A Systematic Yet Flexible System Analysis of Data Entry

Eliz Markowitz & Todd R. Johnson

Previous Work on Systematic Yet Flexible (SYF) Architecture

- Perer & Shneiderman's Seven SYF Design Goals
  - See an overview of the sequential process of actions
  - Step through actions
  - Select actions in any order
  - See completed and remaining actions
  - Annotate their actions
  - Share progress with other users
  - Reapply past paths of exploration on new data

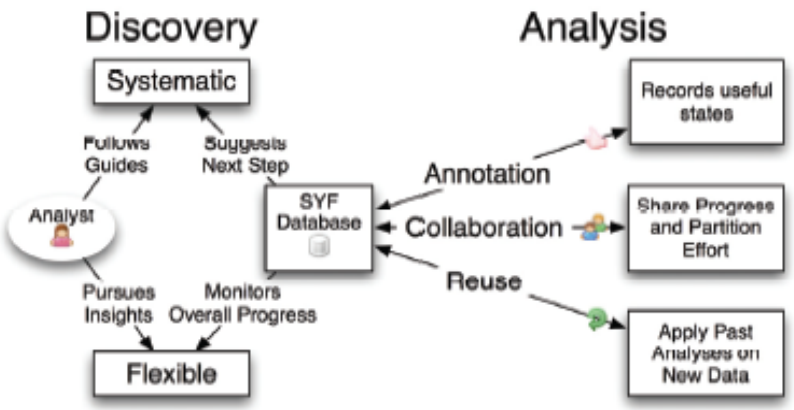


Figure 1. The SYF infrastructure facilitates discovery by providing systematic guides while also allowing users to flexibly pursue insights. SYF also facilitates analysis by allowing users to easily annotate during exploration, share exploration results with colleagues and partition effort, and reapply past exploration paths on new data sets.

Perer A, Shneiderman B. Systematic yet flexible discovery: guiding domain experts through exploratory data analysis. *Proceedings of the 13th International Conference on Intelligent User Interfaces; 2008; New York, NY. 109-118.*

Systematicity & Flexibility

- Systematicity
  - Provides structure to ensure consistency, efficiency, and safety by imposing necessary structure
- Flexibility
  - The ability to constantly adapt to circumstances and still reach the goal state
- Systematicity & Flexibility are at odds with one another

Problem: Balancing Systematicity and Flexibility in Healthcare

- Systematic, consistent approaches
  - Can improve
    - Efficiency
    - Safety
    - Effectiveness
  - Examples
    - Standard operating procedures
    - Clinical Guidelines
    - Decision support
    - Hard stops in EHRs
- But flexibility is needed to accommodate variation common to healthcare

Goals of an SYF Design Framework

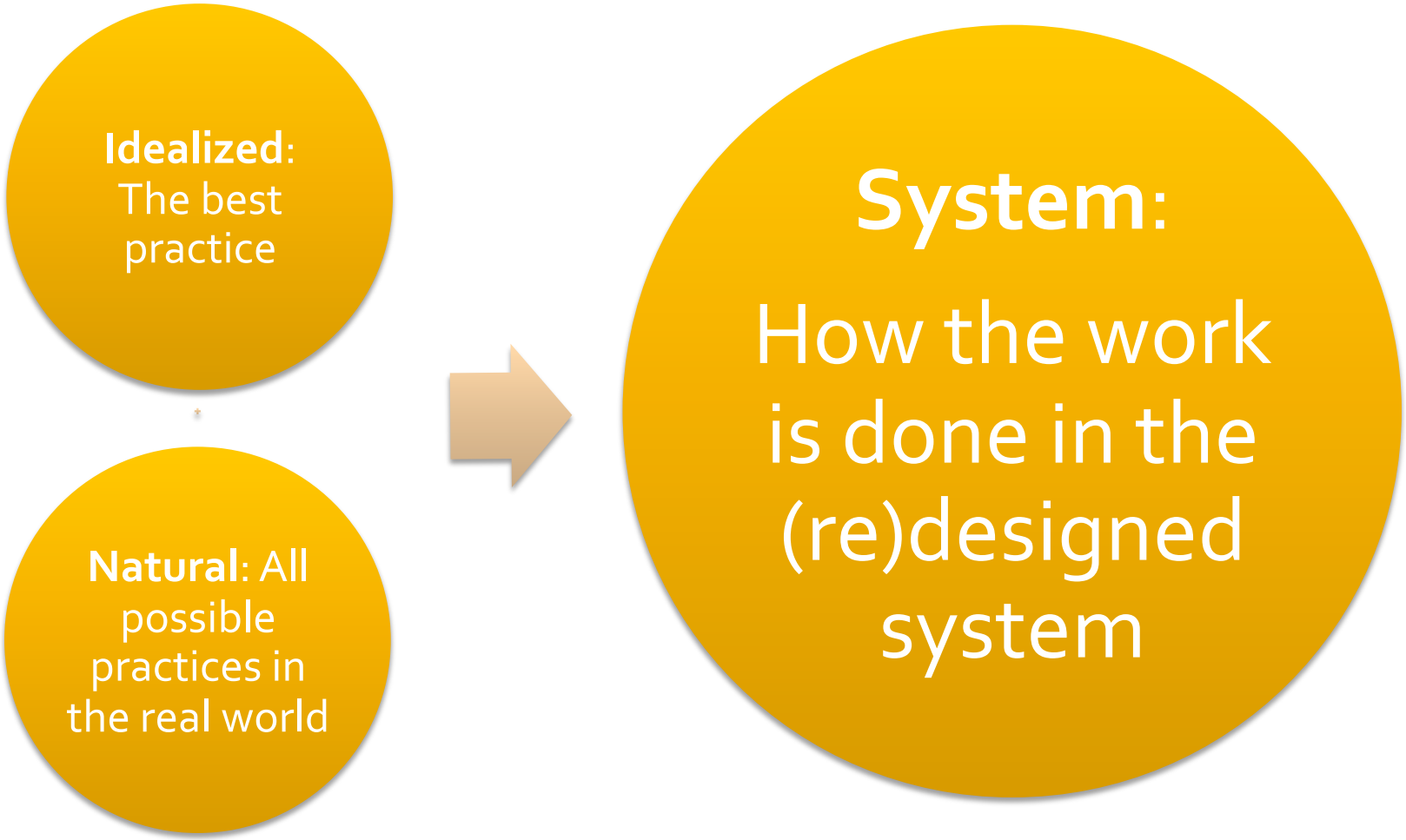
- Guide the design of systems that support graceful degradation from idealized practices to those that are more suitable for a given situation
- Allow exploration of trade-offs among designs
- Provide an objective measure of flexibility for comparing designs

Systematic Yet Flexible System Analysis (SYFSA)

Systematic Yet Flexible System Analysis (SYFSA)

- Identify a task (a problem to be solved)
- Analyze three problem spaces
  - Idealized space: The best or idealized practice
  - Natural space: Natural constraints on task performance
  - System space: The new or redesigned system
- Quantitatively compare flexibility measures for each space

SYFSA in a Nutshell



Information Theoretic Flexibility Measures

SHANNON INFORMATION

- Amount of information measured in bits
- The amount of information between *n* equally likely actions is $\log_2(n)$
- Amount of information in a choice taken with probability p_i *is* $log_2(1/p_i)$

FLEXIBILITY MEASURES

- Thus, the average information over all paths where each path has probability pi is::

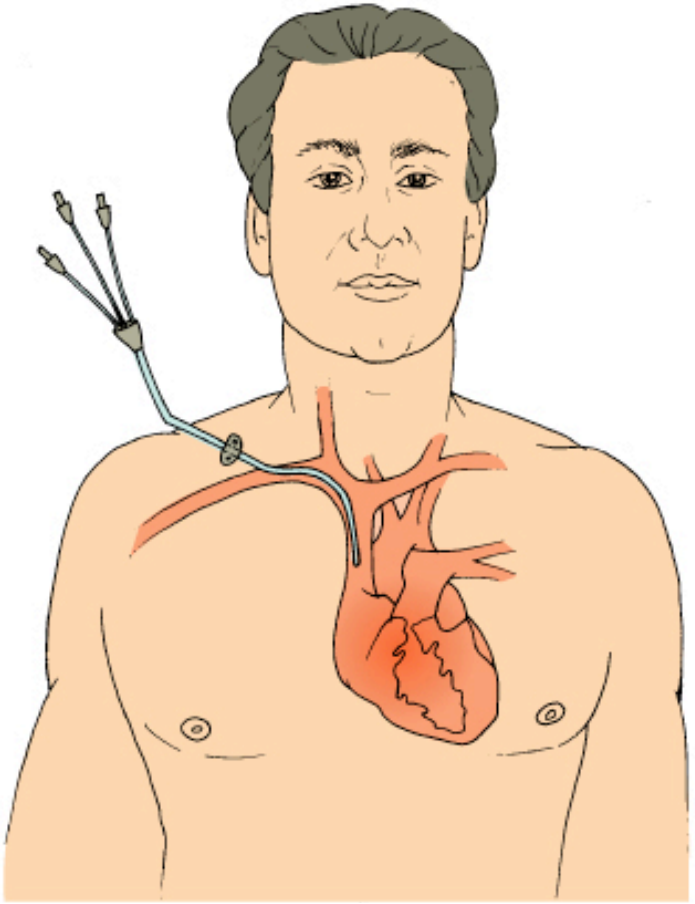
$$P^{\text{avg}} = \sum_{i=1}^{n} p_i \log_2 \left(\frac{1}{p_i} \right)$$

Can convert to percentage flexibility:

$$\%F = \frac{100(p^{avg})}{p^{avg} + 1}$$

Let's consider a task

- Central Line (CL) Insertion
  - Used to deliver medications and/or fluids
- Necessary Actions
  - Sterilize Site
    Drape patient
    Put Hat On
    Put Mask On
    Put Gown On
    Wash hands
    Glove up
    Insert Central Line
    Apply Sterile Dressing



The Central Line Idealized Space

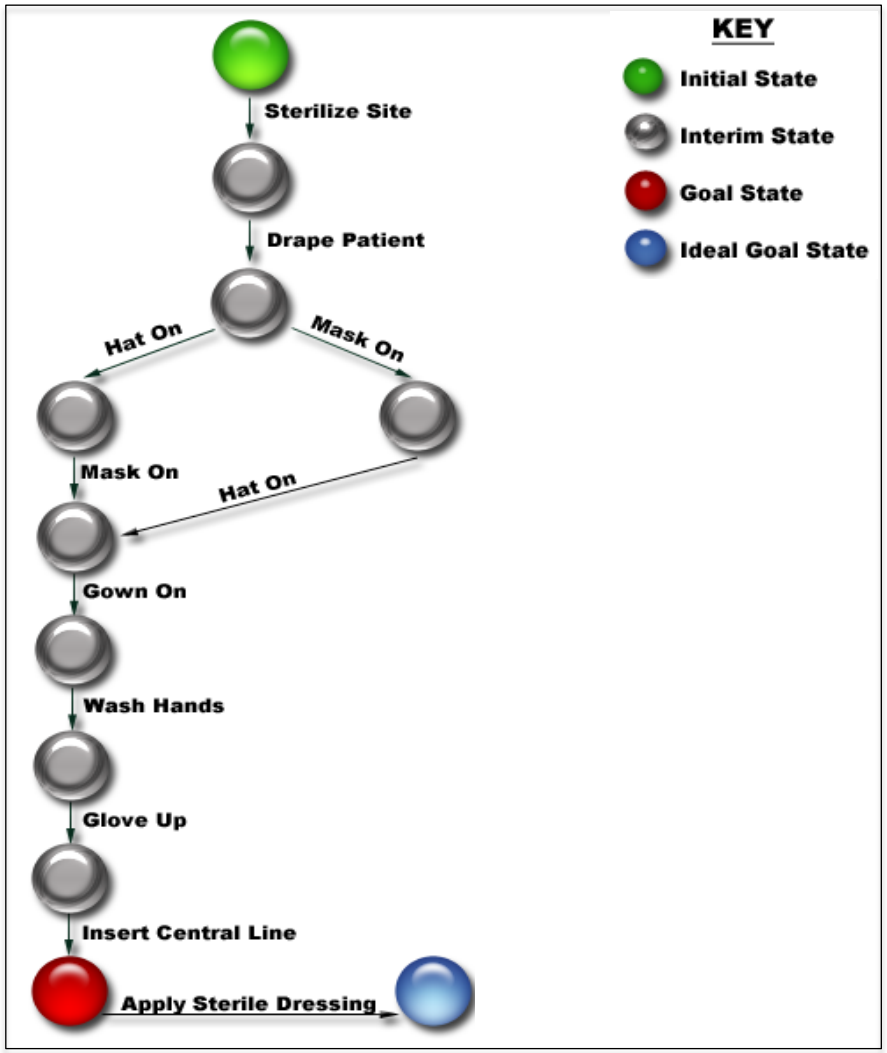
- The assumptions allow us to better assess the validity and scope of the idealized space

Assumptions

① A single caregiver accomplishes the entire task

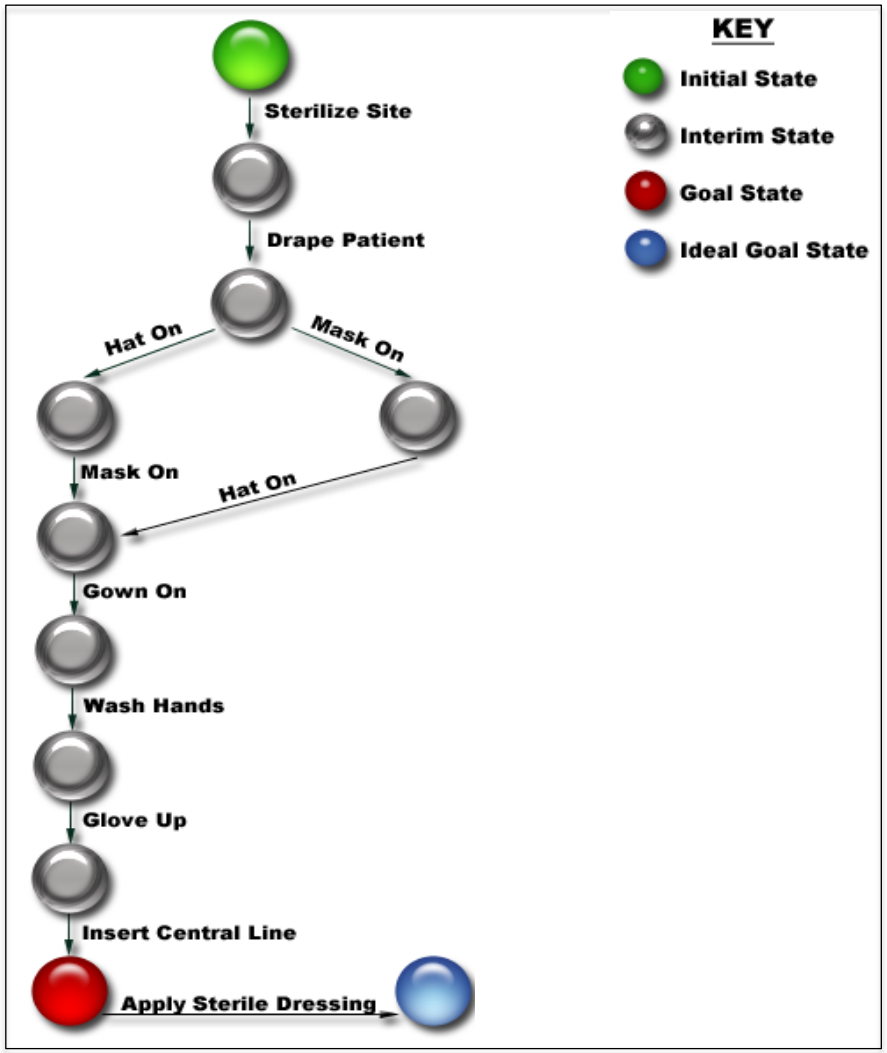
② All supplies needed to do the task are available

③ There is sufficient time to accomplish the procedure according to best practices



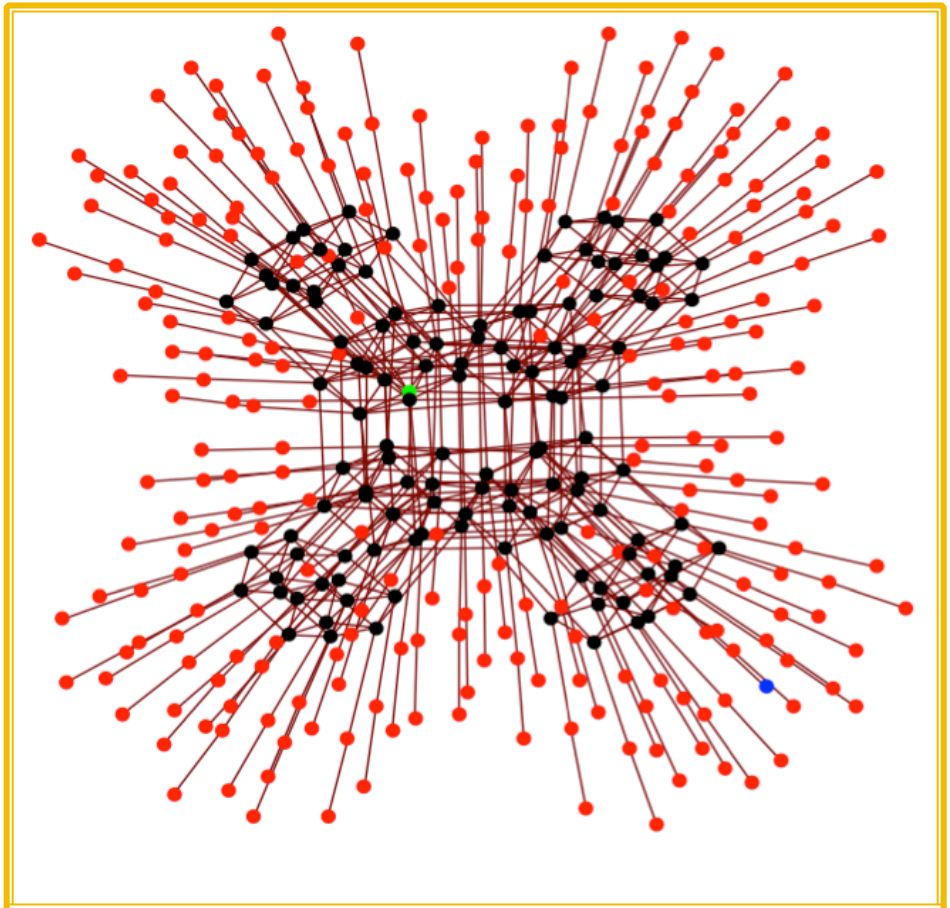
Analysis of the Idealized Space

- Idealized
  - Two equivalent paths of 9 actions
    - Each has probability .5
  - $2 \times 0.5 \times \log_2(\frac{1}{0.5}) = 1$
    - Only requires 1 bit of information
  - 10% flexibility



Analysis of the Natural Space

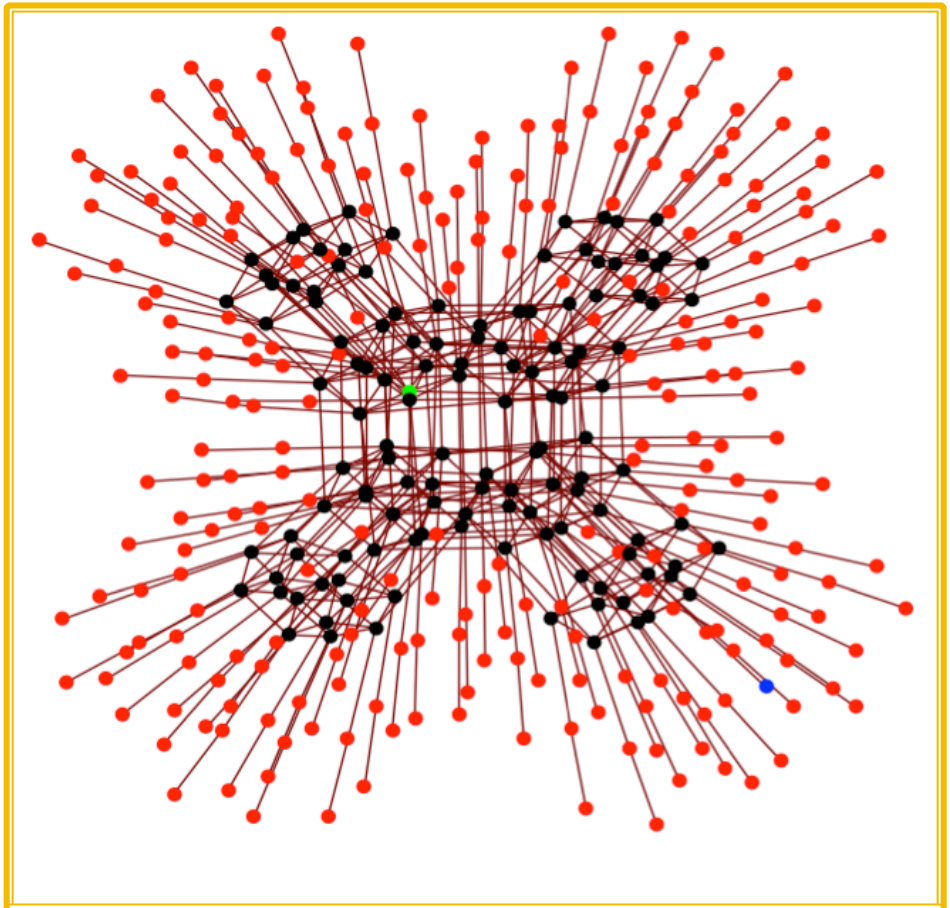
- 13,004 paths to any state in which the central line is inserted
  - 1,680 possible paths to the "idealized" state
  - Only 2 paths contain the appropriate sequence of 9 actions



The natural central line insertion space

Analysis of the Natural Space

- Shortest Path – 1 step
- Average 9.62 bits per path
- Total bits in either *correct* path is 15.2992
- 64.96% flexibility



The natural central line insertion space

Limitations of Original Framework

- Does not allow for spaces with cycles
  - Undo, Backspace, etc.
- Does not address systems that support multiple tasks

Epinephrine Auto-Injector vs. Infusion Pumps

- Single task
  - Delivers Epinephrine
  - Single fixed dose
  - Single fixed rate

- Multiple tasks
  - Delivers a variety of Medication
  - Variable dose
  - Variable rate

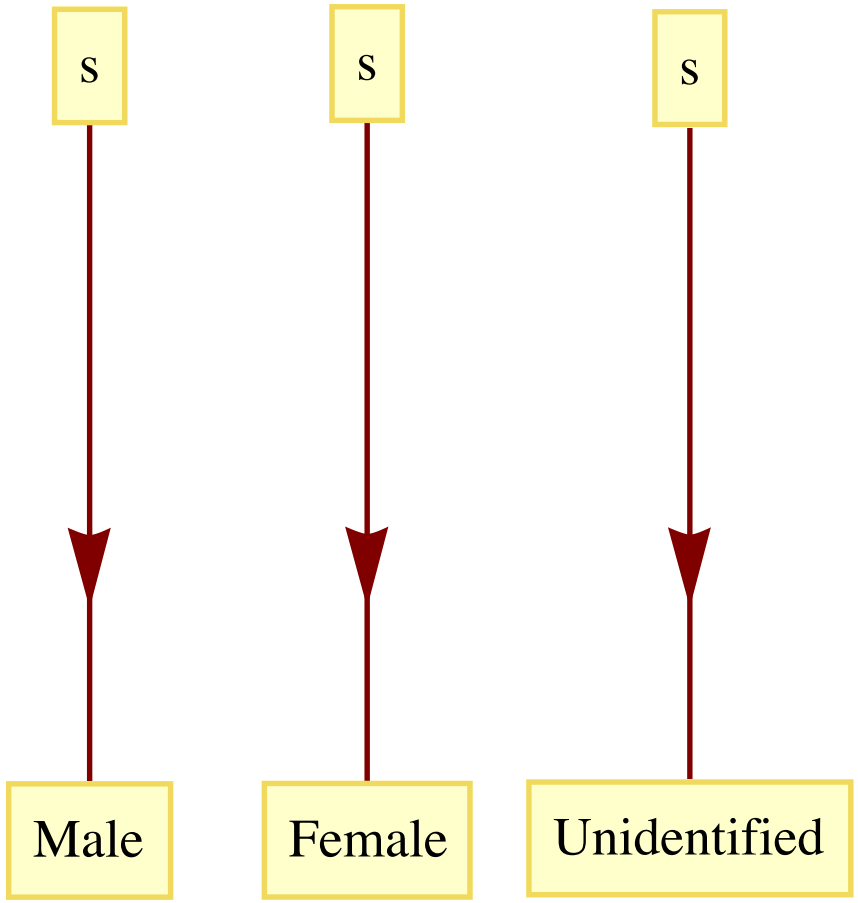
Gender Selection

What is a Task? What is this Task?

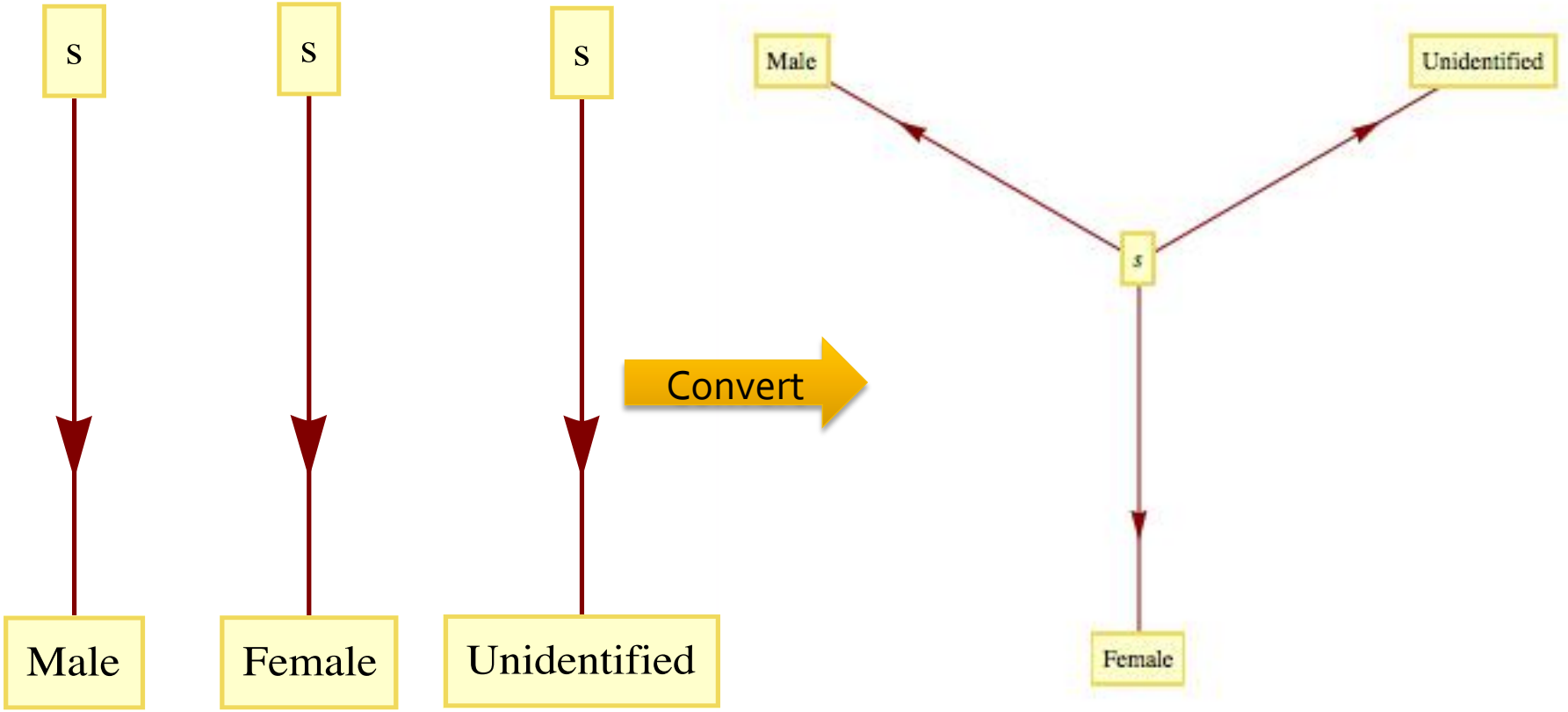
- Task: An Initial state + one or more goal states
- Tasks for Gender Selection
  - Null → Male
  - Null → Female
  - Null → Unidentified

Creating an Idealized Space for Multiple Tasks: Gender Entry

- List the tasks the interface must support
  - s → Male
  - s → Female
  - s → Unidentified
- Each separate task requires o bits
  - o% flexibility

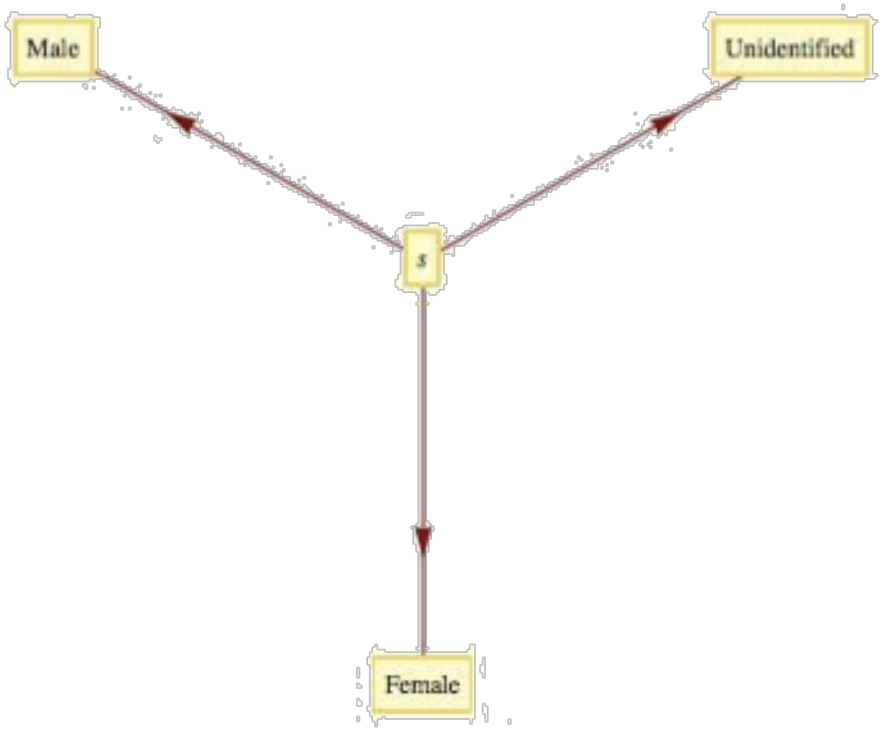


Combine all Task Spaces to Create Idealized space



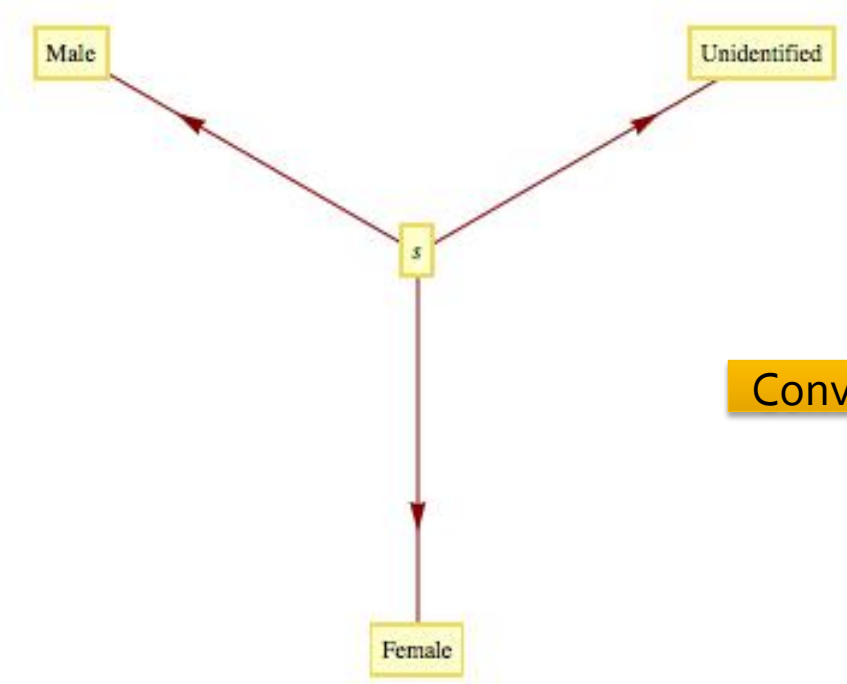
Functional Flexibility

- Average bits per task is
  - $3\left[\frac{\log_2 3}{3}\right] = 1.58$
- Flexibility is 61.2%

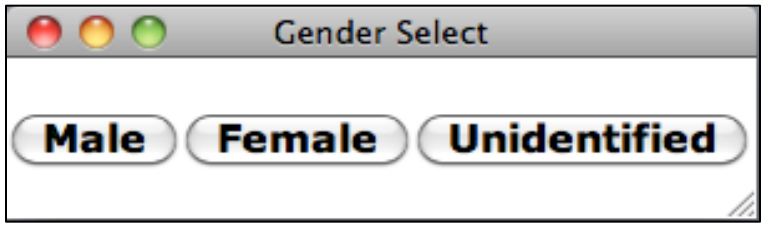


Convert Ideal Space to System Space

IDEAL SPACE



SYSTEM IMPLEMENTATION



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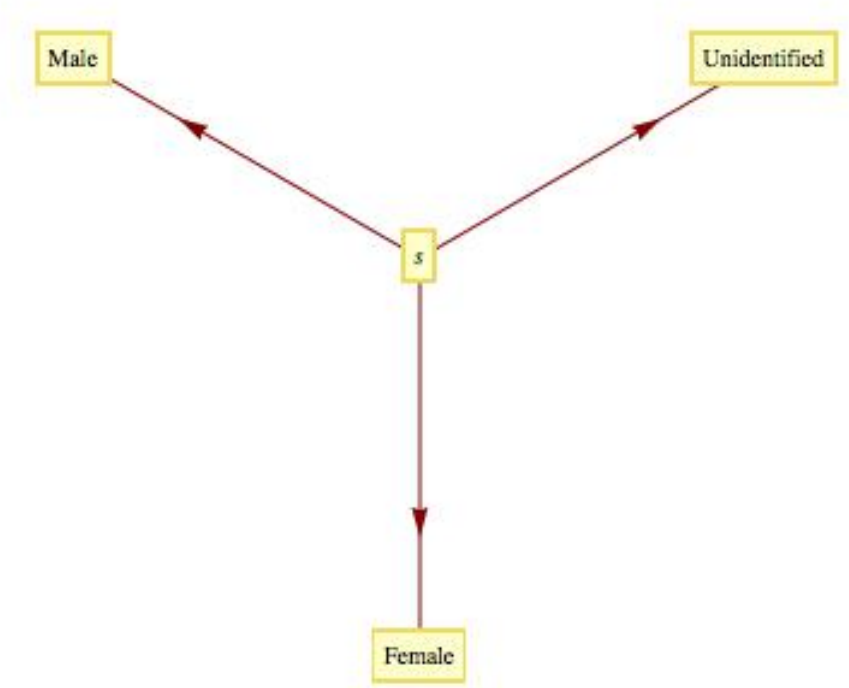
Upon selection, dialog closes and gender selection is recorded, regardless of whether or not the selection is correct.

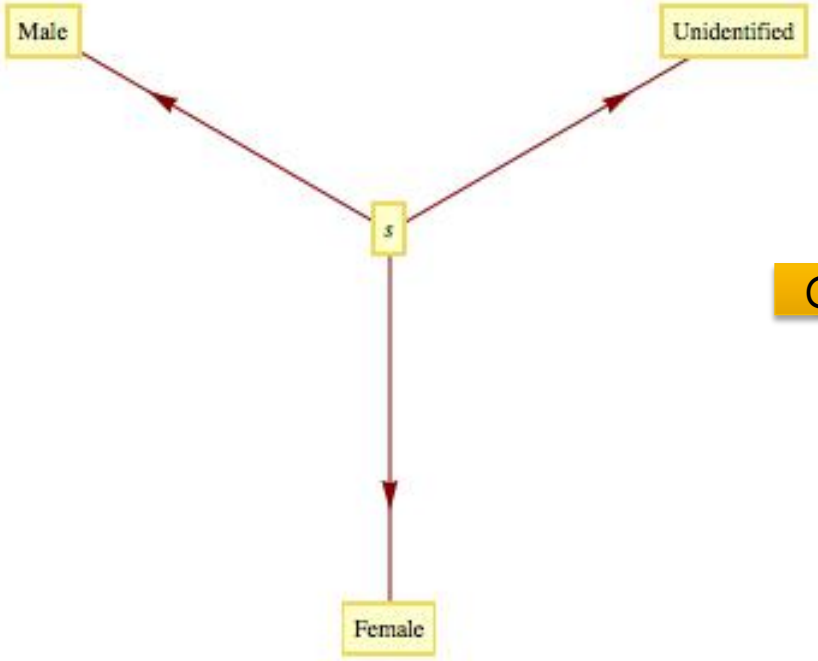
Limitations of System Space

- Since there are multiple tasks, a non-ideal user could make a mistake.
- Does not allow for the user to change his/her mind.



Convert Ideal Space to More Flexible Interface Space with Confirmation

IDEAL SPACE



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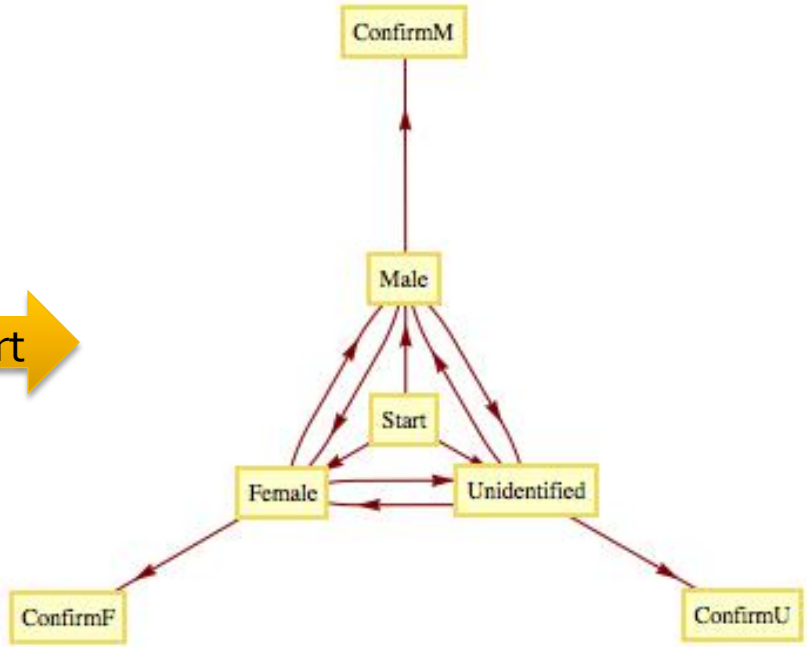
INTERFACE SPACE

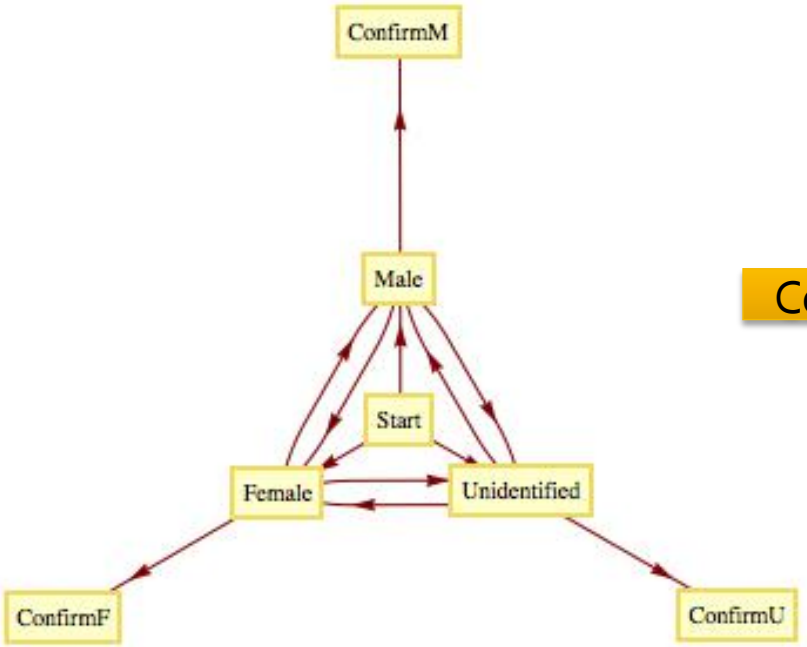


1.58 bits per task
61.2% Flexibility

3.17 bits per task (2 decisions of 3 choices)
76.0% Flexibility

More Flexible System Space I

INTERFACE SPACE



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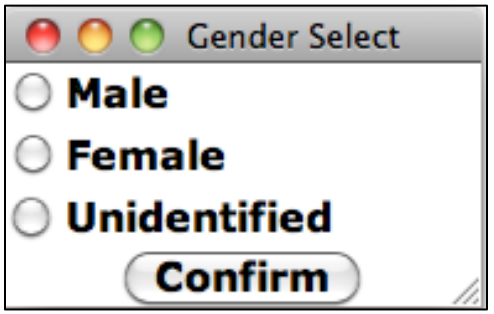
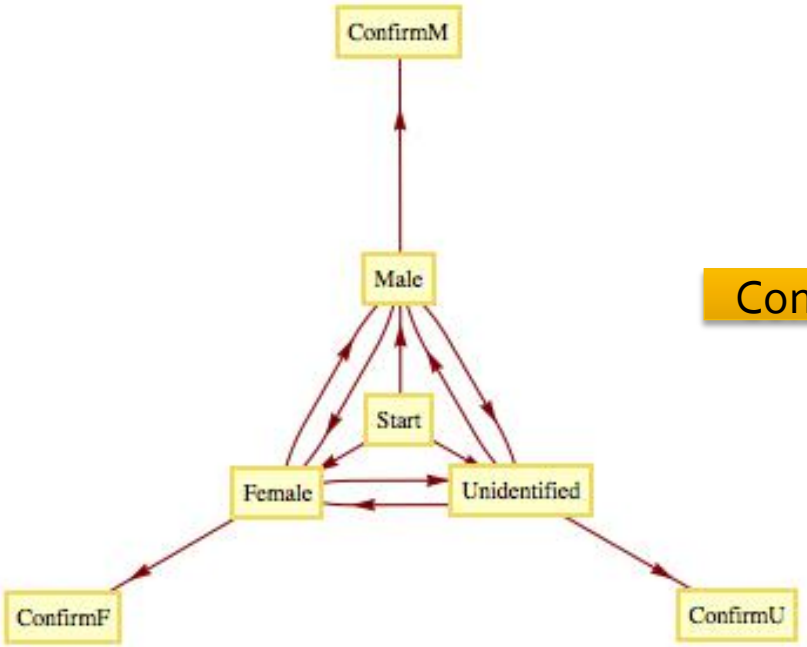
SYSTEM IMPLEMENTATION



More Flexible System Space II

INTERFACE SPACE



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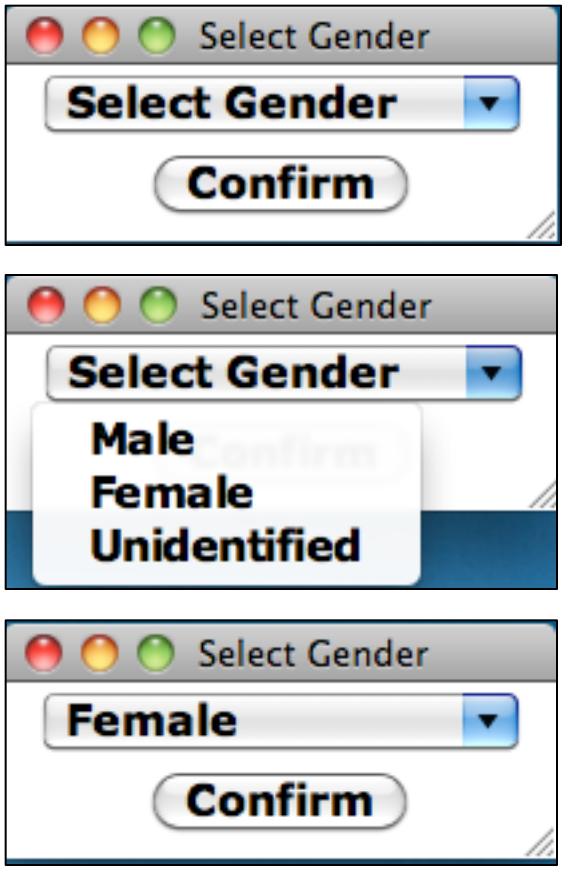
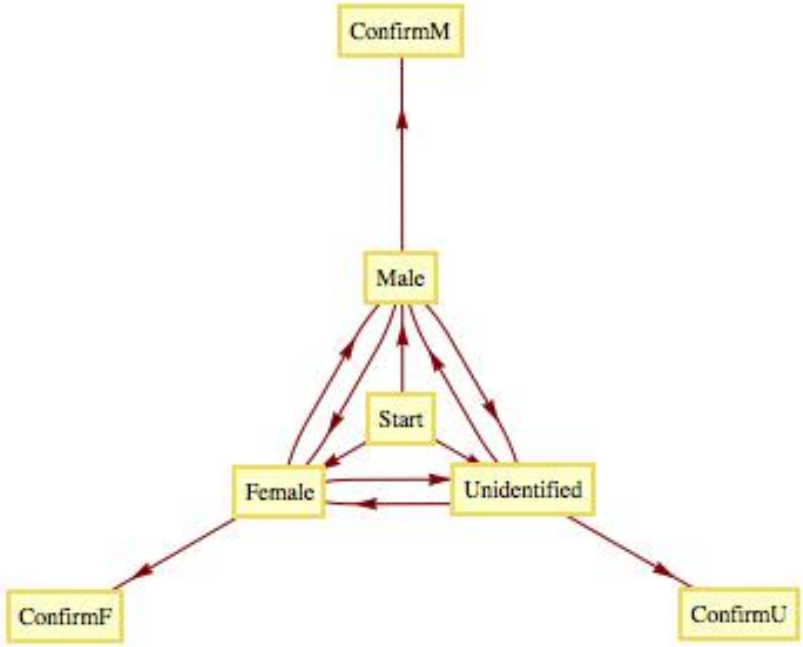
SYSTEM IMPLEMENTATION



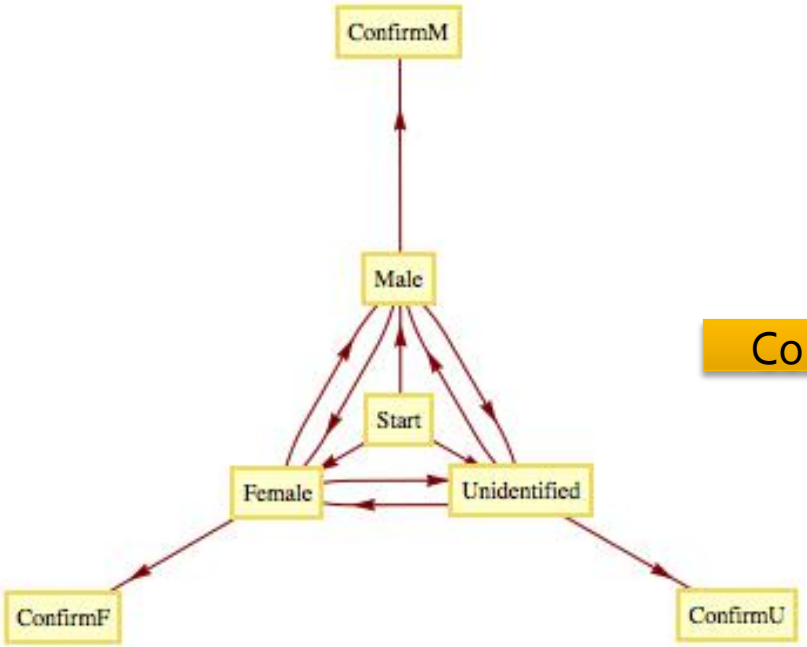
How Can We Analyze This?

- One way to analyze the space is to convert the System Space to a Markov Model.



Convert System Space to Task Graph

SYSTEM SPACE



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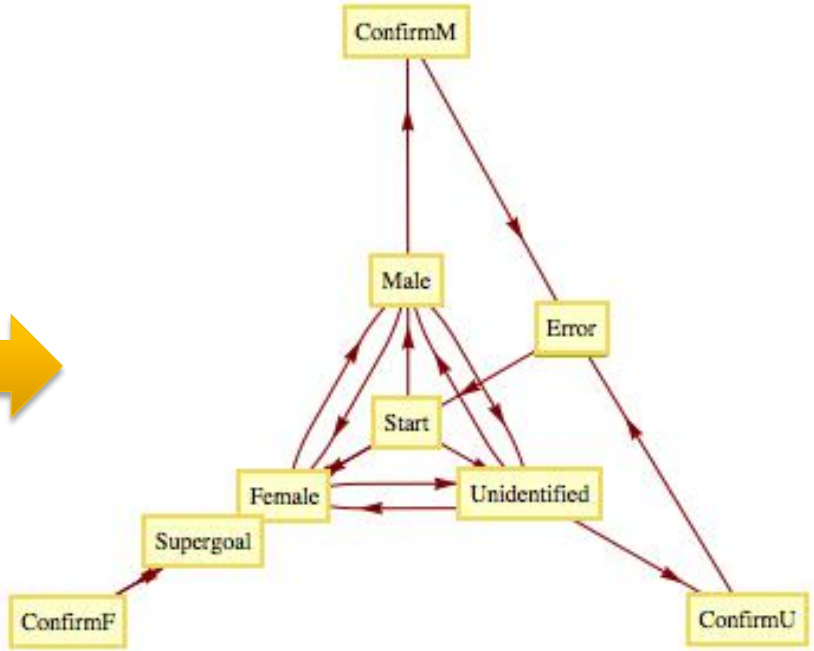
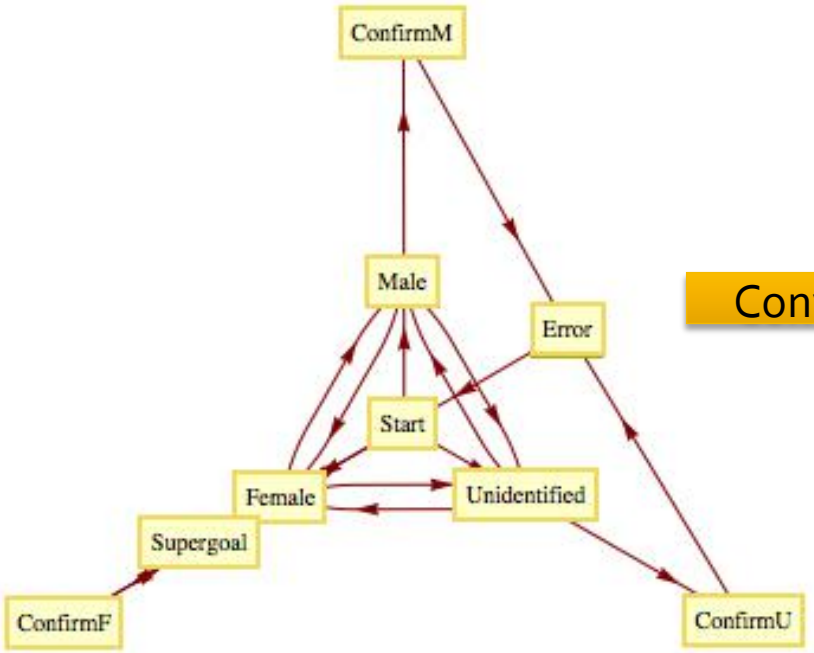
TASK GRAPH



Convert Task Graph to Stationary Distribution

TASK GRAPH



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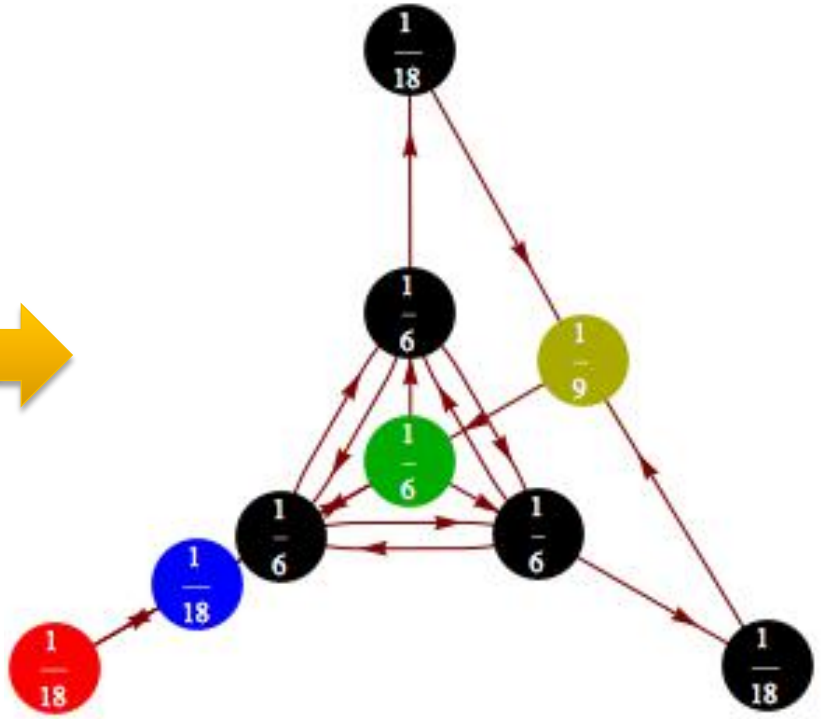
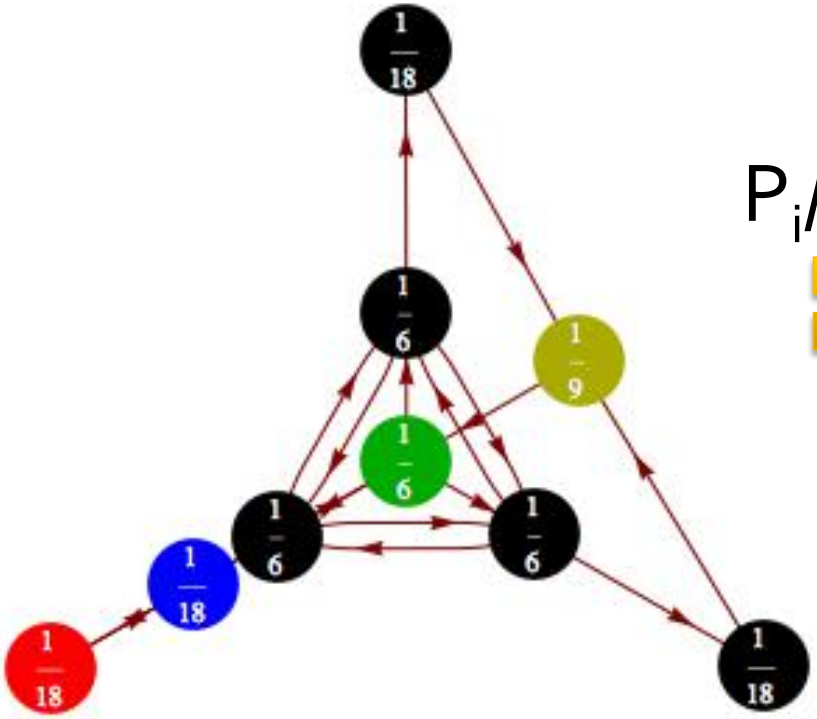
STATIONARY DISTRIBUTION



Proportion of times each state is visited on average in a long run of tasks (assumes random selection)

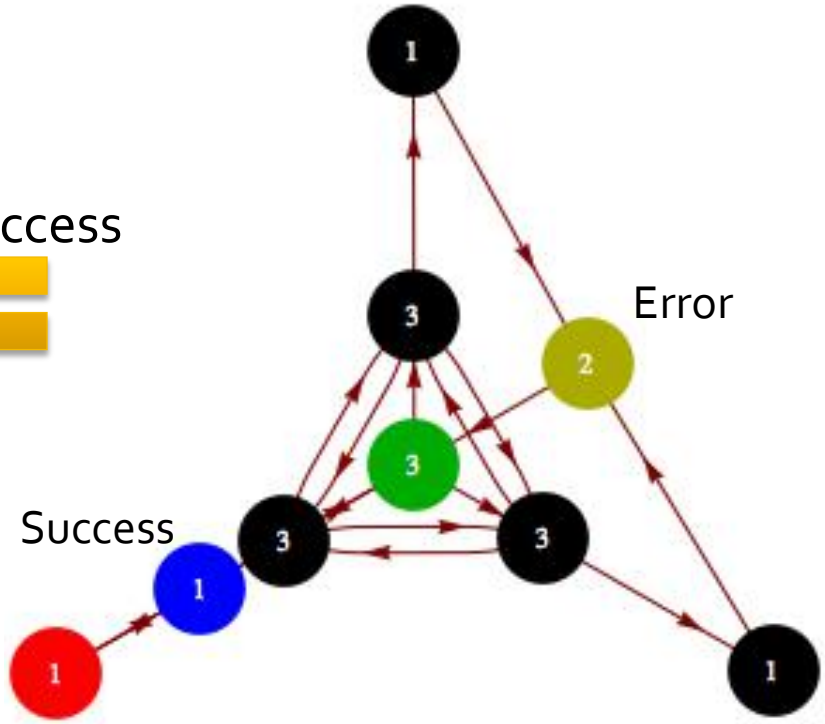
Convert Stationary Distribution to Mean State Visits per Task

STATIONARY DISTRIBUTION



$P_i/P_{success}$ =

MEAN VISITS PER SUCCESSFUL TASK



1 success for every 2 errors,
so task completion rate is 1/(1+2) = 1/3

So…How Can We Compare the Spaces?

- Weighted Bits Per Task
  - Average bits for each successful task completed by a random user
- Mean First Passage
  - Number of steps, on average, to successfully complete task
- Task Efficiency
  - Ideal # of steps / mean first passage
- Task Completion Rate
  - Number of successes divided by number of attempts
- F1
  - The balanced harmonic mean of task completion rate and task efficiency.

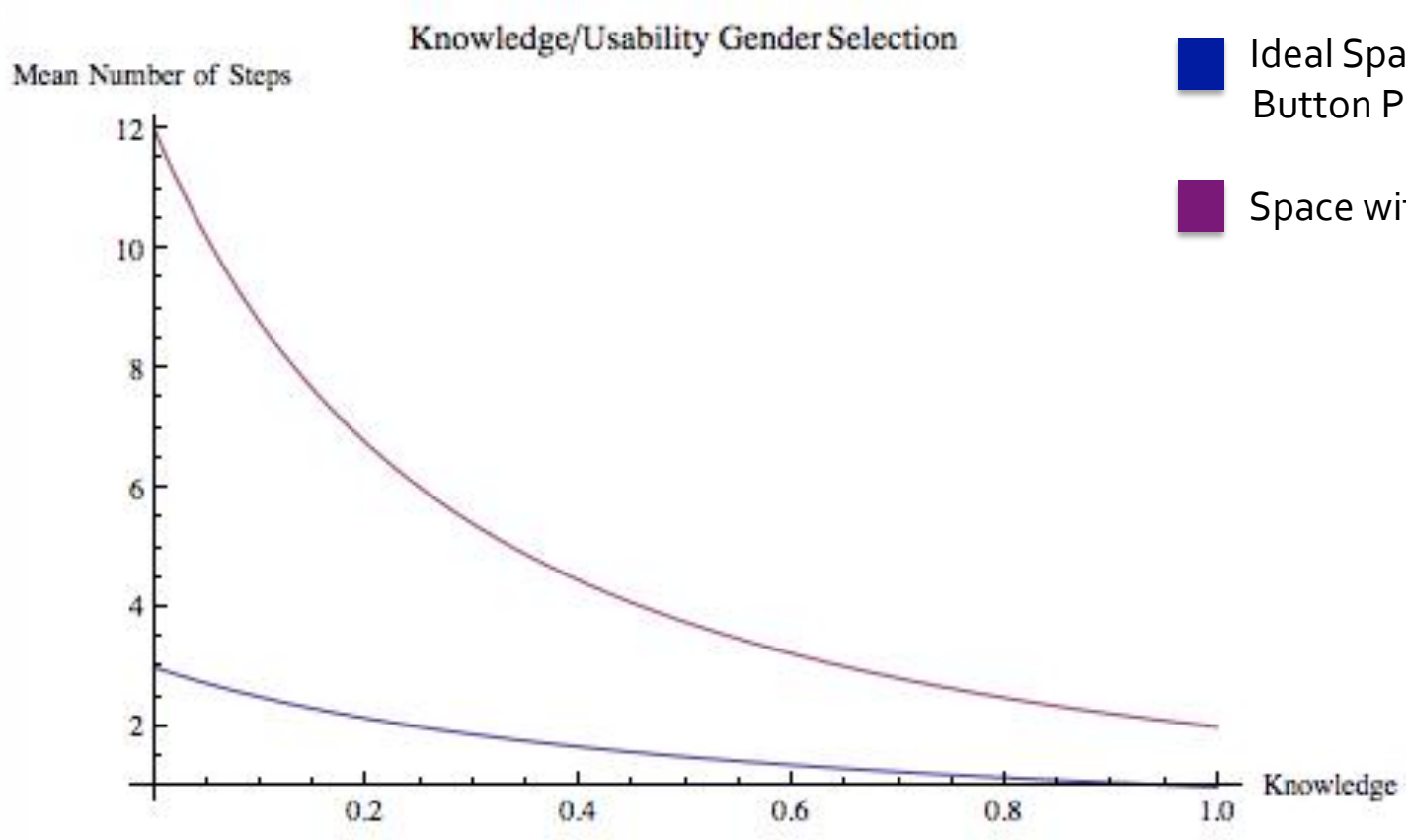
$$F1 = \left(\frac{2 \times TCR \times TE}{TCR + TE} \right)$$

Comparison of Spaces

Space	WBPT	MFP (k = .00)	MFP (k = .95)	TCR (k = .00)	TCR (k = .95)	F1 (k = .95)
No Cycles (INC)	4.75	3.00	1.03	33.33%	96.67%	0.967
Cycles & Confirmation (IC)	19.02	12.00	2.10	33.33%	99.89%	0.974

- MFP will always be higher with the IC due to the necessity of making two decisions instead of one
- While the TCR is equal at k = 0.0, at k = 0.95 the TCR of the IC space surpasses that of the INC space.
- The F1 score of the IC space also surpasses that of the INC space at k = 0.95

Mean First Passage

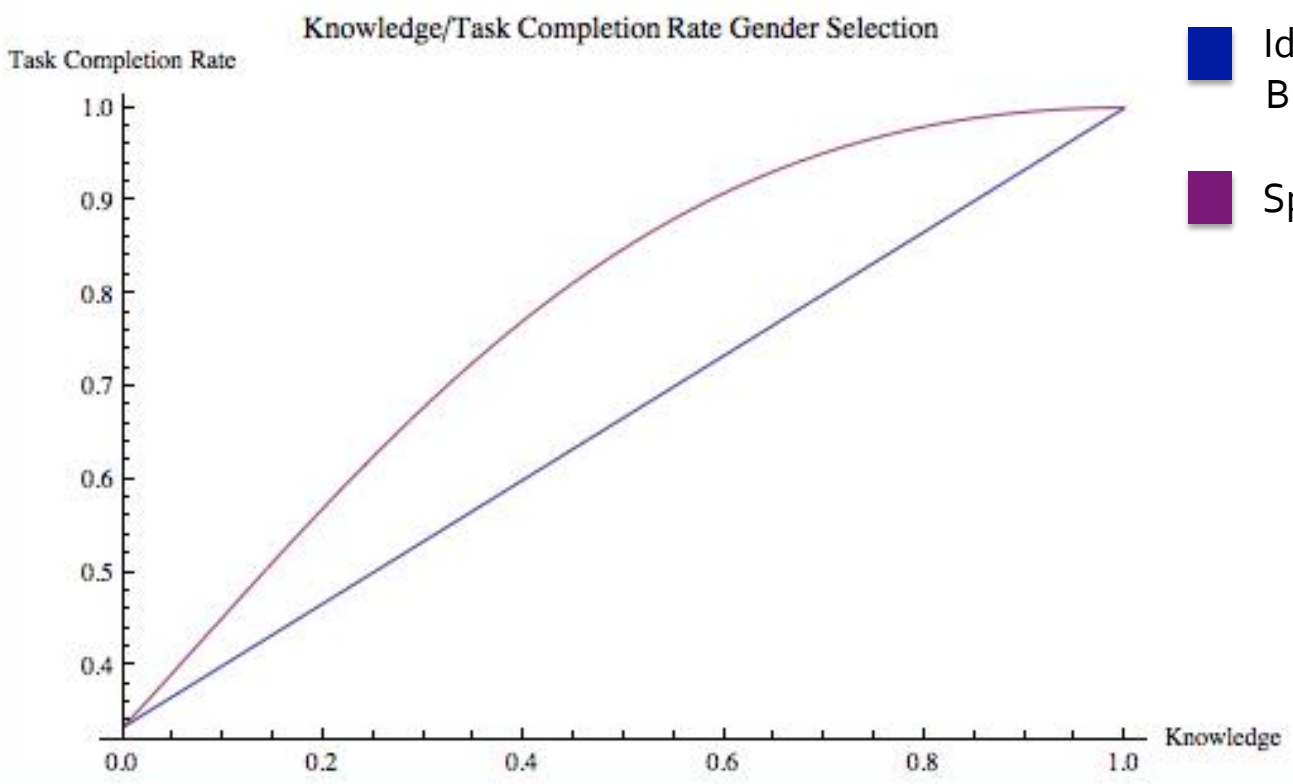


Ideal Space No Cycles & Button Press (INC)

Space with Cycles (IC)

- INC starts close to the designer at 3 steps
- IC takes 12 steps

Task Completion Rate

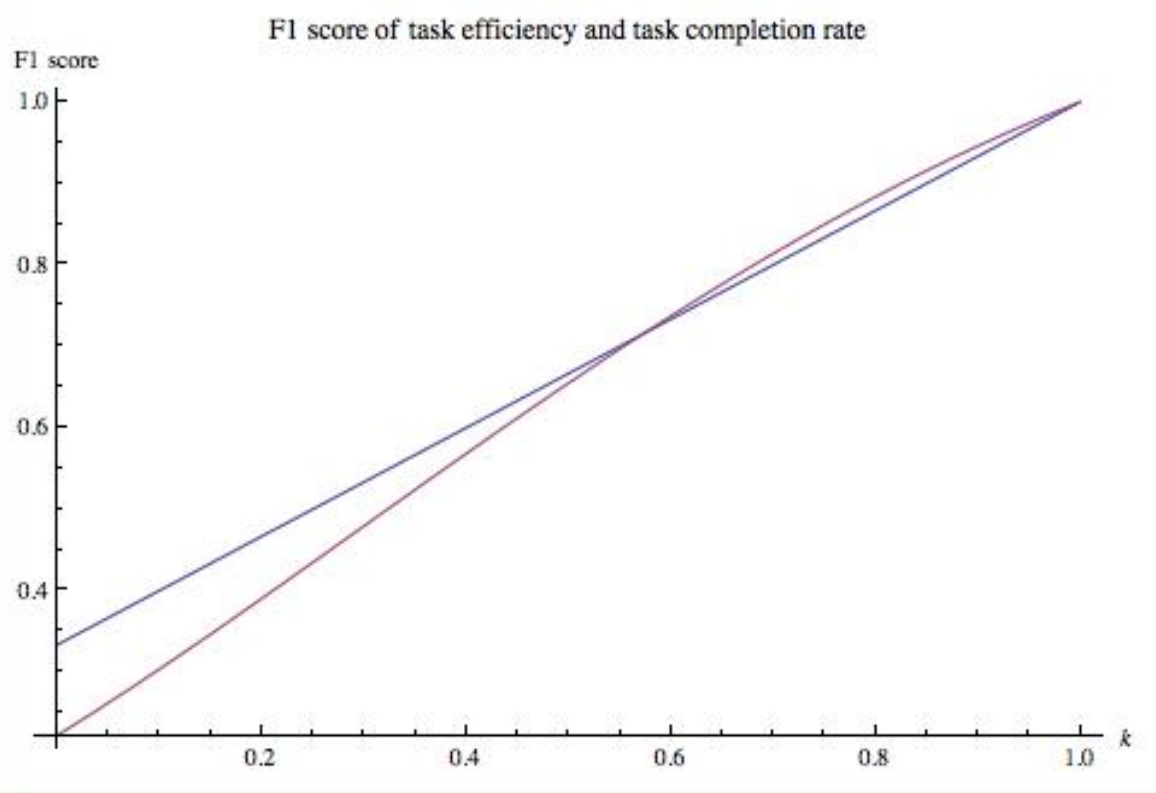


Ideal Space No Cycles & Button Press (INC)

Space with Cycles (IC)

- IC has a higher TCR among knowledge levels

F1 Score of All Spaces



Ideal Space No Cycles & Button Press (INC)

Space with Cycles (IC)

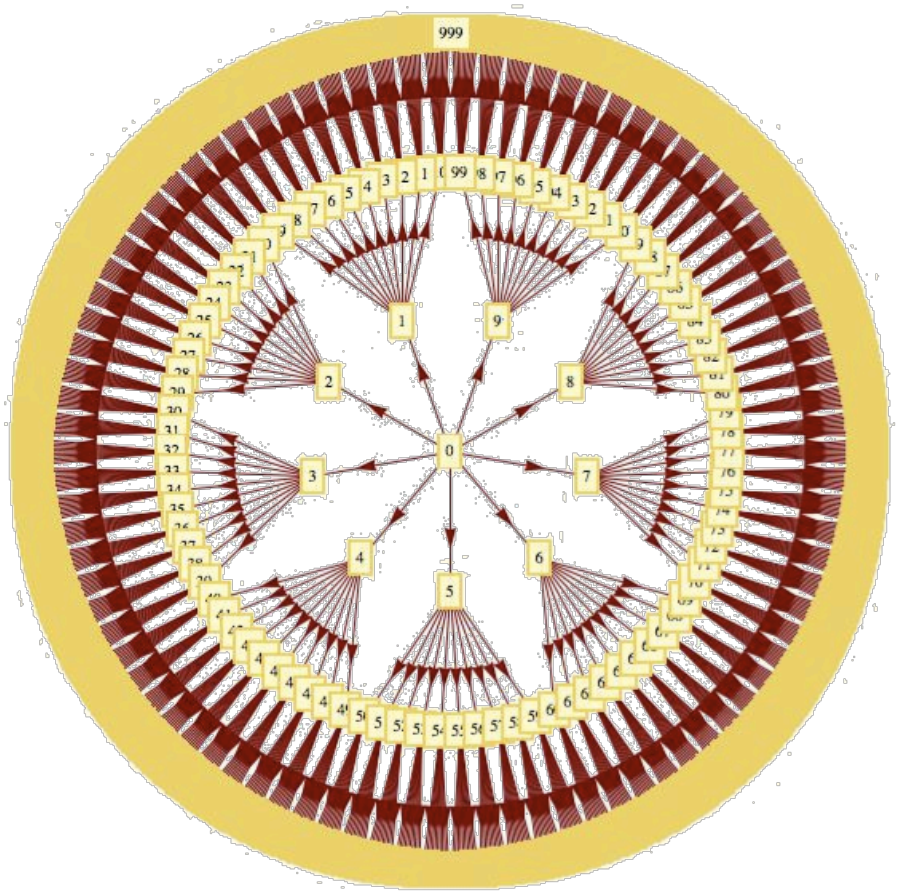
- As the knowledge of the user increases, so to does the F1 score.
- At approximately $k = 0.55$, the sacrifice of efficiency for flexibility leads to a higher F1 score

Conclusion

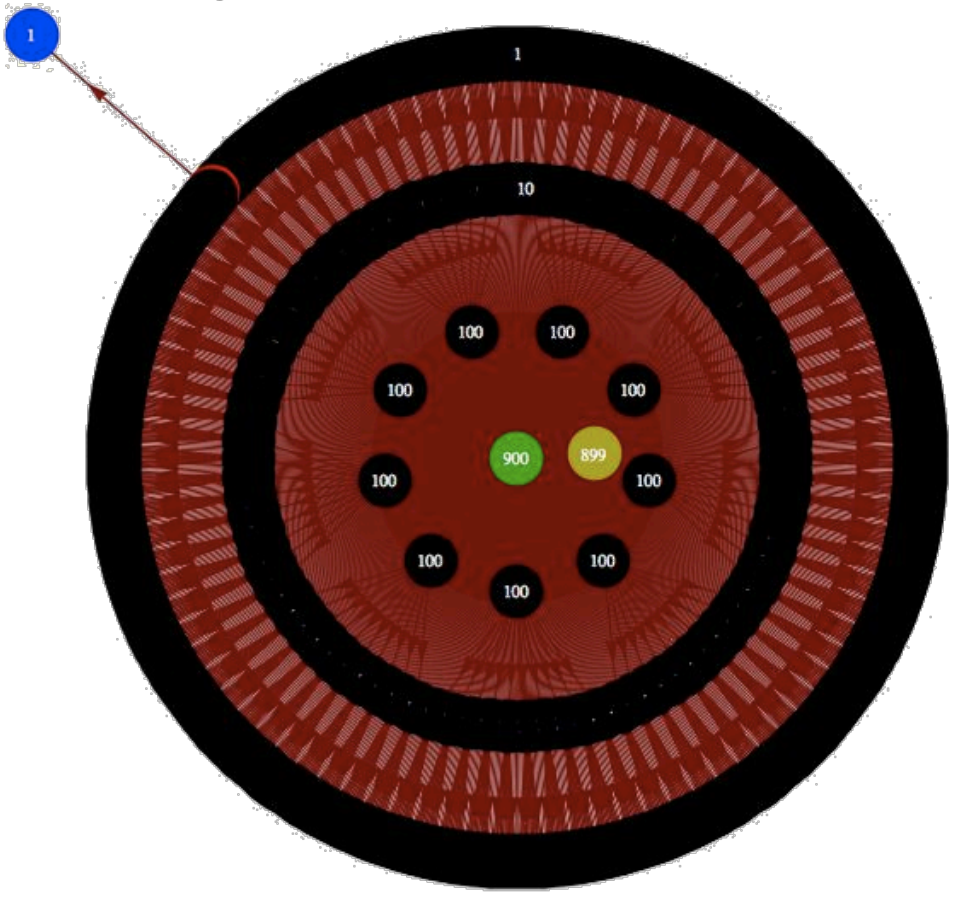
- Given an ideal space:
  - Decrease system flexibility to prevent paths that are not in the idealized space
  - Increase system flexibility to allow error recovery from paths that do not align with the current goal.

Future Work: Analyze Complex Tasks

Conduct SYFSA on Complex Tasks such as 10 Digit Number Entry or Medication Ordering



IDEALIZED SPACE



MARKOV MODEL

Acknowledgements

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Questions?

- Ask 'em!