Formal Methods for Interactive Systems

Part 3 — Task Analysis

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Tasks and Task Analysis

Task: the activity that has to be performed to achieve a goal

Tasks and Task Analysis

Task: the activity that has to be performed to achieve a goal

Task Analysis:
the process of analysing the way people perform tasks:

- what people do
- what things they work with
- what they must know

Method for Task analysis

General Method

- observe the user’s behaviour
- collect unstructured lists of words and actions
- organise using notation or diagrams

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Focus on the user's objective obsevable behaviour rather than on the user's internal mental model

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- collect unstructured lists of words and actions
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Focus on the user’s objective obsevable behaviour rather than on the user’s internal mental model

However, it might involve building a conceptual model

Purpose of Task Analysis

- production of training material and documentation

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- production of training material and documentation
- contribute to the design of a new system
  - building a conceptual model
  - generation of user interfaces

Approaches to Task Analysis

Three different approaches:

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Three different approaches:

- task decomposition
- knowledge-based techniques
- entity-relationship-based analysis

Task Decomposition

- describe the actions people do
- structure them within task-subtask hierarchy
- describe order of subtasks

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Hierarchical Task Analysis (HTA)

- text and diagrams to show hierarchy
- plans to describe order

HTA: Textual Notation

Hierarchy description:

0. make a cup of tea
   1. boil water
   2. empty pot
   3. put tea leaves in pot
   4. pour in boiling water
   5. wait 5 minutes
   6. pour tea

HTA: Textual Notation

Hierarchy description:

0. make a cup of tea
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Plans

Plan 0. do 1
at the same time, if pot is full do 2
then do 3 – 4 – 5
after 5 minutes do 6

Generating the Hierarchy

- get list of tasks
- group tasks into higher level tasks
- decompose lower level tasks further

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How to know when to stop?

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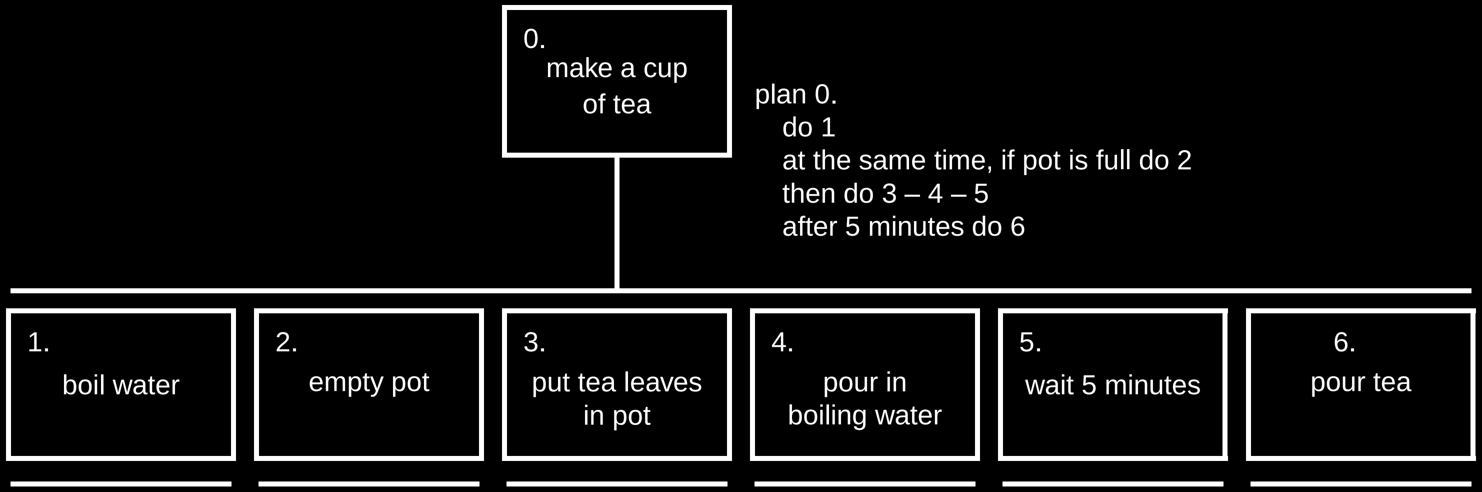
How to know when to stop?

Stopping rules:

- Simplicity: Is the task simple enough?
- Purpose: Is the task relevant?
- Motor Action: lowest sensible level

HTA: Diagrammatic Notation



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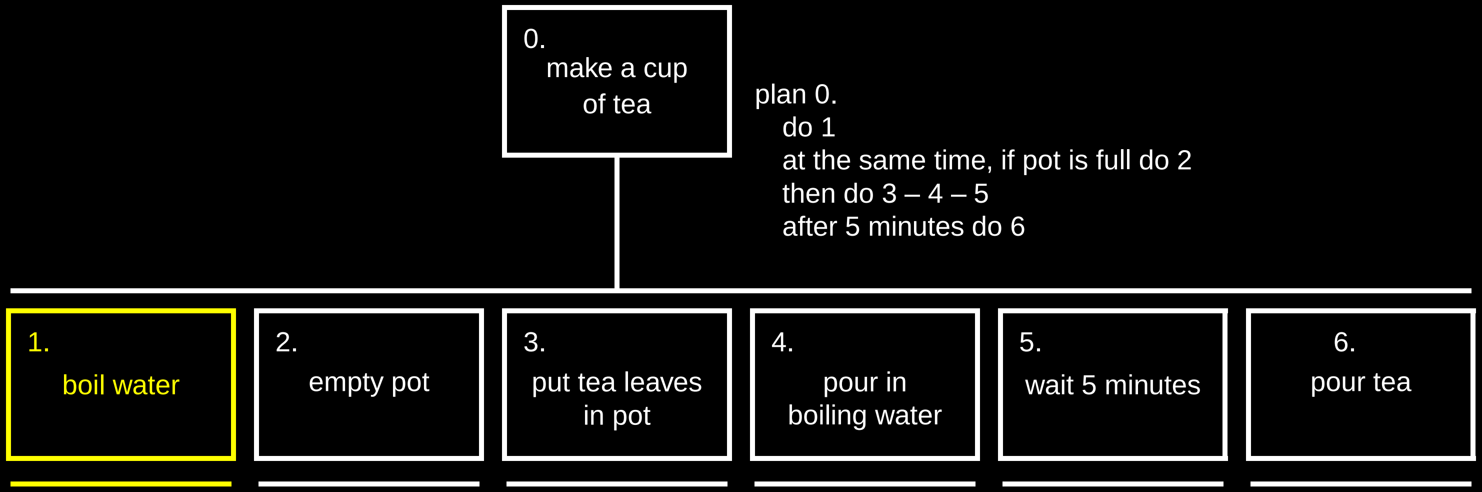
HTA: Decomposition



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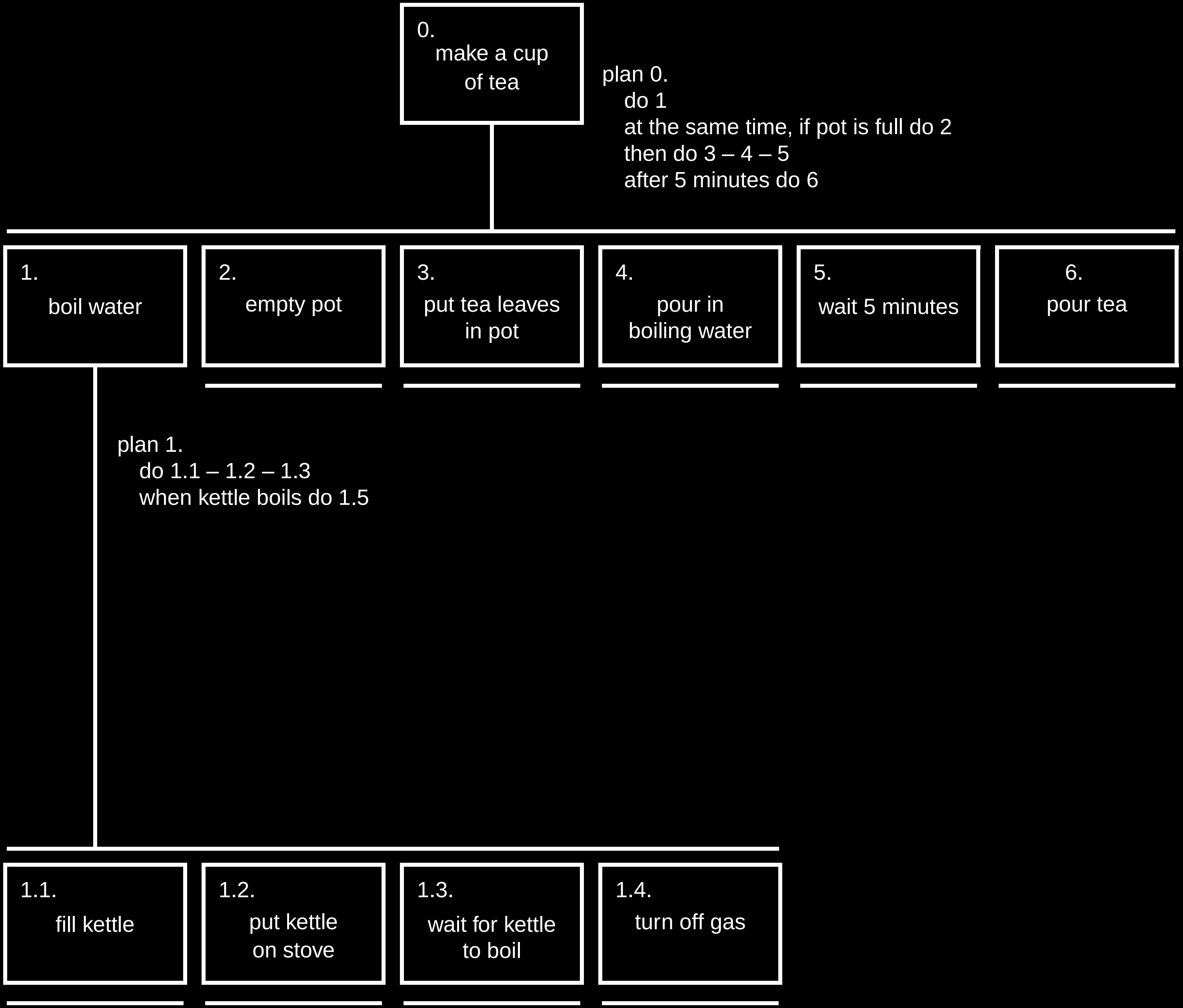

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plan 1.
do 1.1 – 1.2 – 1.3
when kettle boils do 1.5

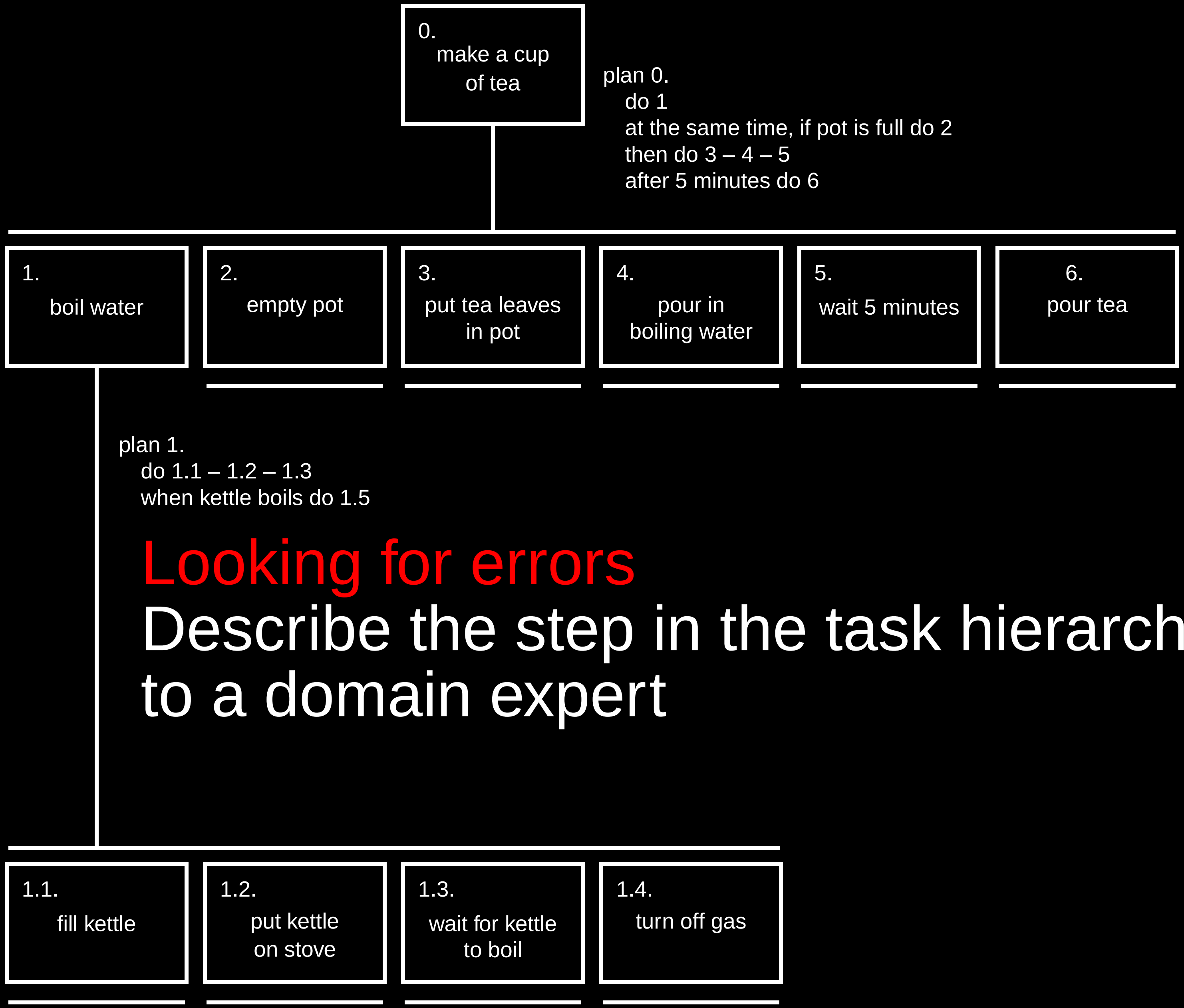
1.1. fill kettle

1.2. put kettle on stove

1.3. wait for kettle to boil

1.4. turn off gas

HTA: Domain Expert



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Looking for errors

Describe the step in the task hierarchy to a domain expert

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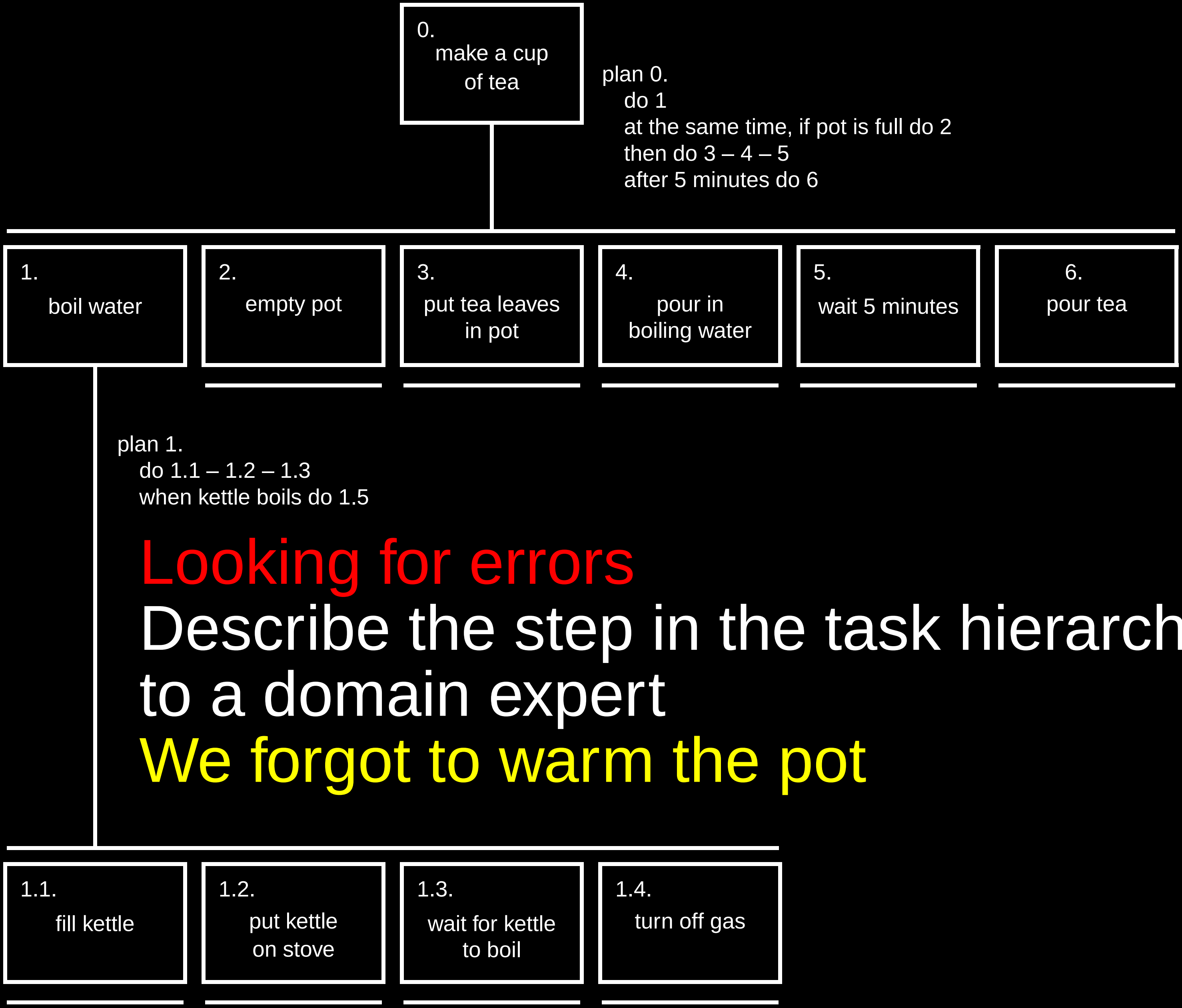

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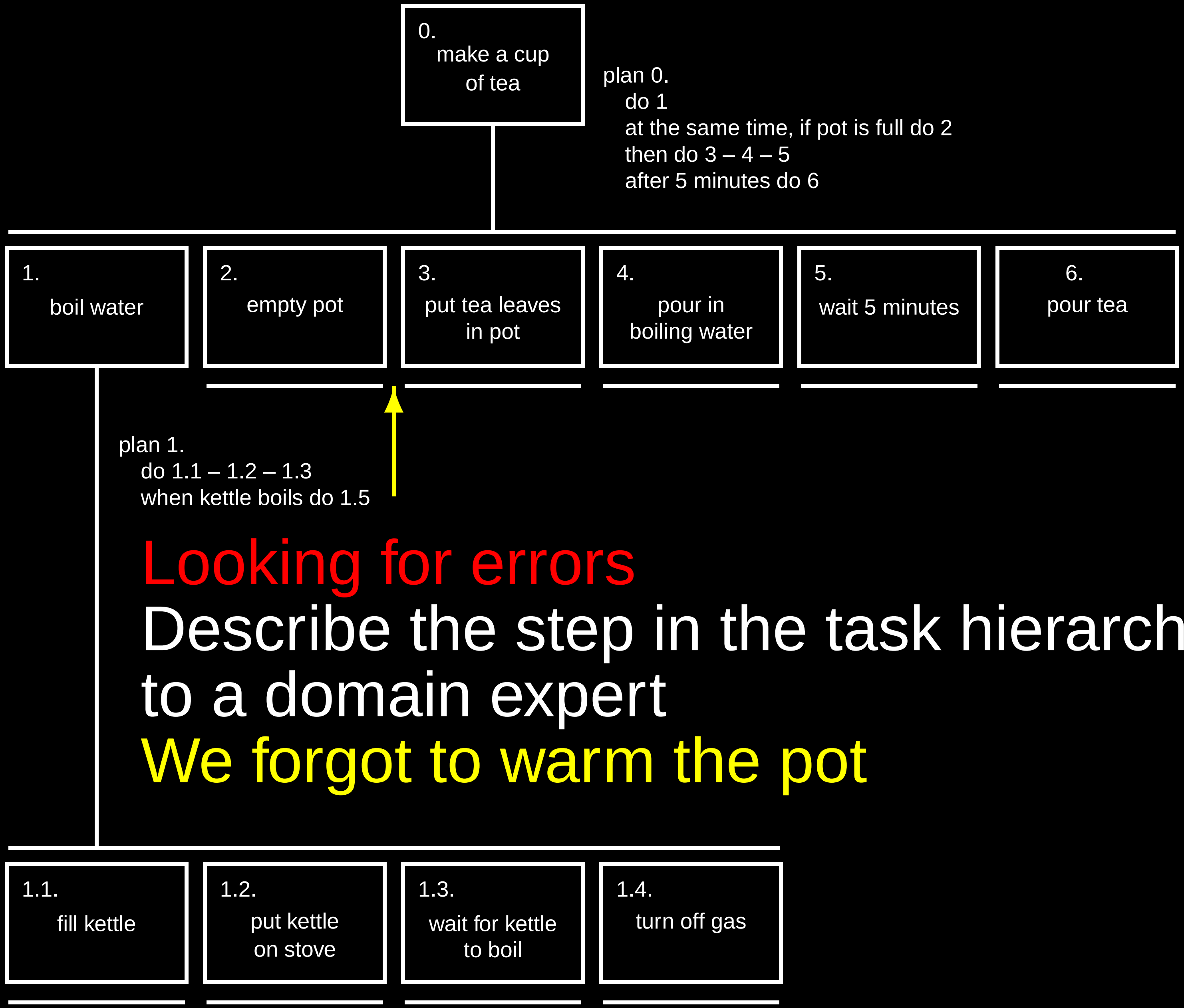
Describe the step in the task hierarchy to a domain expert

We forgot to warm the pot

HTA: Domain Expert



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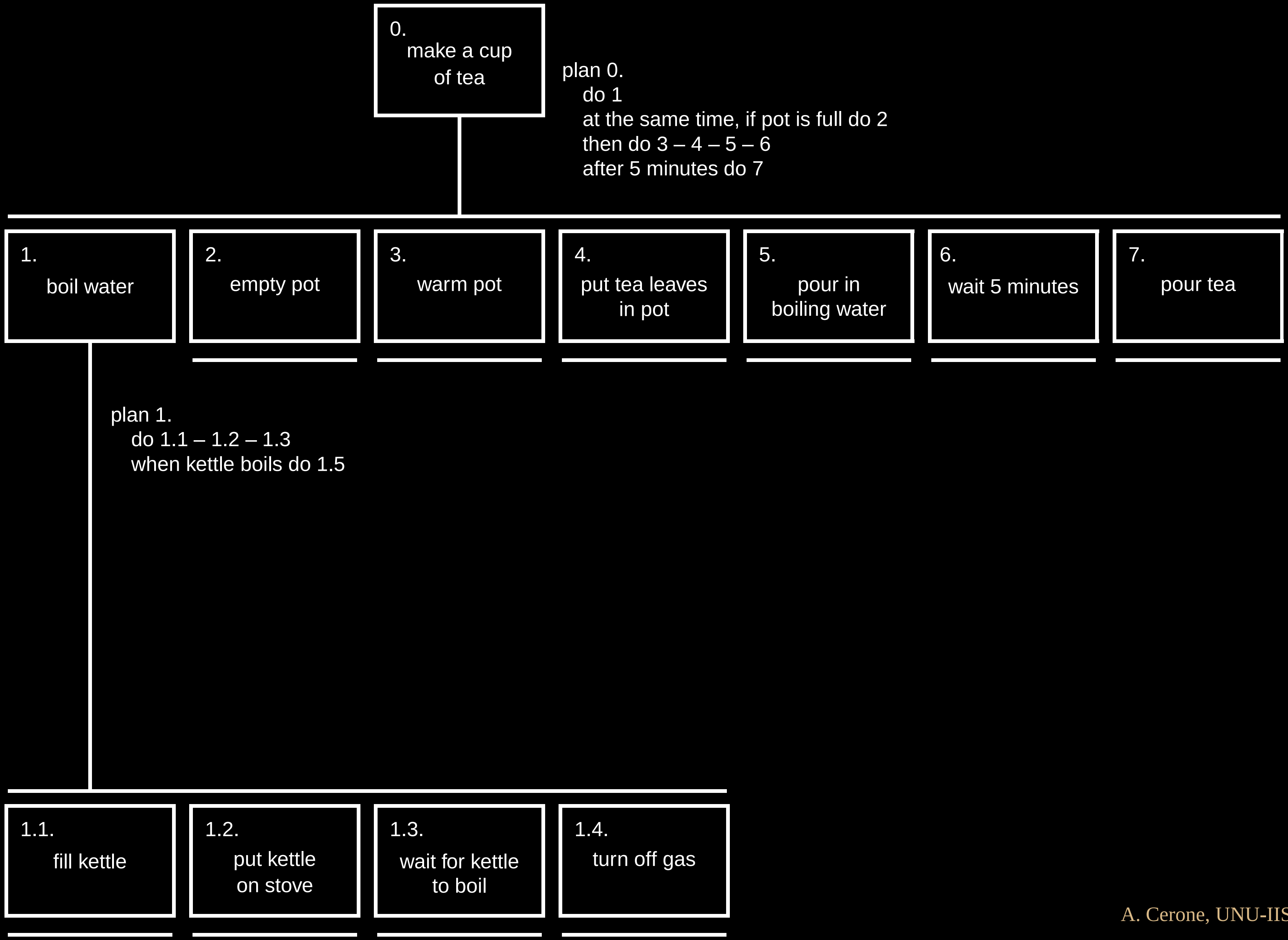
Looking for errors

Describe the step in the task hierarchy to a domain expert

We forgot to warm the pot

HTA: Omissions



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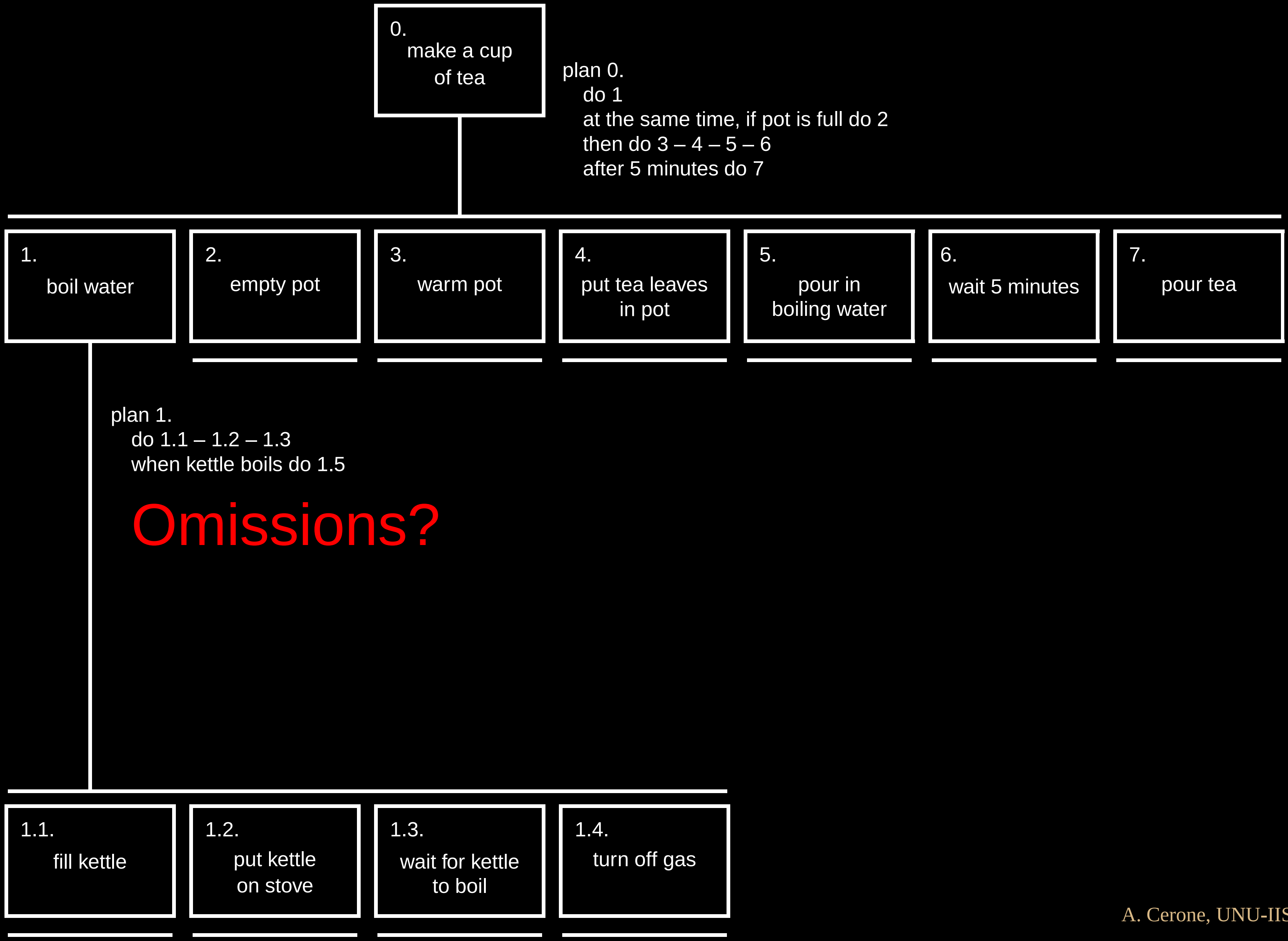

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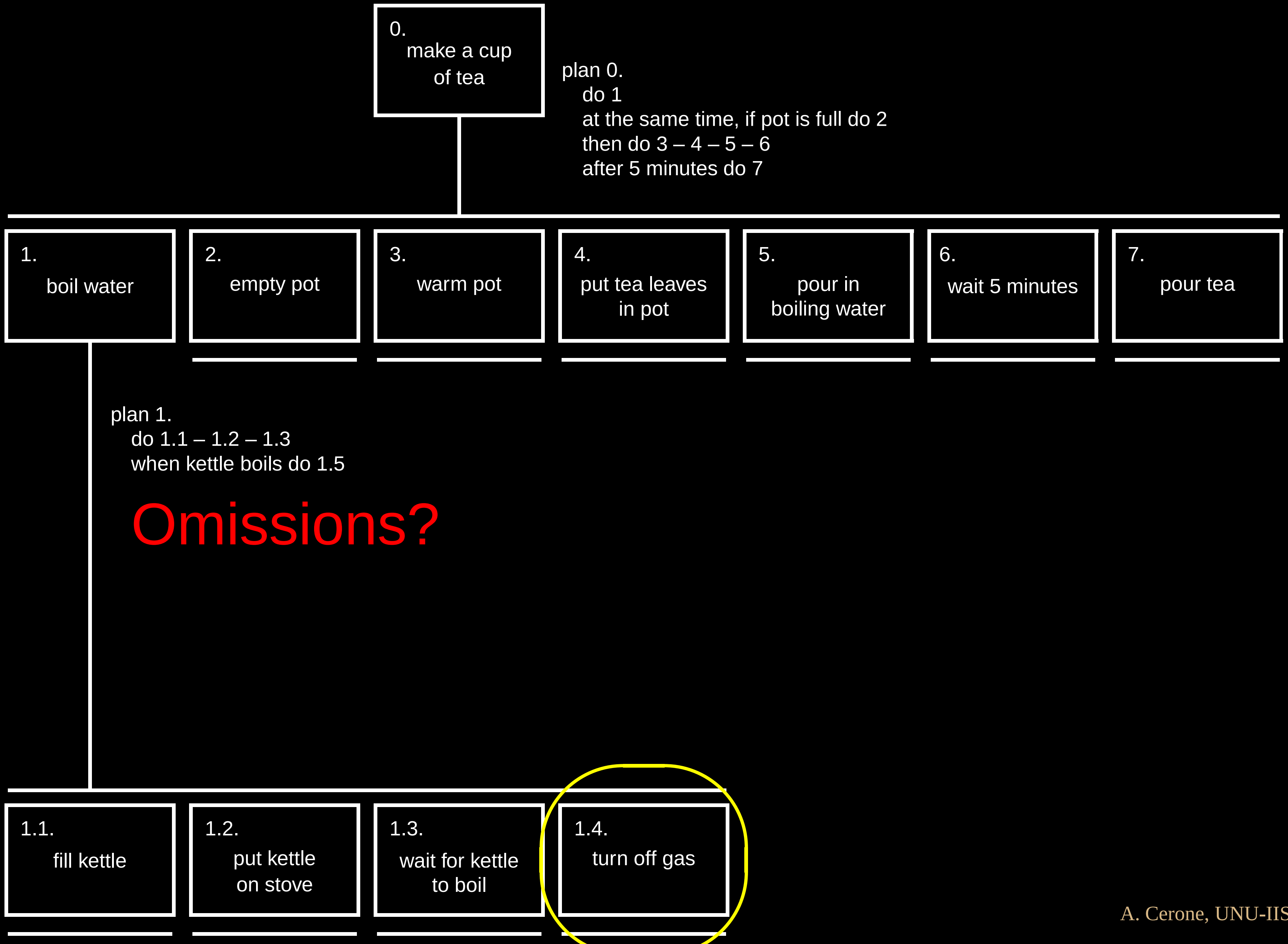

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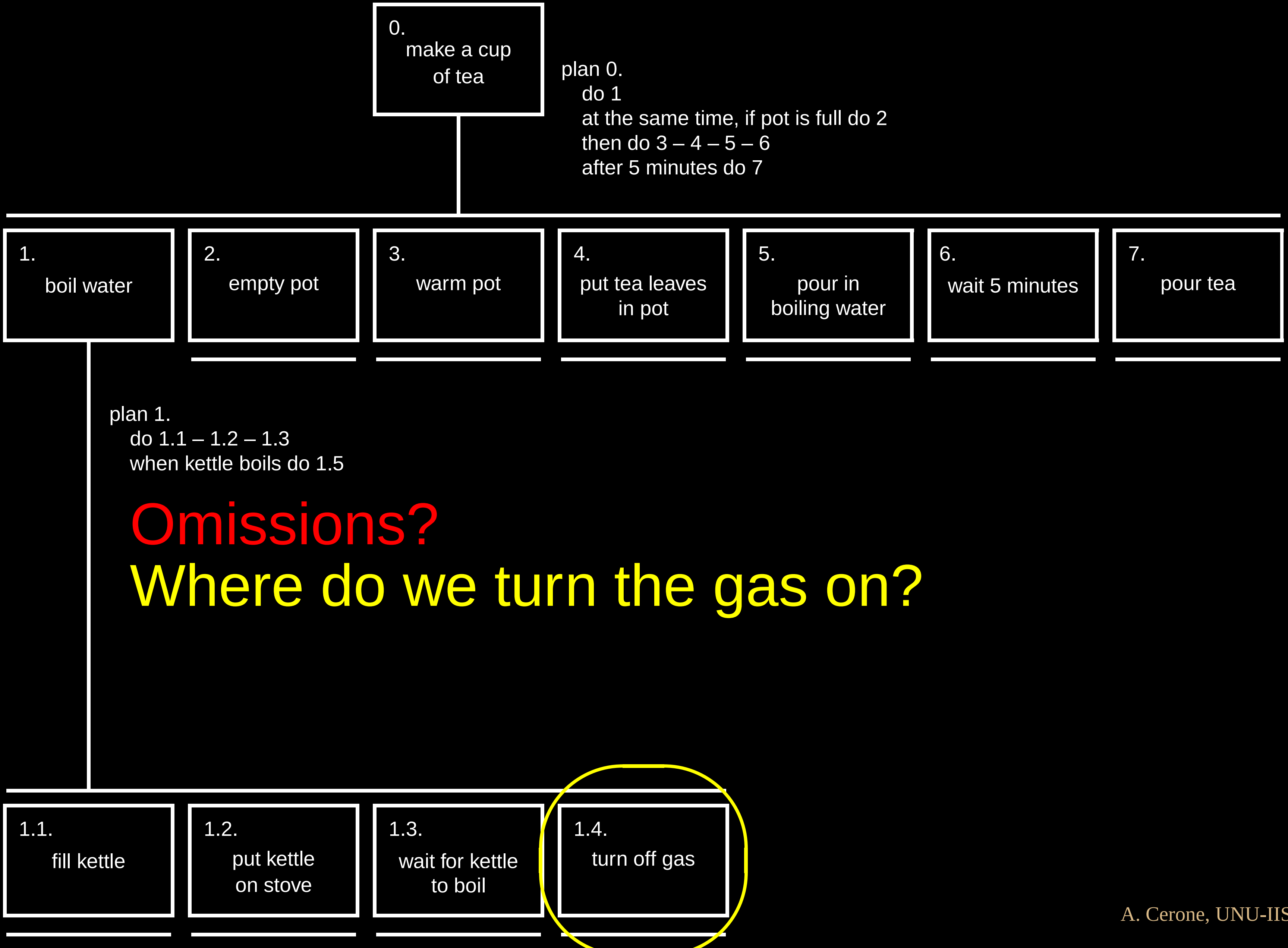

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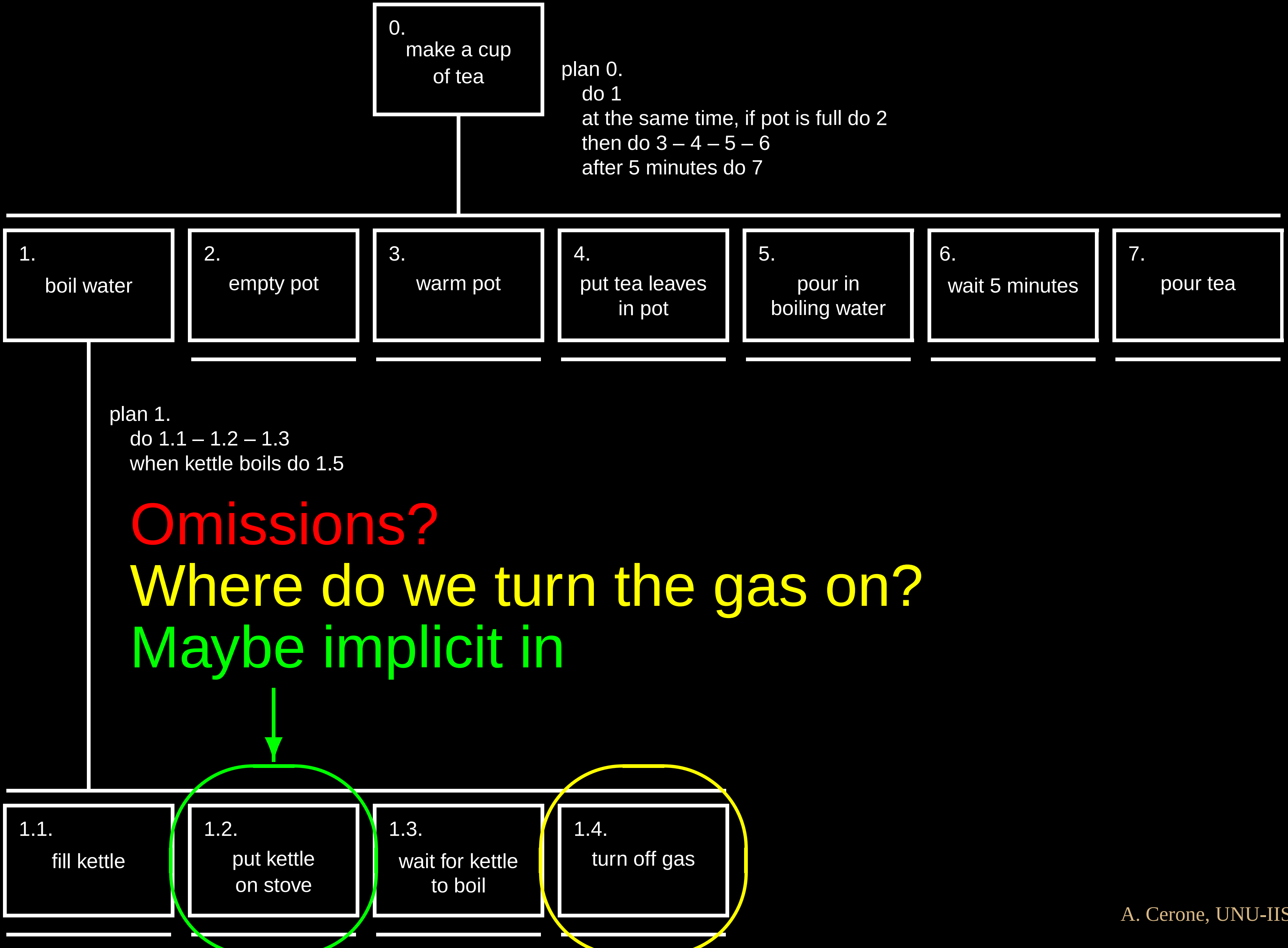
Omissions?

Where do we turn the gas on?

HTA: Omissions



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Omissions?

Where do we turn the gas on?

Maybe implicit in

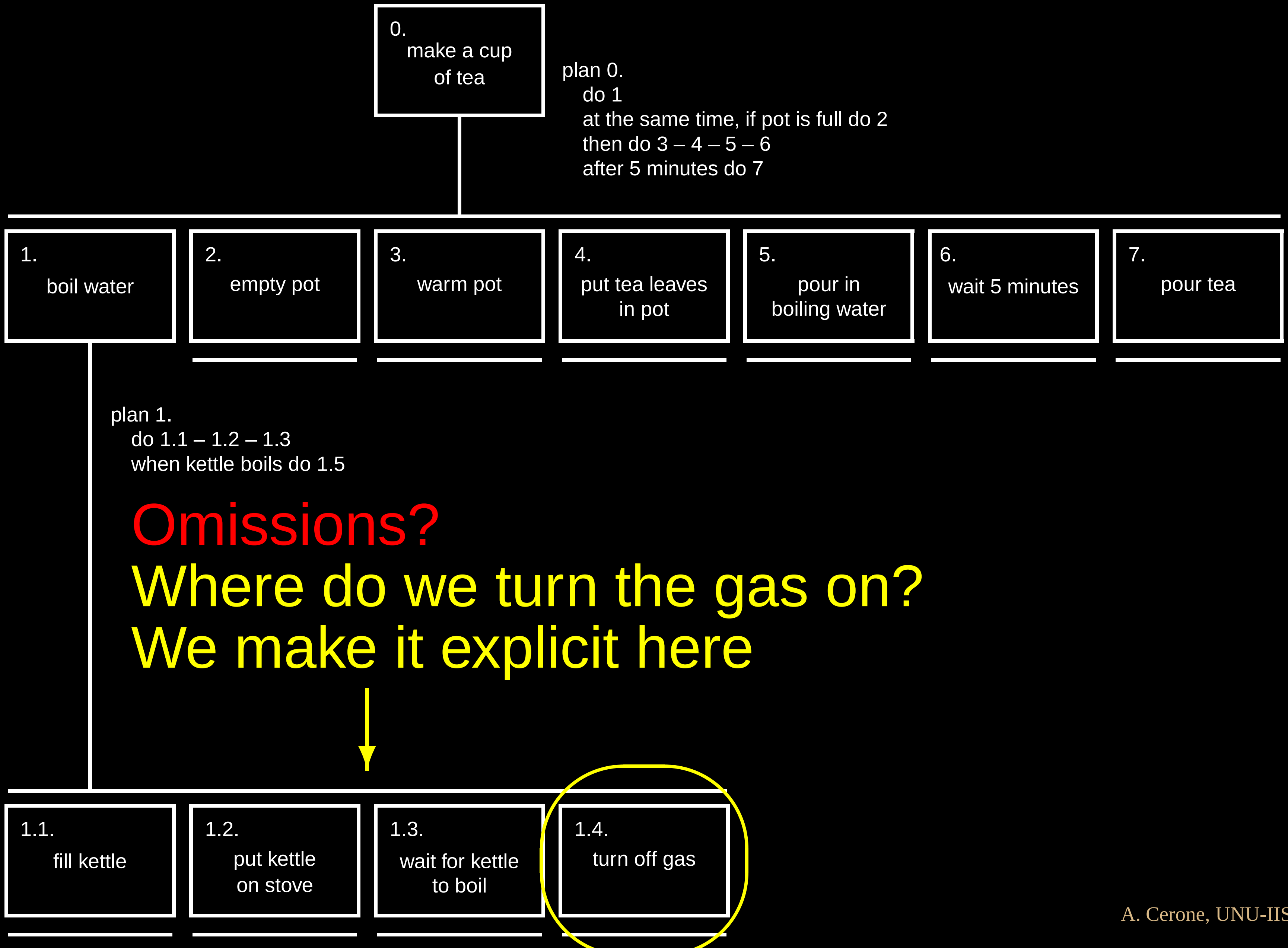
1.1. fill kettle

1.2. put kettle on stove

1.3. wait for kettle to boil

1.4. turn off gas

HTA: Omissions



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Omissions?
Where do we turn the gas on?
We make it explicit here

1.1. fill kettle

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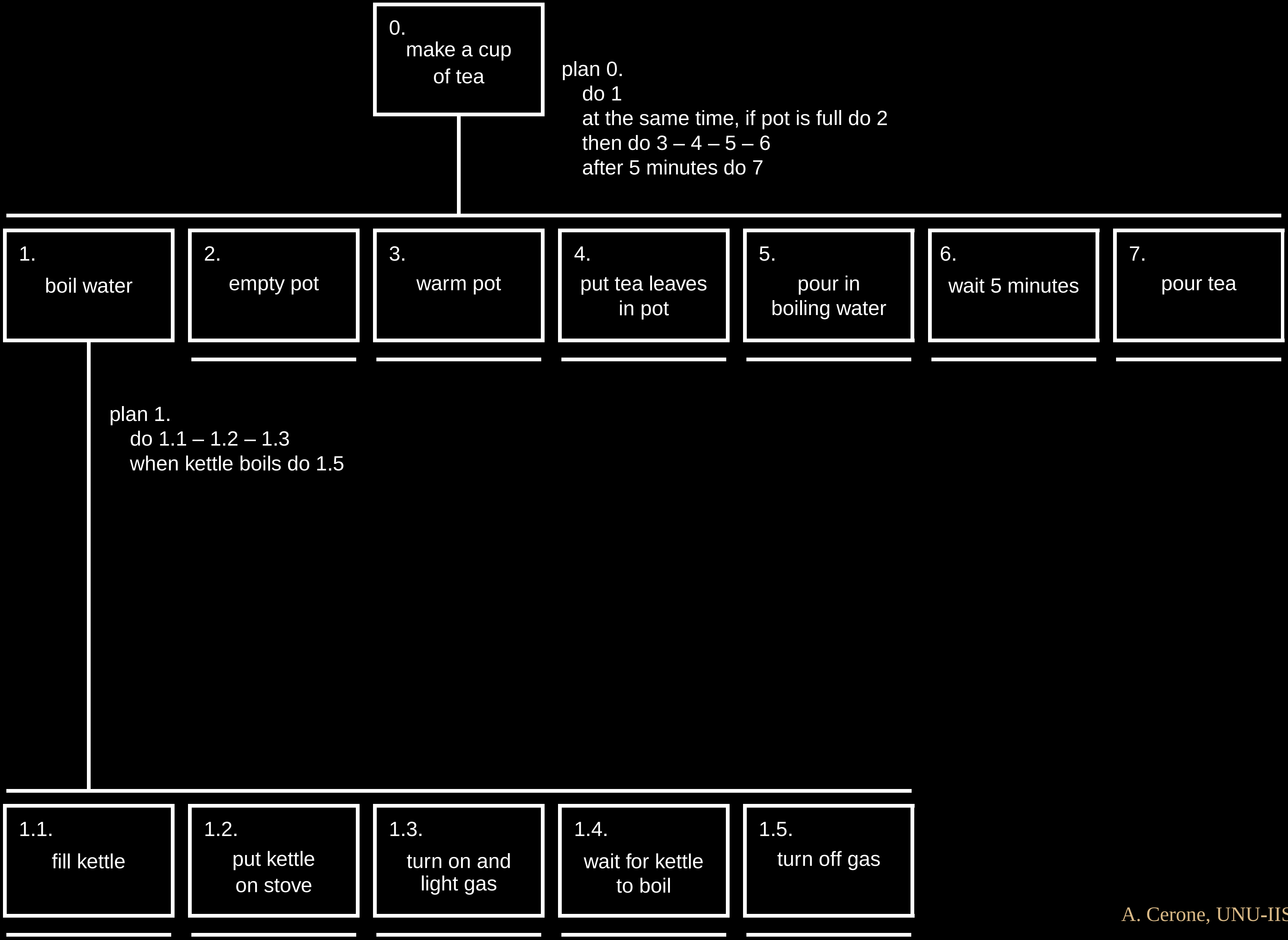
HTA: Umbalanced Hierarchy



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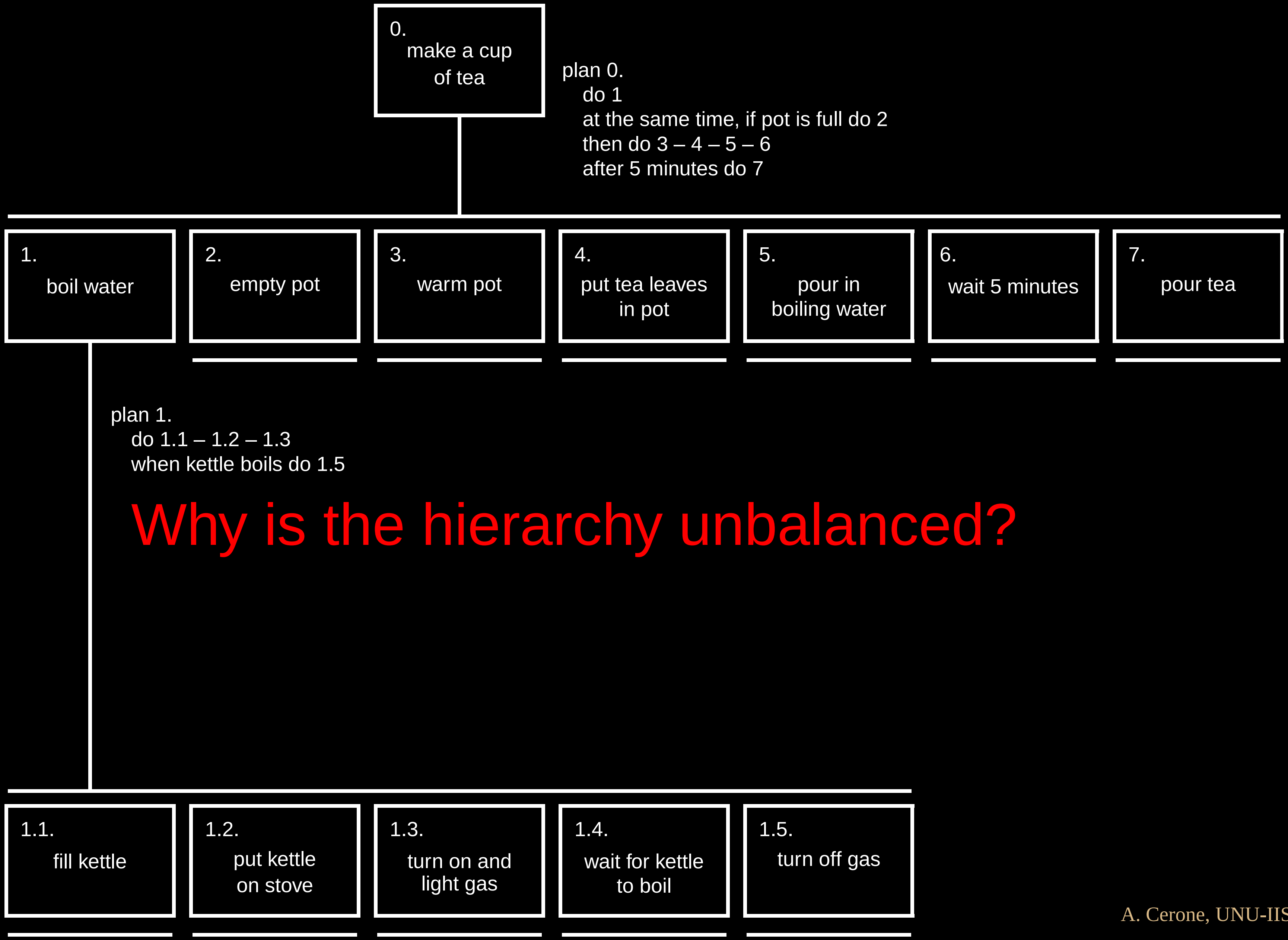

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Why is the hierarchy unbalanced?

1.1. fill kettle

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1.4. wait for kettle to boil

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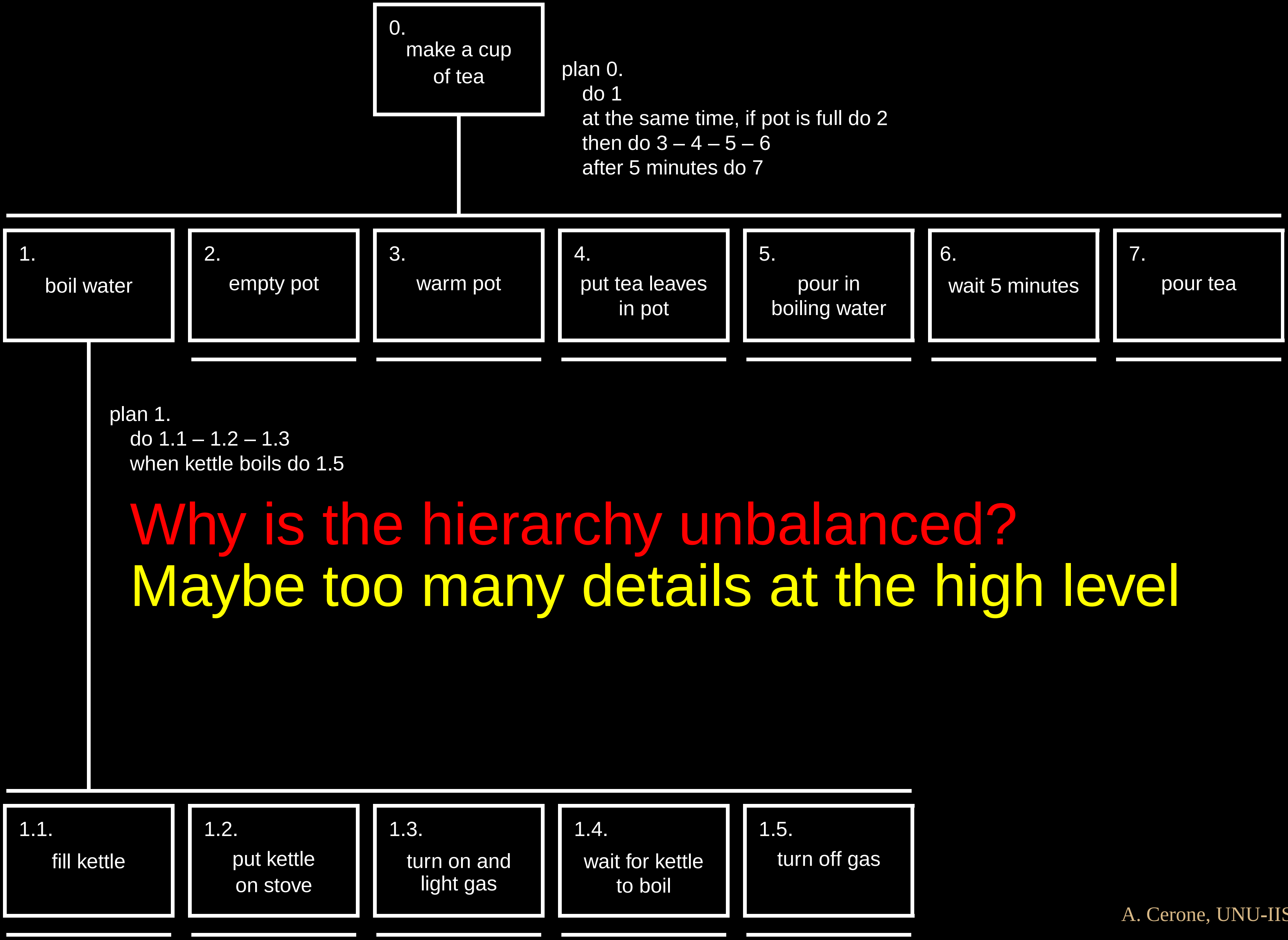

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plan 1.
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when kettle boils do 1.5

Why is the hierarchy unbalanced?

Maybe too many details at the high level

1.1. fill kettle

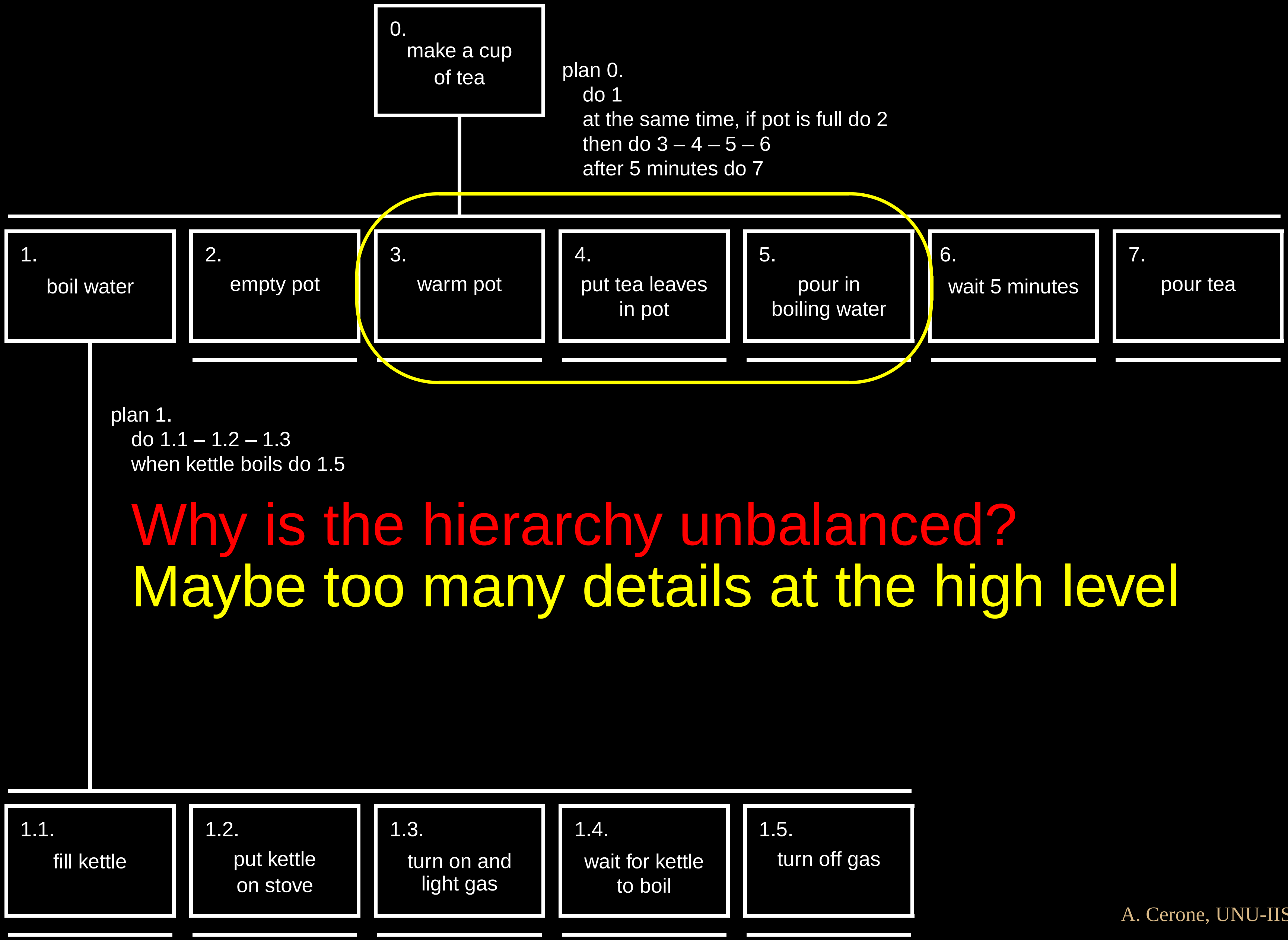
1.2. put kettle on stove

1.3. turn on and light gas

1.4. wait for kettle to boil

1.5. turn off gas

HTA: Umbalanced Hierarchy



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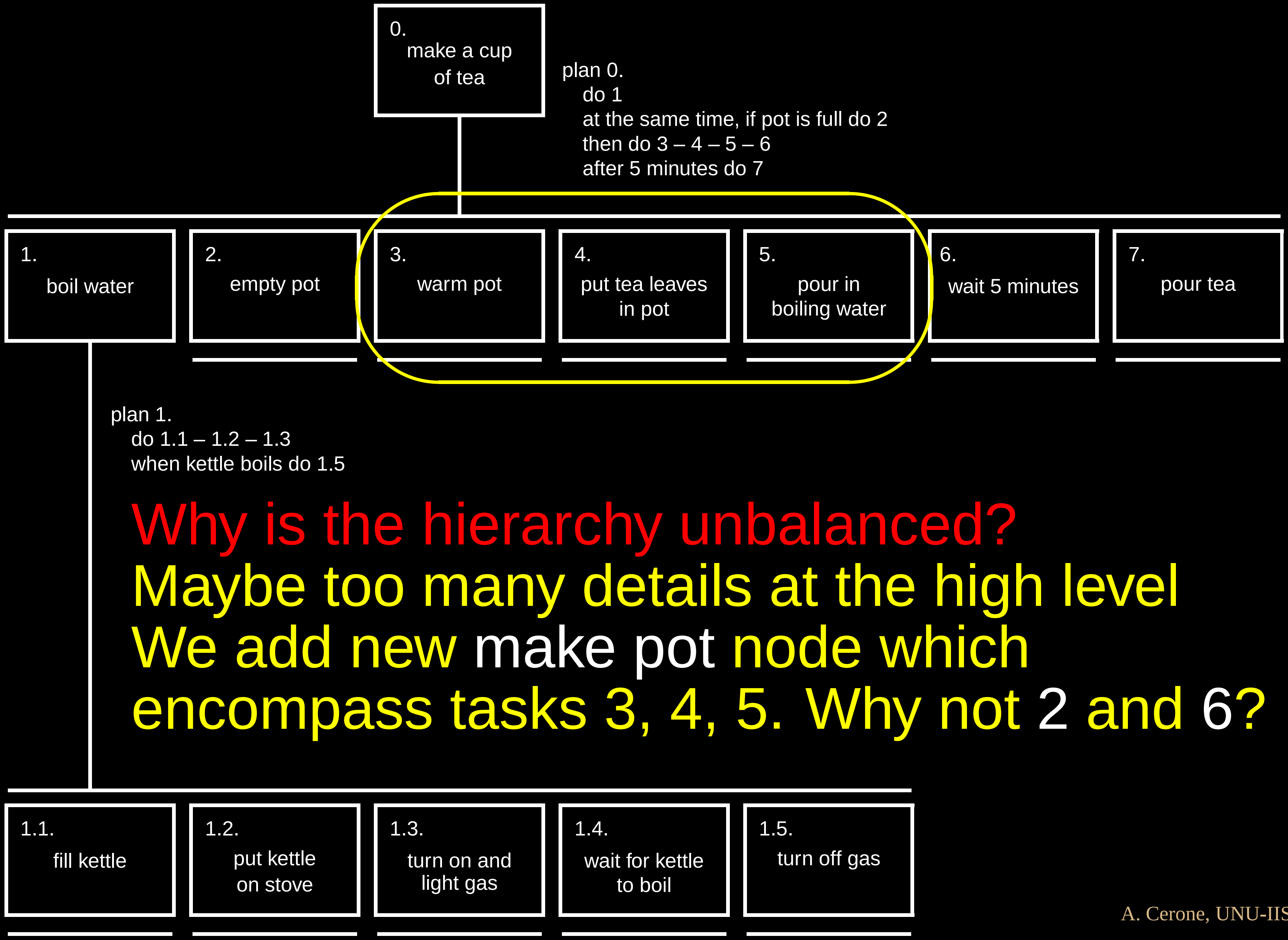

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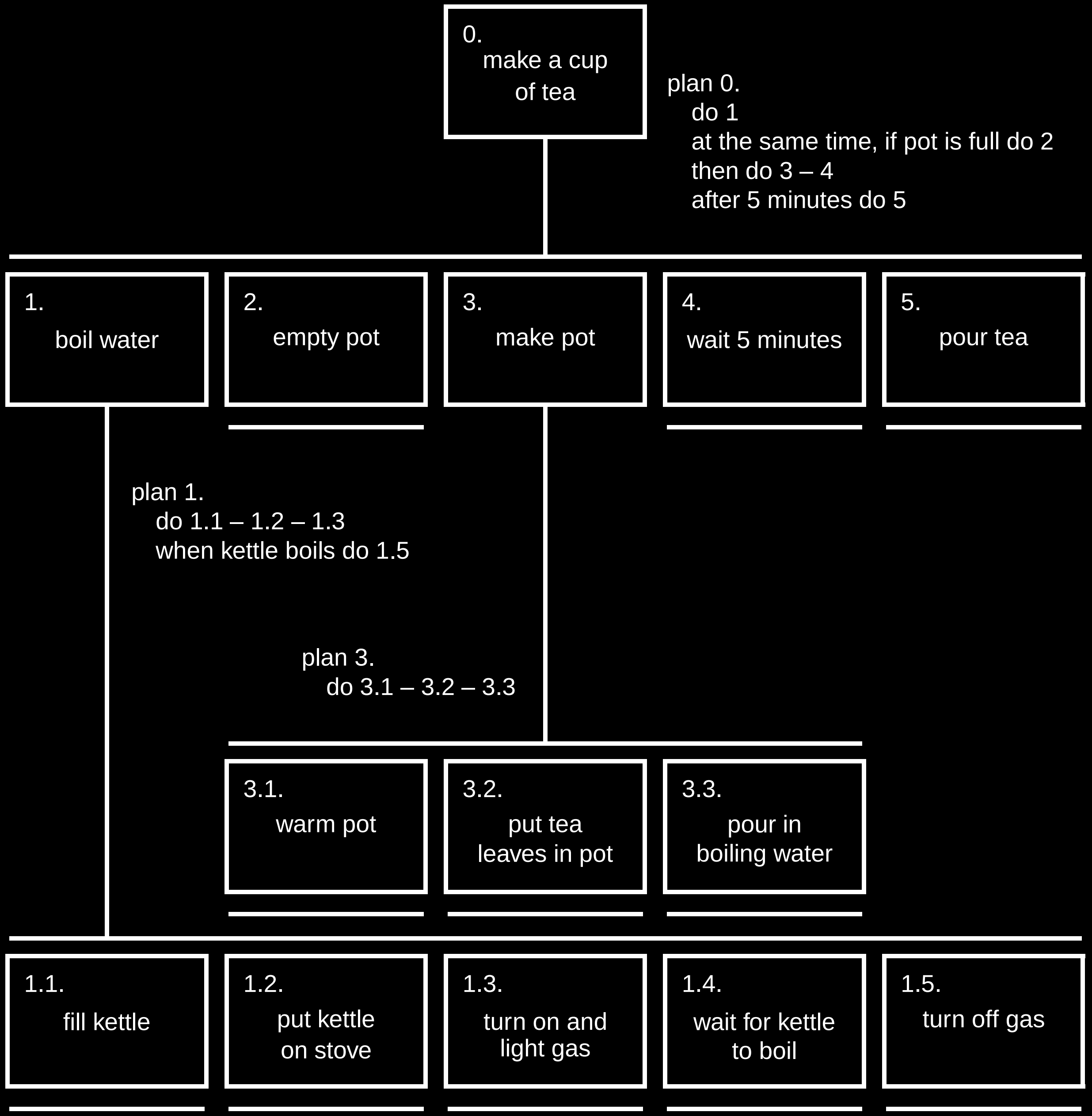
Why is the hierarchy unbalanced?
Maybe too many details at the high level
We add new make pot node which
encompass tasks 3, 4, 5. Why not 2 and 6?

HTA: Further Decompositions



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plan 1.
do 1.1 – 1.2 – 1.3
when kettle boils do 1.5

plan 3.
do 3.1 – 3.2 – 3.3

3.1. warm pot

3.2. put tea leaves in pot

3.3. pour in boiling water

1.1. fill kettle

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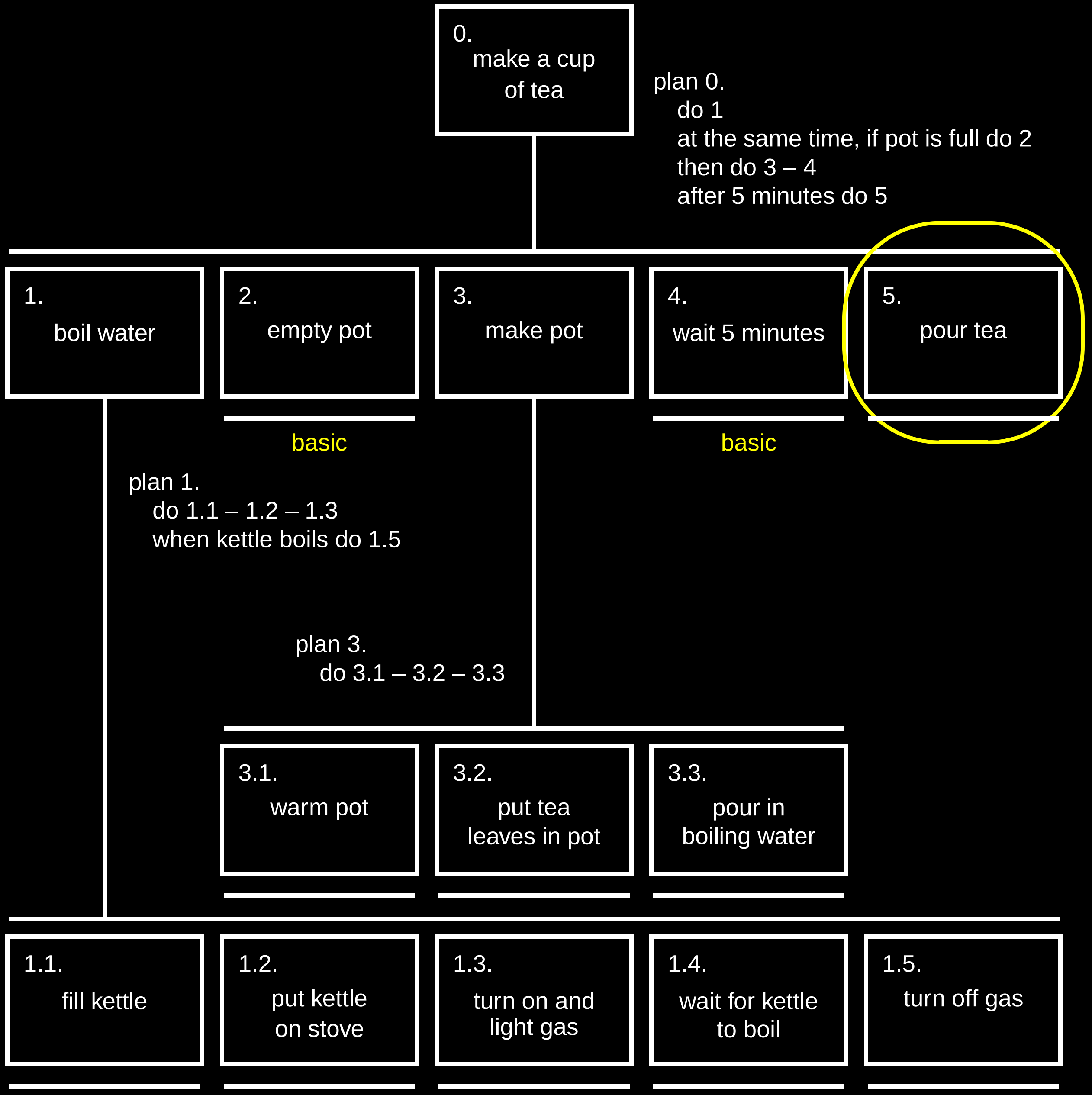

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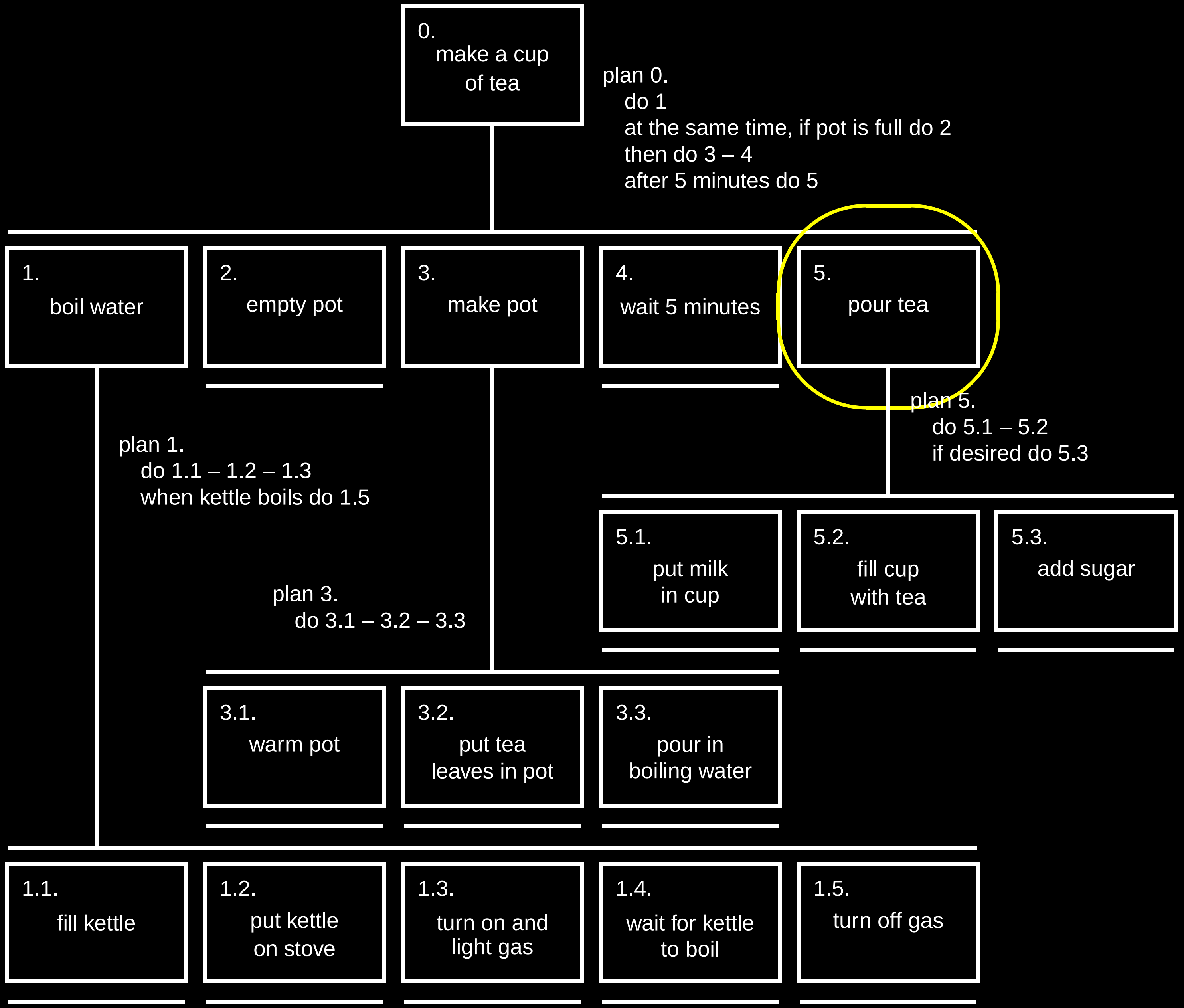

plan 0.
do 1
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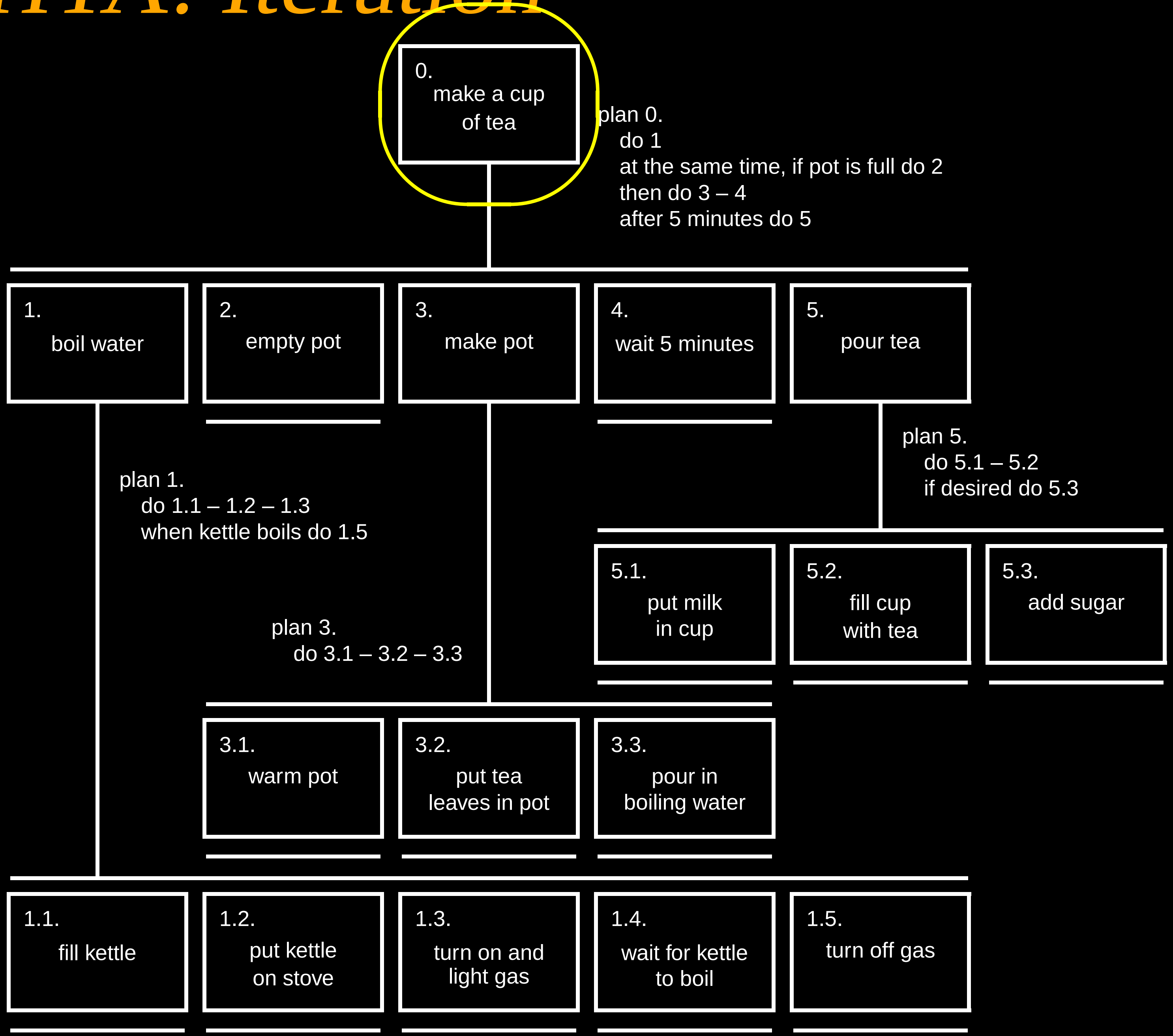
then do 3 – 4
after 5 minutes do 5

plan 5.
do 5.1 – 5.2
if desired do 5.3

plan 1.
do 1.1 – 1.2 – 1.3
when kettle boils do 1.5

plan 3.
do 3.1 – 3.2 – 3.3

HTA: Iteration



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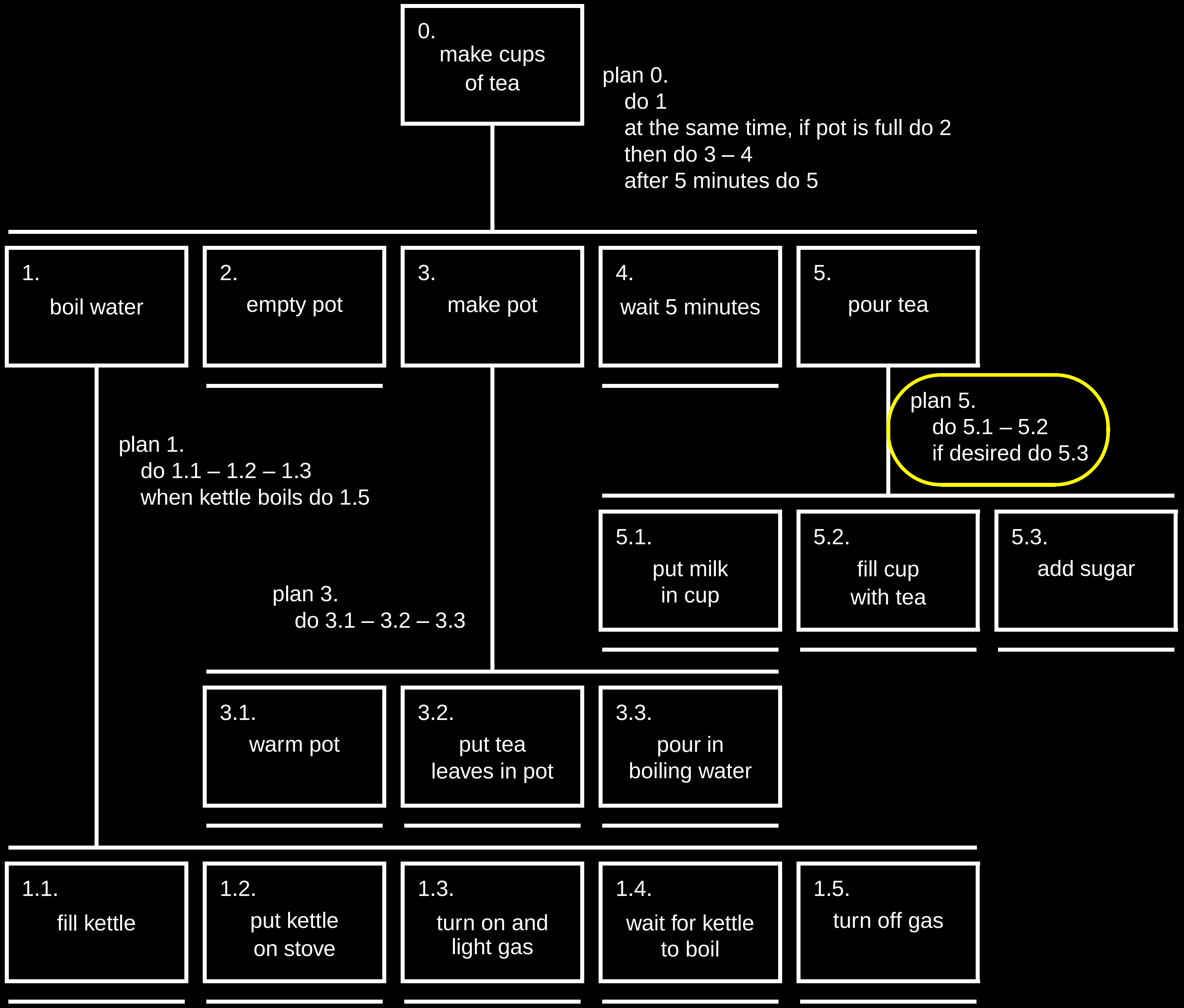

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5. pour tea

plan 5.
do 5.1 – 5.2
if desired do 5.3

plan 1.
do 1.1 – 1.2 – 1.3
when kettle boils do 1.5

5.1. put milk in cup

5.2. fill cup with tea

5.3. add sugar

plan 3.
do 3.1 – 3.2 – 3.3

3.1. warm pot

3.2. put tea leaves in pot

3.3. pour in boiling water

1.1. fill kettle

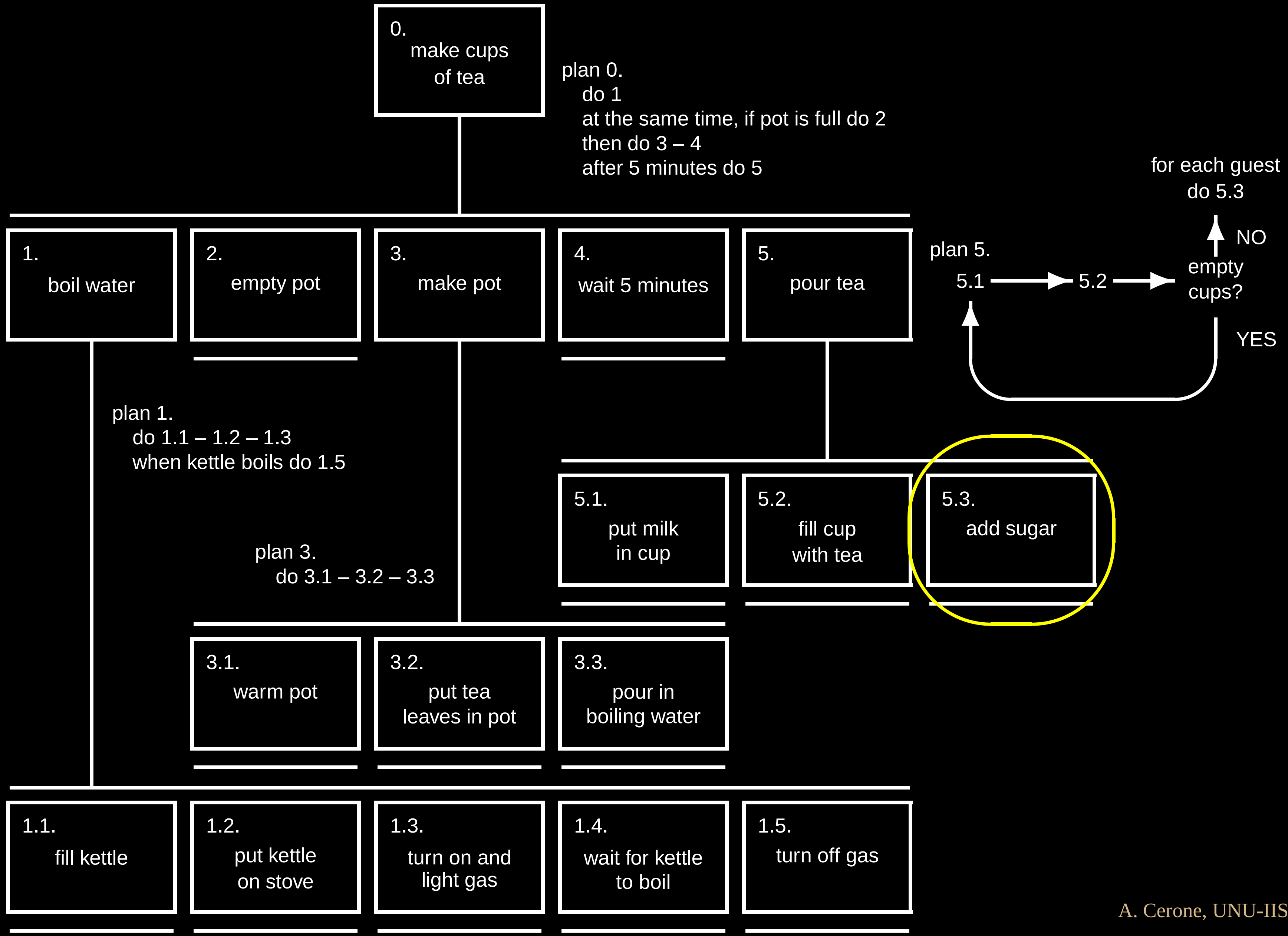
1.2. put kettle on stove

1.3. turn on and light gas

1.4. wait for kettle to boil

1.5. turn off gas

HTA: Iteration



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1. boil water

2. empty pot

3. make pot

4. wait 5 minutes

5. pour tea

plan 5.
5.1 → 5.2 → empty cups?
NO → for each guest do 5.3
YES → 5.1

plan 1.
do 1.1 – 1.2 – 1.3
when kettle boils do 1.5

5.1. put milk in cup

5.2. fill cup with tea

5.3. add sugar

plan 3.
do 3.1 – 3.2 – 3.3

3.1. warm pot

3.2. put tea leaves in pot

3.3. pour in boiling water

1.1. fill kettle

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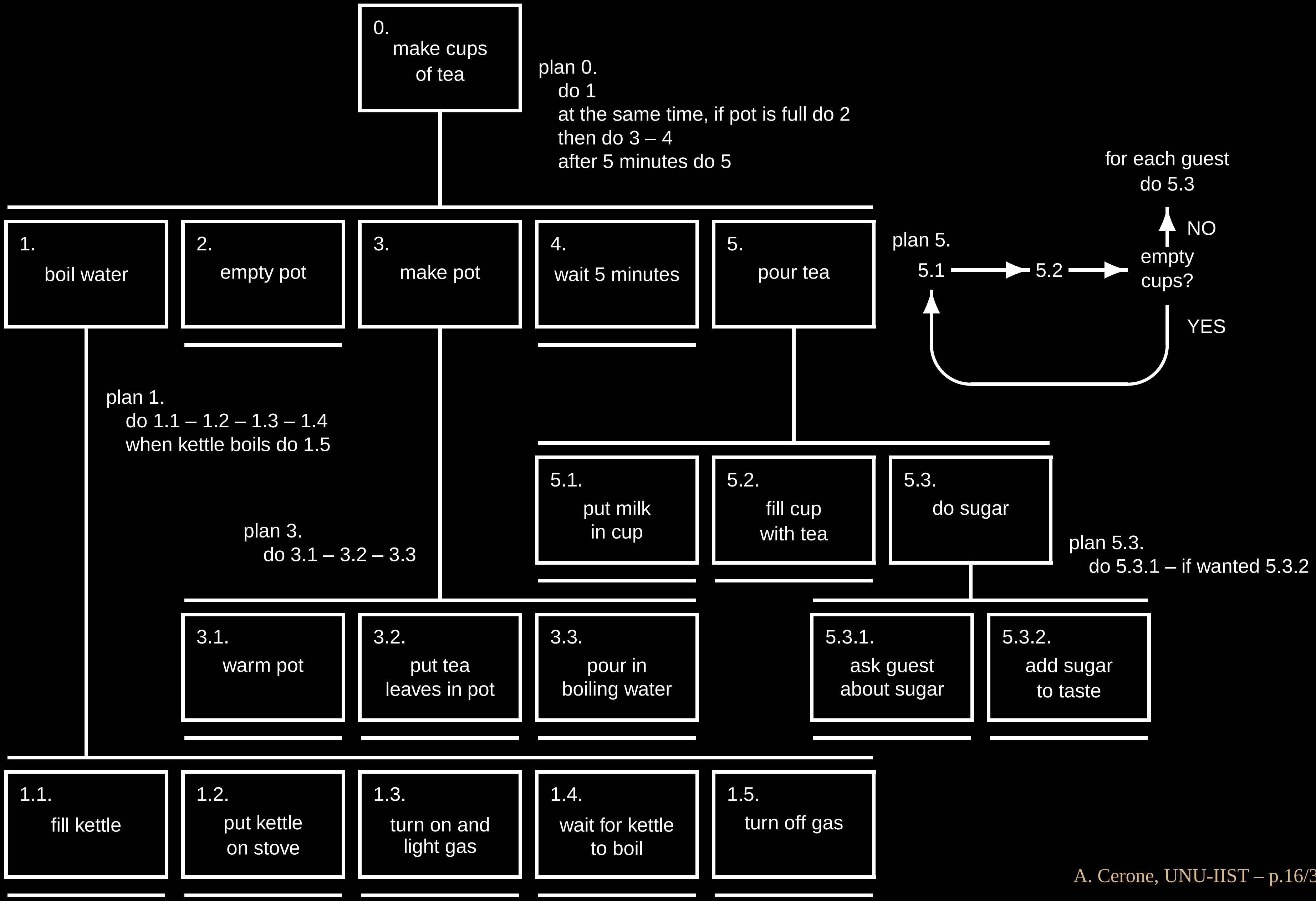
HTA: Final Decomposition



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after 5 minutes do 5

1. boil water

2. empty pot

3. make pot

4. wait 5 minutes

5. pour tea

plan 5.
5.1 → 5.2 → empty cups?
NO → for each guest do 5.3
YES → 5.1

plan 1.
do 1.1 – 1.2 – 1.3 – 1.4
when kettle boils do 1.5

5.1. put milk in cup

5.2. fill cup with tea

5.3. do sugar

plan 3.
do 3.1 – 3.2 – 3.3

plan 5.3.
do 5.3.1 – if wanted 5.3.2

3.1. warm pot

3.2. put tea leaves in pot

3.3. pour in boiling water

5.3.1. ask guest about sugar

5.3.2. add sugar to taste

1.1. fill kettle

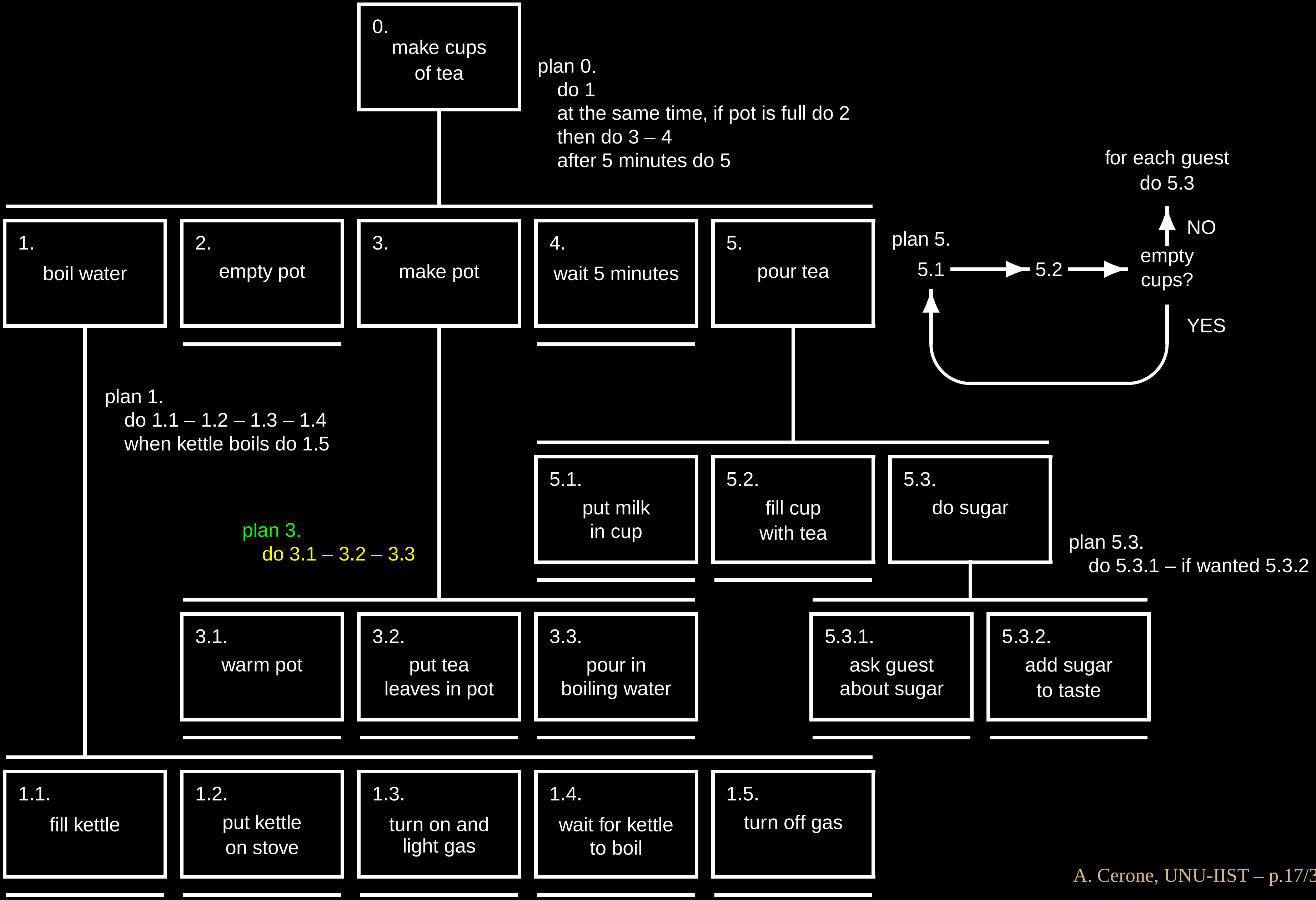
1.2. put kettle on stove

1.3. turn on and light gas

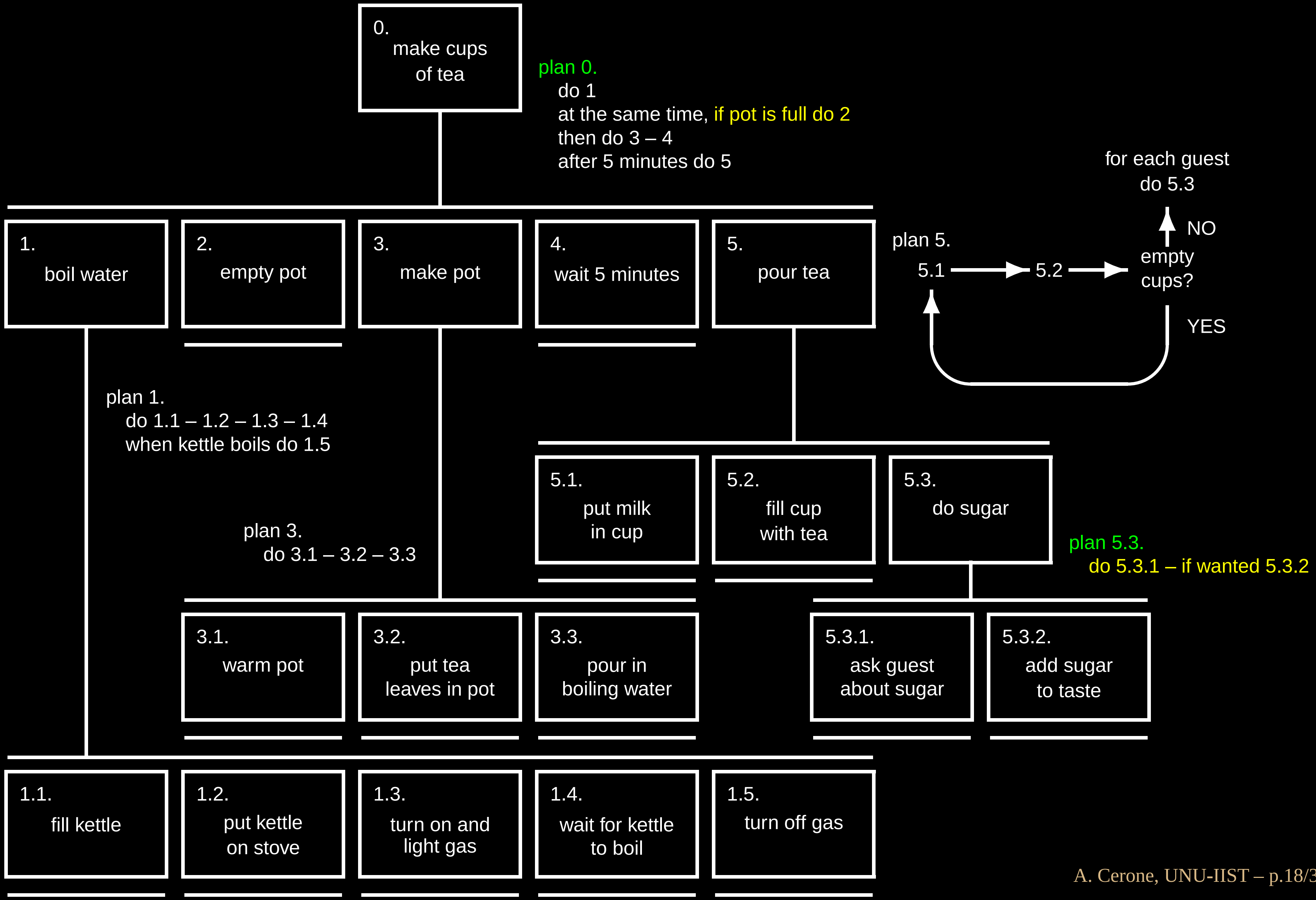
1.4. wait for kettle to boil

1.5. turn off gas

HTA: Fixed Sequence



HTA: Optional Tasks



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1.
boil water

2.
empty pot

3.
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4.
wait 5 minutes

5.
pour tea

plan 5.
5.1 → 5.2 → empty cups?
NO
for each guest do 5.3
YES

plan 1.
do 1.1 – 1.2 – 1.3 – 1.4
when kettle boils do 1.5

plan 3.
do 3.1 – 3.2 – 3.3

5.1.
put milk in cup

5.2.
fill cup with tea

5.3.
do sugar

plan 5.3.
do 5.3.1 – if wanted 5.3.2

3.1.
warm pot

3.2.
put tea leaves in pot

3.3.
pour in boiling water

5.3.1.
ask guest about sugar

5.3.2.
add sugar to taste

1.1.
fill kettle

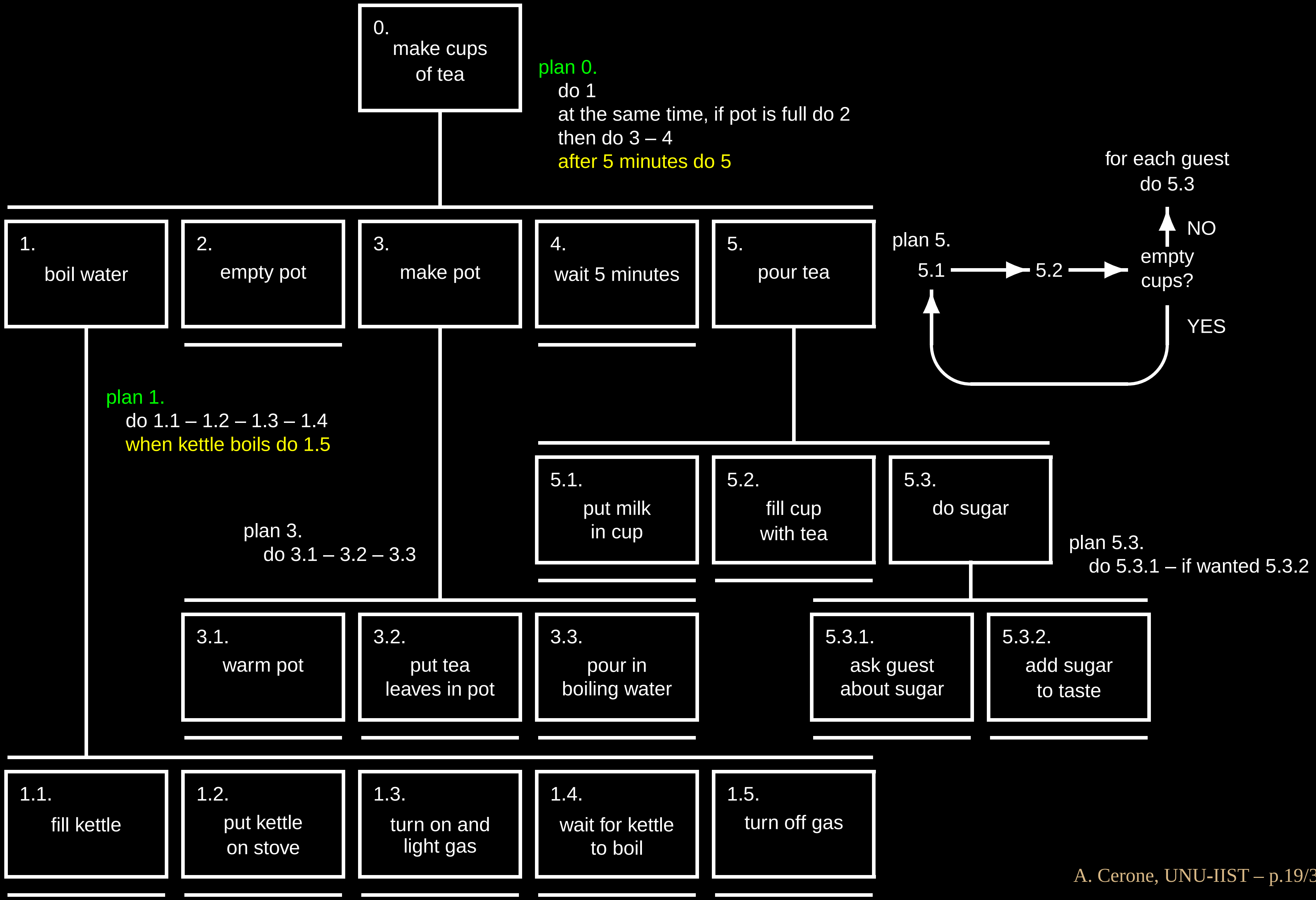
1.2.
put kettle on stove

1.3.
turn on and light gas

1.4.
wait for kettle to boil

1.5.
turn off gas

HTA: Waiting for Events



0. make cups of tea

plan 0.
do 1
at the same time, if pot is full do 2
then do 3 – 4
after 5 minutes do 5

1. boil water

2. empty pot

3. make pot

4. wait 5 minutes

5. pour tea

plan 5.
5.1 → 5.2 → empty cups?
NO → for each guest do 5.3
YES → 5.1

plan 1.
do 1.1 – 1.2 – 1.3 – 1.4
when kettle boils do 1.5

5.1. put milk in cup

5.2. fill cup with tea

5.3. do sugar

plan 3.
do 3.1 – 3.2 – 3.3

plan 5.3.
do 5.3.1 – if wanted 5.3.2

3.1. warm pot

3.2. put tea leaves in pot

3.3. pour in boiling water

5.3.1. ask guest about sugar

5.3.2. add sugar to taste

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1.2. put kettle on stove

1.3. turn on and light gas

1.4. wait for kettle to boil

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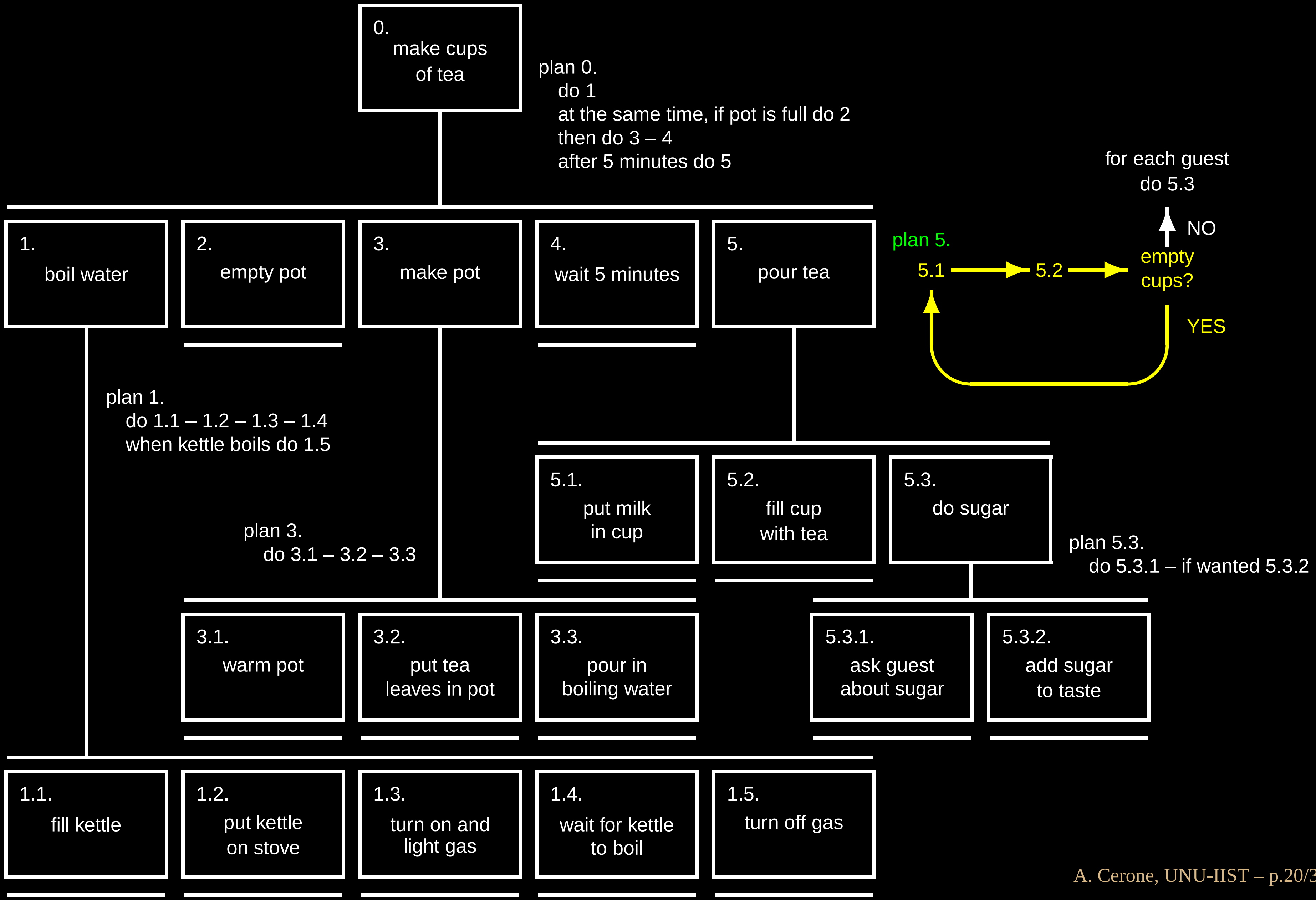
HTA: Cycles



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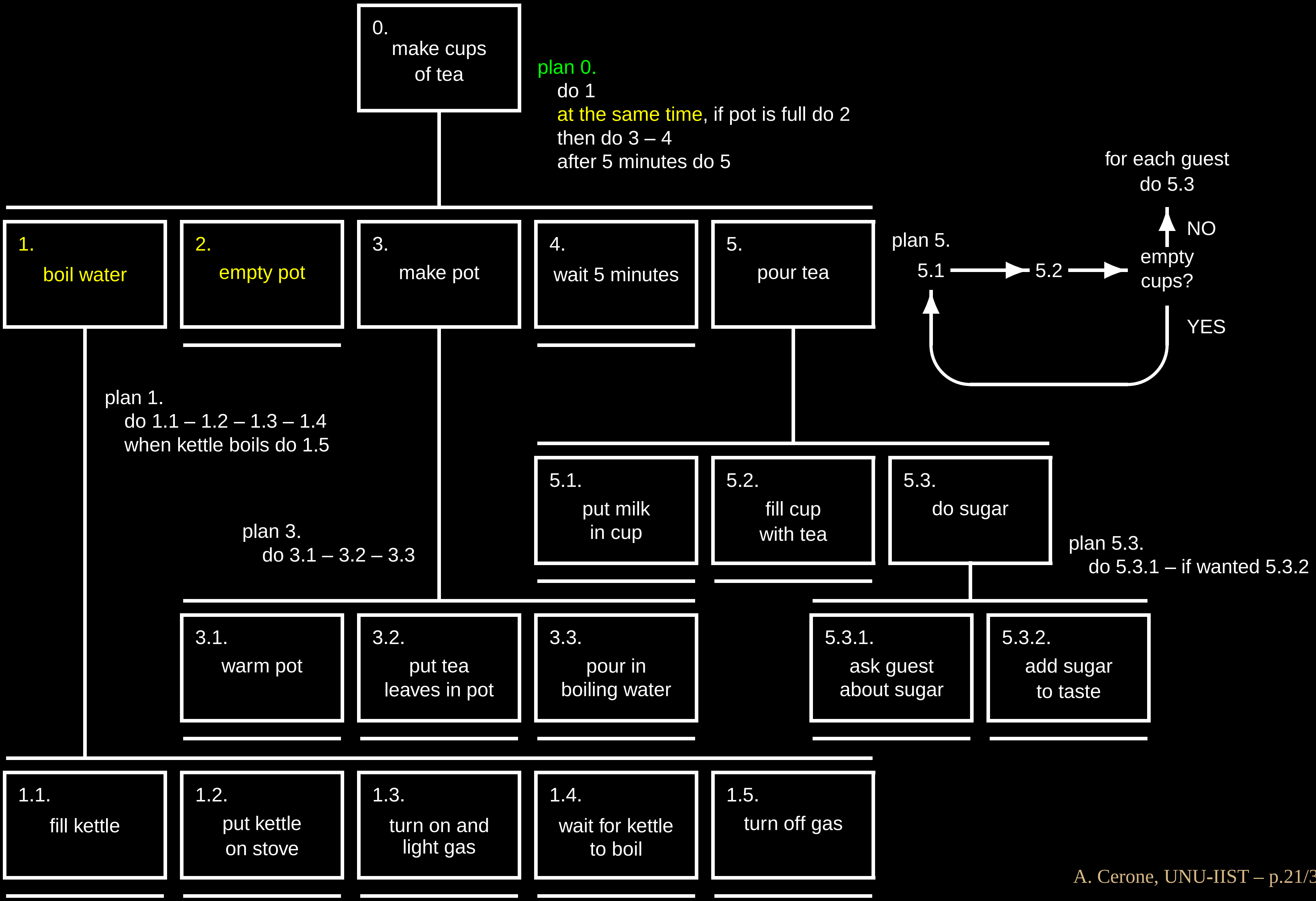
HTA: Time-sharing



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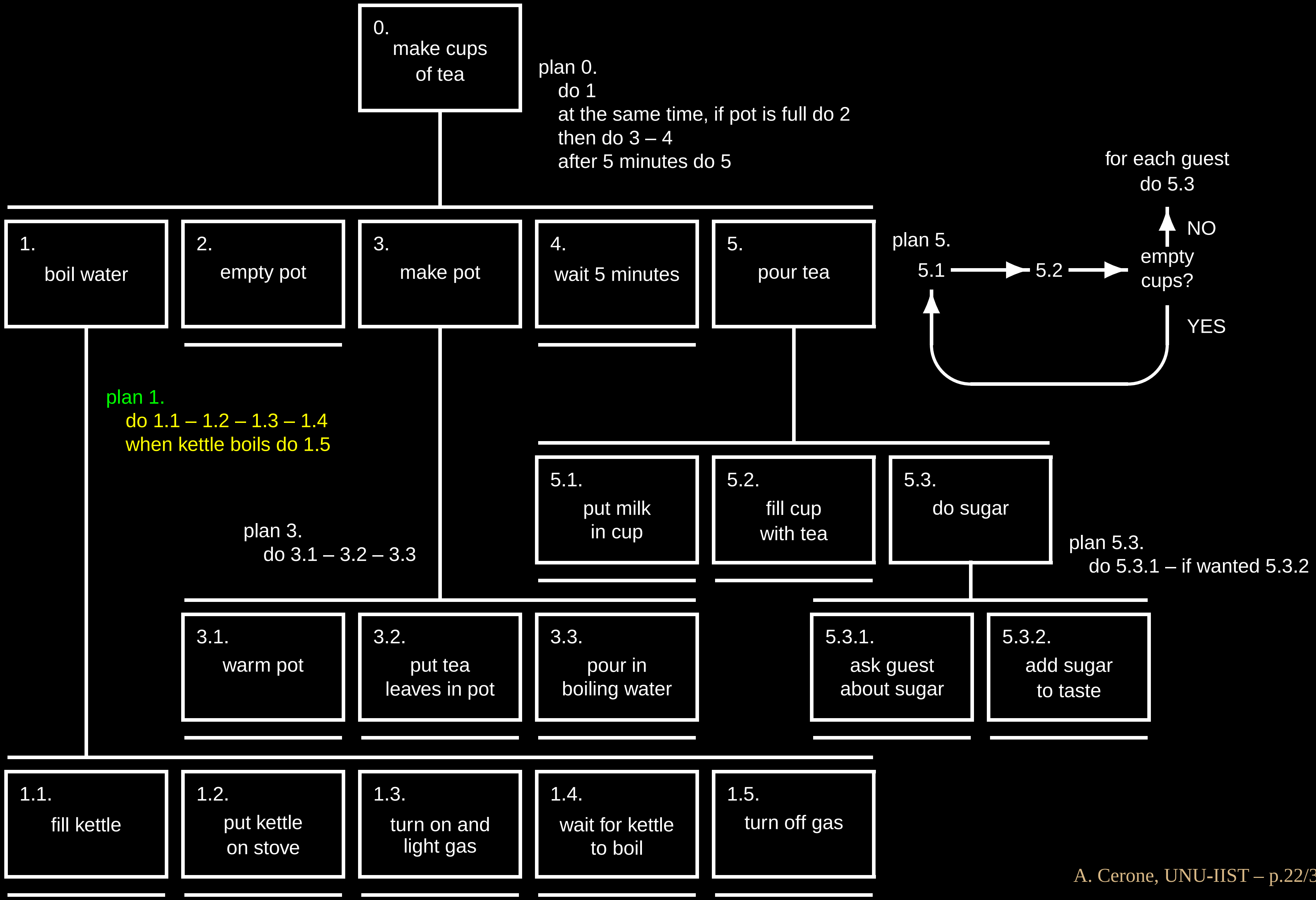
HTA: Mixtures



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Decomposition Heuristics

- paired actions
  e.g., turn on and turn on gas
- restructure/balance e.g., generate make pot and decompose pour tea
- generalise
  e.g., from make a cup of tea to make cups of tea

Knowledge-based Analysis

- list objects used in tasks
- list actions performed
- build taxomomies of them

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Aim

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- $\Longrightarrow$ help in production of teaching material
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Technique: Task Analysis for Knowledge Description — TAKD

Example: Kitchen Items

- kitchen items
  - preparation
    - bowl, plate, chopping board
  - cooking
    - frying pan, casserole, saucepan
  - dining
    - plate, soup bowl, casserole, glass

TDH notation

TDH — Task Descriptive Hierarchy

```
kitchen item OR
{____  preparation
{              bowl, plate, chopping board
{____  cooking
{              frying pan, casserole, saucepan
{____  dining
               plate, soup bowl, casserole, glass
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Uniqueness Rule:

A complete TDH can distinguish any two specific objects

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Uniqueness Rule:

A complete TDH can distinguish any two specific objects

TDH: Branching Type

```
kitchen item AND
/___  function OR
/        {___  preparation
/        {          bowl, plate, chopping board
/        {___  cooking
/        {          frying pan, casserole, saucepan
/        {___  dining XOR
/                   |___  for food
/                   |          plate, soup bowl, casserole
/                   |___  for drink
/                              glass
/___  shape XOR
...
```

TDH: Branching Type

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/___  function OR
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/     {___  dining XOR
/           |___  for food
/           |        plate, soup bowl, casserole
/           |___  for drink
/                    glass
/___  shape XOR
...
```

kitchen item/function{dining(for food)/shape(dished)}/

KRG — Knowledge Representation Grammar

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/     {        bowl, plate, chopping board
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/     {___  dining XOR
/           |___  for food
/           |        plate, soup bowl, casserole
/           |___  for drink
/                    glass
/___  shape XOR
...
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/           |___  for food
/           |        plate, soup bowl, casserole
/           |___  for drink
/                    glass
/___  shape XOR
...
```

kitchen item/function{preparation,dining(for food)/shape(flat)}/

KRG — Knowledge Representation Grammar

Taxomomy of Actions

```
kitchen job OR
{____  preparation
{              beating, mixing
{____  cooking
{              frying, boiling, baking
{____  dining
               pouring, eating, drinking
```

ER-based techniques

Entity-Relationship Based Techniques

- list objects used in tasks
- list actions performed
- define relationships between object and actions

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Entity-Relationship Based Techniques

- list objects used in tasks
- list actions performed
- define relationships between object and actions

- similar to techniques used in database and OO
- but includes non-computer entities
- emphasis on domain understanding rather than implementation

Example: Vera’s Veggies

- Vera’s Veggies a market gardening firm
- owner/manager: Vera
- employes: Sam and Tony
- tools include a tractor Fergie
- two fields and a glasshouse
- new computer controlled irrigation system

Object Classification

- concrete objects
  simple things: spade, plough, glasshouse

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Object Classification

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  simple things: spade, plough, glasshouse
- actors
  human: Vera, Sam, Tony, the customers
  non-human: irrigation system
- composite objects
  sets: the team = Vera, Sam, Tony
  tuples: tractor = $<$ Fergie, plough$>$

Attributes

An irrigation pump may have:

- status: on/off/faulty
- capacity: 100 litres/minute

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- status: on/off/faulty
- capacity: 100 litres/minute

However, emphasis on object participation in tasks:

- keep only relevant attributes (e.g., status)
- no need for completeness, but convenient to be initially overinclusive and drop unnecessary attributes later

Actions

Agent performs Action to change Patient

Actions

Agent performs Action to change Patient

Sam planted the leeks

Actions

Agent	performs	Action	to change	Patient	using	Instrument
Sam		planted		the leeks		

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irrigation system (control)		is turned on (automatically)				

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Vera (message)		told		Sam	to	···

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irrigation system (control)		is turned on (automatically)				
Vera (indirect agent)		programmed		the irrigation system		···
Vera (message)		told		Sam	to	···
Vera as worker		···				
Vera as manager		···				

(agents may act in several roles)

Object and Actions

Object Sam human actor

Actions:

S1: drive tractor
S2: dig carrots

Object and Actions

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Actions:
    S1: drive tractor
    S2: dig carrots
Object Vera human actor | the proprietor
Actions: as worker
    V1: plant marrow seed
    V2: programme irrigation controller
Actions: as manager
    V3: tell sam to dig the carrots

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Actions: as manager
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Object the men composite
Comprises: Sam, Tony
Object glasshouse simple
Attribute: humidity: 0–100%
Object Irrigation Controller non-human
Actions:
    IC1: turn on Pump 1
    IC2: turn on Pump 2
    IC3: turn on Pump 3

Events

- performing of an action
  Sam dug the carrots

Events

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Events

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- timed events
  at midnight

Relationships

Object Marrow simple
Actions:

- M1: germinate
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- location (Pump 1, glasshouse)

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- Ev2: midnight

Relations object-object

- location (Pump 1, glasshouse)

Relation action-object

patient (V3, Sam)

— Vera tells Sam to dig

patient (S2, the carrots)

— Sam digs the carrots ...

instrument (S2, spade)

— ... with the spade

Relations action-event

Relations action-event
before (V1, M1)
— the marrow must be sown before it can germinate
before (M1, M2)
— the marrow must germinate before it can grow

V1: plant marrow seed
M1: germinate
M2: grow

Relations action-event

Relations action-event

before (V1, M1)

— the marrow must be sown before it can germinate

before (M1, M2)

— the marrow must germinate before it can grow

triggers (Ev2, IC1)

— when it is midnight the control turns on Pump 1

Ev1: humidity drops below 25%

IC1: turn on Pump 1

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Relations action-event

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— the marrow must be sown before it can germinate

before (M1, M2)
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— when it is midnight the control turns on Pump 1

causes (V2, IC1)
— the controller turns on Pump1
because Vera programmed it

V2: programme irrigation controller

IC1: turn on Pump 1

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causes (V3, S2)
— Sam digs the carrots
because Vera told him to do so

V3: tell sam to dig the carrots

S2: dig carrots

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— Sam digs the carrots
because Vera told him to do so

Ordering of events better described using HTA
either to analyse order of subtasks and actions
annotated with objects
or to represent the life-cycle of a specific object

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Purposes:

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  - lift focus from system to use
  - suggest candidates for automation
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- documentation and teaching