td>inter-LC</td>
<td>either</td>
</tr>
<tr>
<td>any</td>
<td>any</td>
<td>any</td>
<td>any</td>
<td>any</td>
<td>none</td>
</tr>
</tbody>
</table>

10 category basis for specifying “change-related” ilities
Using the Basis to Map Ility Term Labels
An Early Application

Interviews should be used to associate ility term labels with particular choices in the bases

Once the ility term mapping “dictionary” is populated, whenever choices are made in the bases, associated ility terms can be assigned.
# Prescriptive Semantic Basis for Change-type Ilities

In response to “perturbation” in “context”, desire “agent” to make some “change” in “system” that is “valuable”

<table>
<thead>
<tr>
<th>Perturbation</th>
<th>Context</th>
<th>Phase</th>
<th>Agent</th>
<th>Impetus (optional)</th>
<th>Mech</th>
<th>Outcome</th>
<th>Valuable</th>
</tr>
</thead>
<tbody>
<tr>
<td>occasion</td>
<td>required</td>
<td>general</td>
<td>optional</td>
<td>optional, null</td>
<td>null</td>
<td>required</td>
<td>optional</td>
</tr>
</tbody>
</table>

**Example:**

- **Perturbation:** change in environment
- **Context:** response to change
- **Phase:** immediate response
- **Agent:** organization
- **Impetus (optional):** increase in demand
- **Mech:** increased production
- **Outcome:** increased profit
- **Valuable:** increased profitability

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**Note:** This table is a template for describing the effects of perturbations on systems. It is designed to be filled in with specific scenarios to illustrate the application of prescriptive semantic basis for change-type ilities.
In response to "perturbation" in “context” during "phase" desire “agent” to make some "nature" impetus to the system "parameter" from "origin(s)" to "destination(s)" in the "aspect" using "mechanism" in order to have an "effect" to the outcome "parameter" from "origin(s)" to "destination(s)" in the "aspect" of the "abstraction" that are valuable with respect to thresholds in “reaction”, “span”, “cost” and "benefits"

The semantic basis would be used differently in different use cases

**Full basis:**
- When trying to write a very specific requirement statement (should not occur until AFTER analysis to determine what should be done)

**Subset of basis:**
- Early in the design phase, leave out the “valuable” categories (these are subjective, depend on outside factors)
- If one is trying to avoid fixating on a solution-centric approach, leave out change mechanism (allow engineers to propose own alternatives)
Variations on the Statement (11)

In response to "perturbation" in "context" during "phase" desire "agent" to make some "nature" impetus to the system "parameter" from "origin(s)" to "destination(s)" in the "aspect" using "mechanism" in order to have an "effect" to the outcome "parameter" from "origin(s)" to "destination(s)" in the "aspect" of the "abstraction" that are valuable with respect to thresholds in "reaction", "span", "cost" and "benefits".

When to use: if there is a constraint to make use of an existing/inherited mechanism, for example.

Note: This version is OUTCOME oriented, leaving open the “valuable” specification, but leaves in the “mechanism” category to constrain how the change should occur.
Variations on the Statement (10)

In response to "perturbation" in “context” during "phase" desire “agent” to make some "nature" impetus to the system "parameter" from "origin(s)" to "destination(s)" in the "aspect" using "mechanism" in order to have an "effect" to the outcome "parameter" from "origin(s)" to "destination(s)" in the "aspect" of the "abstraction" that are valuable with respect to thresholds in “reaction”, “span”, “cost” and "benefits"

In response to "perturbation" in “context” during "phase" desire “agent” to have an "effect" to the outcome "parameter" from "origin(s)" to "destination(s)" in the "aspect" of the "abstraction" that are valuable

When to use: early in design in order to not over specify the change mechanism (allow engineers to propose/evaluate alternatives), or impetus (i.e. this is OUTCOME oriented).

Note: Leaving out “valuable” part of statement supports exploration. Later, when implications of ility statement are better understood, one can specify (differently across stakeholders, if desired) subjective thresholds on what makes the change “valuable.”
In response to "perturbation" in "context" during "phase" desire "agent" to make some "nature" impetus to the system "parameter" from "origin(s)" to "destination(s)" in the "aspect" using "mechanism" in order to have an "effect" to the outcome "parameter" from "origin(s)" to "destination(s)" in the "aspect" of the "abstraction" that are valuable with respect to thresholds in "reaction", "span", "cost" and "benefits".

In response to "perturbation" in "context" during "phase" desire "agent" to make some "nature" impetus to the system "parameter" from "origin(s)" to "destination(s)" in the "aspect" using "mechanism" in order to have an "effect" to the outcome "parameter" of the "abstraction" that is valuable.

In response to "loud noises" in "night", during "ops" desire "owner" to be able to "increase" the "level of volume" of the "his stereo" in "less than one second".

Desire stereo to be **flexibly scalable** in **volume** in **less than one second**.
In response to "perturbation" in “context” during "phase" desire “agent” to make some "nature" impetus to the system "parameter" from "origin(s)" to "destination(s)" in the "aspect" using "mechanism" in order to have an "effect" to the outcome "parameter" from "origin(s)" to "destination(s)" in the "aspect" of the "abstraction" that are valuable with respect to thresholds in “reaction”, “span”, “cost” and "benefits".

In response to "perturbation" in “context” during "phase" desire “agent” to be able to "effect" the outcome "parameter" of the "abstraction" that is valuable.

In response to “loud noises" in “night”, during “ops" desire “owner” to be able to “increase" the “level of volume” of the “his stereo” in “less than one second”.

In response to “loud noises” at “night” during “ops”, desire “owner” to be able to impetus

{“increase" the “knob angle level" from “one state" to “many states" in the “system form"} through “turning the knob" that results in the outcome

{“increasing" the “volume level" from “one state” to “many states" in the “system function"} in the “owner’s stereo" that “takes less than one second"
### Collecting System Change Examples for Illustrating Basis Use

<table>
<thead>
<tr>
<th>System Name</th>
<th>Change Description</th>
<th>Related Itility Labels</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMMWV</td>
<td>Improvement to replace IEDs and ambush tactics in urban warfare, desire AM General to change armor to improve performance in the HMMWV, for quick deployability and rapid deployment.</td>
<td>Changeability, Predictability, Value/Return on Investment</td>
</tr>
<tr>
<td>9-57</td>
<td>Improvement in increased demand for alternative fuel sources in a concept of reducing dependence on foreign oil. Need to change fuel system to use 0-20 engines (flex fuel).</td>
<td>Changeability, Predictability, Value/Return on Investment</td>
</tr>
<tr>
<td>9-6</td>
<td>Improvement to extend the longer range, some ground use in air or external tanks, a need to extend or handle points. Improvement in change the increased range.</td>
<td>Changeability, Predictability, Value/Return on Investment</td>
</tr>
<tr>
<td>F-35 Joint</td>
<td>Improvement in higher efficiency in a new emerging environment (cloud), desire Swiss engineers made some improvements to change by replacing all systems with items that are always available and values.</td>
<td>Changeability, Predictability, Value/Return on Investment</td>
</tr>
<tr>
<td>9-62</td>
<td>Improvement in changing the requirements in the dual armed engine sector and NVG, engagement, desire to balance the HMMWV into a new helicopter suitable for militarywendness. Developed from the B-25, Black Hawk (A-25 the HMMWV was planned to utilize as many components and subsystems from the right side Black Hawk. The H-62 ended up with a redesigned, new dynamic component system, cost, and quality.</td>
<td>Changeability, Predictability, Value/Return on Investment</td>
</tr>
<tr>
<td>HMMWV</td>
<td>Improvement in improved IEDs and ambush tactics in &quot;urban warfare&quot;, desire &quot;AM General&quot; to change the armor to improve performance in the HMMWV, for quick deployability and rapid deployment.</td>
<td>Changeability, Predictability, Value/Return on Investment</td>
</tr>
</tbody>
</table>

In response to "perturbation" in "context" during "phase" desire "agent" to have an "effect" to the outcome "parameter" from "origin(s)" to "destination(s)" in the "aspect" of the "abstraction" that are valuable.

In response to "improved IEDs and ambush tactics" in "urban warfare", during "pre-ops" desire "AM General" to make an "increase" to the "armor" from "baseline" to "above baseline" in the "form" of the "HMMWV design" that is valuable.

For existing changeable systems, this is a descriptive capture of a change statement, potentially implemented at various levels of specificity.
• Full verbose statement is unwieldy when viewed in “English”

• Construction of “plain English” phrasing is partly customized based on particular statement

• A “translator” would be valuable in converting the basis category choices into English

• We see this translation layer and underlying “little language” as key contributions of this work

• Next phase research will develop the translation layer and seek collaboration with team for feedback and testing
- Spiraling on web service implementation of basis
- Resulted in clarifications on categories
  - Including “naming” and optional fields
- Illustrated need for examples
- Motivated need for translation layer

Growing complexity of “full basis” highlights need for (1) different use cases (subsets of basis), and (2) translation layer for practitioner use
Revisiting “Ilities Tradespace”

- Semantic basis with ility term labels mapped would be able to show relationship between ilities within the spanned semantic field
  - Can you have a flexible AND robust system?
  - Can you have a single adaptably, scalable, extensible, affordable change?
  - What metrics can be used to evaluate and valuate along ilities?

- What are the fundamental tradeoffs between change-type ilities?
  - Categorical choice differences
  - Means to ends differences?
Next Steps & Research Questions

- **High level feedback**
  - Does this approach make sense?

- **Applicability to Semantic Fields**
  - Does this basis only apply to “change-type” semantic field?
  - What are the members of this field?
  - What other semantic fields may exist?
  - Can a different basis be used for each semantic field?

- **Refinement of basis**
  - What are appropriate basis categories?
  - What are appropriate choices within a category?

- **Refinement of ility labels**
  - Are there consensus patterns in matching SEAril ilities to basis?
  - Are there consensus patterns for given ility terms without provided definitions?
  - How do other definitions for ility labels map to basis?

- **Prescriptive use**
  - Can someone use the basis to generate change statements, which will automatically label with the appropriate ilities?
  - How useful is the change statement for supporting verifiable requirements?

Ultimate Goal: develop the basis/bases to be a prescriptive instrument(s) for spanning the semantic fields whose union encompass all “ilities”

Ultimately we do not want more definitions, but rather, unambiguous, verifiable, standardized representations of desired system properties.

The intent of this work is to inspire alternative approaches to dealing with, and to promote conversations about, the semantic problem for system ilities.
Thank you for your attention!

Questions?

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