

Outline

Grounding

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- Common ground
- Grounding
- Contribution model (Clark&Schaeffer 1989; Clark 1996)
- Grounding Act model (Traum 1994, 1999)

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Grounding

- Participants in conversation try to ground what they do together, i.e., to establish things as common ground *well enough for current purposes*
- CG is an essential condition for all joint activities, because it is crucial for *coordination of joint action*
- Two people's CG is the sum of their mutual/common/joint/shared knowledge, beliefs and suppositions
- Grounding is the process augmenting the CG (by engaging in conversation)

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CG-Shared Representation

p is CG for members of community C iff

- Every member of C has information that basis b holds
- b indicates to every member of C that every member of C has information that b holds
- b indicates to members of C that p

Example of shared basis: A, B , conch shell

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Individual CG-Shared

- Only an omniscient being can have the “full” CG-Shared representation (cf. the Byzantine Generals’ Problem)
- Individual agents act on their beliefs and assumptions about what their CG is
- Agents may have conflicting information
- Agents are deceivable
- Cf. also David Lewis, Robert Stalnaker and Paul Grice on the origins of CG-Shared

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Justification of Shared Bases

- Shared bases differ in quality of evidence, i.e., how well each piece of CG is justified
- The principle of justification:
In practice, people take a proposition p to be CG in a community C when they believe they have a proper shared basis for p in C

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Joint Closure Principle

- Joint closure principle: People (should) work hard to establish shared bases for their CG
- If the principle of joint closure through positive evidence is right, conversation participants should look for and provide grounding evidence ... and they do!

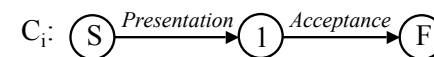
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Clark's Contribution Model

- Contribution to conversation: a signal successfully understood (\Rightarrow joint action!)
 - Presentation phase: A presents a signal for B to understand. A assumes that if B gives evidence e or stronger, A can believe B understood
 - Acceptance phase: B accepts A's signal by giving evidence e' that she believes she understands and assumes that once A registers e' , A will also believe this



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Concluded Contribution

A: I would like to speak to Mr. Jones please.

B: I am connecting you.

A: I would like to speak to Mr. Jones please.

B: Sorry, he is out of lunch.

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Grounding Evidence

Types of evidence of understanding

1. Verbatim display
2. Demonstration
3. Acknowledgement
4. Initiation of relevant next contribution
5. Continued attention

[Clark&Schaefer 1989, Clark 1996]

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Joint Action Ladder

A's actions	B's actions
1 proposing joint project w	considering proposal of w
2 signaling that p	recognizing that p
3 presenting signal s	identifying signal s
4 executing behaviour t	attending to behavior t

Grounding states (= levels of understanding):

- State 4: B is considering taking up A's proposed joint project
- State 3: B understood what A meant (but isn't in state 4)
- State 2: B identified A's presentation correctly (but isn't in state 3)
- State 1: B noticed that A has executed a presentation (but isn't in state 2)
- State 0: B noticed that A has executed some communicative behavior

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Grounding Criterion

- Joint closure: agents try to establish shared basis for the mutual belief that they have succeeded in their joint activity *well enough for the current purposes*
- Each agent uses their own standard to evaluate whether the evidence is sufficient

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Other Contribution Patterns

- Typically, problems of joint closure, I.e., not completed or continuing
 - Acceptance phase expansion when B has some trouble understanding (\Rightarrow e.g., clarification, repair...)
 - Presentation phase expansion = dividing up and possibly requesting feedback, e.g., confirmation, verification

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Embedding of Contributions

- Every signal is part of a presentation phase of a projected contribution.

(Holds also for repair initiation and even for any acceptance phase.)

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Conversation as a Process

Crucial problem with Clark&Schaeffer's contribution model:

- Description of what is grounded as a result of a complete conversation
- Not process(ing)-oriented

\Rightarrow Traum 1994, 1999

\Rightarrow Cahn& Brennan 1999

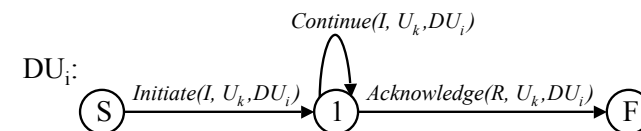
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Traum's Model of Grounding Acts

- What is the function of utterance U_k ?
 - Does U_k initiate, continue or complete a discourse unit DU_i ?



Discourse unit (DU_i): unit of (to be) grounded content

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Examples of Grounding Acts in Traum's Model

- (1) 1:A: Move the boxcar to Corning *Init(A,1,DU1)*
 2:A: and load it with oranges *Cont(A,2,DU1)*
 3:B: OK *Ack(B,3,DU1)*
- (2) 1:A: Move the boxcar to Corning *Init(A,1,DU1)*
 2:B: OK *Ack(B,2,DU1)*
 3:A: and load it with oranges *Init(A,3,DU2)*
 4:B: OK *Ack(B,4,DU2)*

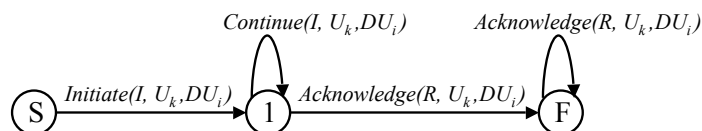
(see Traum 1998)

What's a Discourse Unit?

- (1) 1:A: Move the boxcar to Corning *Init(A,1,DU1)*
 2:A: and load it with oranges *Cont(A,2,DU1)*
 3:B: OK *Ack(B,3,DU1)*
- (1') 1:A: Move the boxcar to Corning *Init(A,1,DU1)*
 2:A: and load it with oranges *Init(A,3,DU2)*
 3:B: OK *Ack(B,4,DU1+DU2)*
- (2') 1:A: Move the boxcar to Corning *Init(A,1,DU1)*
 2:B: OK *Ack(B,2,DU1)*
 3:A: and load it with oranges *Init(A,3,DU2)*
 4:B: OK *Ack(B,4,DU2)*

What's a Discourse Unit?

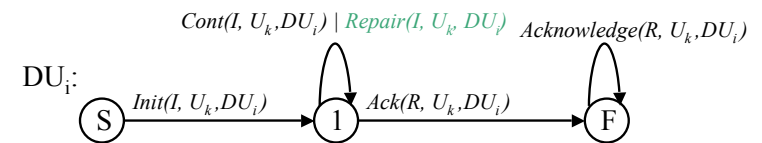
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 3:B: OK *Ack(B,3,DU1)*
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 4:B: OK *Ack(B,4,DU1)*



Adding Self-Repair

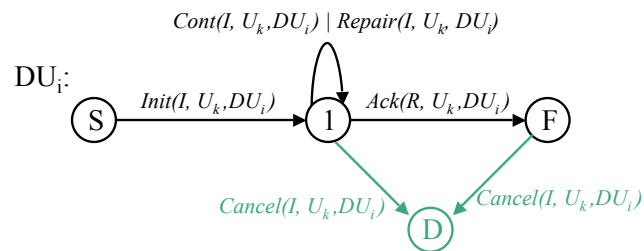
• Self-repair (of DU_i by I):

- (3) 1:A: Move the boxcar to Bath *Init(A,1,DU1)*
 2:A: I mean, Corning *Repair(A,2,DU1)*
 3:B: OK *Ack(B,3,DU1)*



Adding Cancellation

- Abandoning of DU_i by I:



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Cancellation Example

- (3) 1:A: Move the boxcar to Bath $Init(A,1,DU1)$
 2:A: and load it with oranges $Cont(A,2,DU1)$
 3:B: OK $Ack(B,3,DU1)$
 4:A: Eh, no, forget that. $Cancel(A,4,DU1)$
- 5:A: Move the boxcar to Corning $Init(A,5,DU2)$

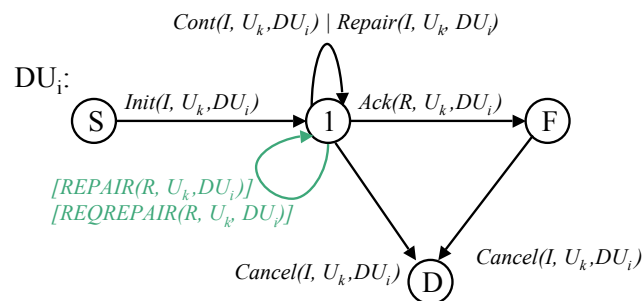
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Adding Other-Repair

- Other-repair and repair-request (of DU_i by R):



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Other-Repair Example

- (4) 1:A: Move the boxcar to Bath $Init(A,1,DU1)$
 2:B: To Corning $Repair(B,2,DU1)$
 $\approx Init(B,2,DU2)$
 3:A: Oh, sure. $Ack(A,3,DU2)$
- (5) 1:A: Move the boxcar to Bath $Init(A,1,DU1)$
 2:B: Bath? $ReqRepr(B,2,DU1)$
 $\approx Init(B,2,DU2)$
 3:A: Oh, Corning. $Ack(A,3,DU2)$
 4:B: OK $Repair(A,3,DU1)$
 $Ack(R,4,DU1)$

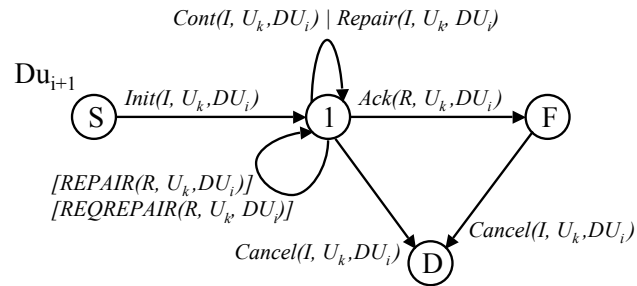
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Recursive Embedding

- Other-repair is itself an embedded DU_{i+1}
- $\text{Repair}(R, U_k, DU_i) \approx \text{Init}(I, U_k, DU_{i+1})$
- $\text{ReqRepair}(R, U_k, DU_i) \approx \text{Init}(I, U_k, DU_{i+1})$



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Other-Repair (Request) Example

- | | |
|---|--|
| <p>(6) 1:A: Move the boxcar to Corning
 2:A: and load it with pineapples
 3:B: OK
 4:A: I mean, oranges.
 5:A: OK.</p> | <p>$\text{Init}(A,1,DU1)$
 $\text{Cont}(A,2,DU1)$
 $\text{Ack}(B,3,DU1)$
 $\text{Repair}(A,4,DU1)$
 $\text{Ack}(B,5,DU1)$</p> |
| <p>(7) 1:A: Move the boxcar to Corning
 2:A: and load it with pineapples
 3:B: OK.
 4:B: Pineapples?
 5:A: I mean, oranges.
 6:B: OK.</p> | <p>$\text{Init}(A,1,DU1)$
 $\text{Cont}(A,2,DU1)$
 $\text{Ack}(B,3,DU1)$
 $\text{ReqRepr}(B,4,DU1)$
 $\text{Repair}(A,5,DU1)$
 $\text{Ack}(B,6,DU1)$</p> |

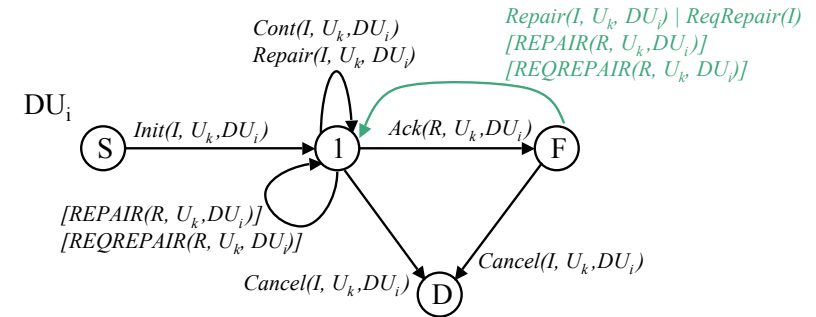
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More Repair (Requests)

- Other-repair and repair-request (of DU_i by I/R):



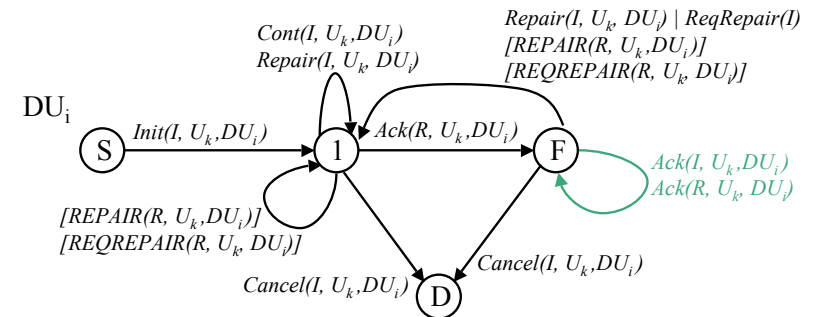
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More Acknowledgements

- Acknowledgements of completed DU_i by I or R



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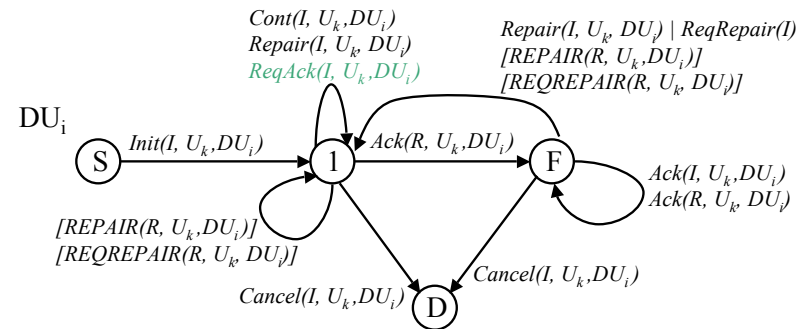
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Acknowledgements Example

- | | |
|-------------------------------------|---------------|
| (8) 1:A: Move the boxcar to Corning | Init(A,1,DU1) |
| 2:A: and load it with oranges | Cont(A,2,DU1) |
| 3:B: OK | Ack(B,3,DU1) |
| 4:B: To Corning, load with oranges. | Ack(B,4,DU1) |
| 4:A: OK | Ack(A,5,DU1) |

Acknowledgement Requests

- Acknowledgement request by I



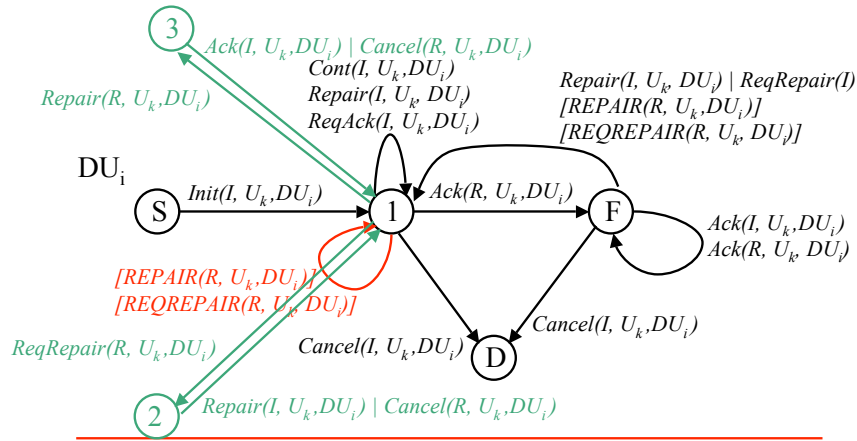
Acknowledgement Request Example

- | | |
|-------------------------------------|---------------|
| (8) 1:A: Move the boxcar to Corning | Init(A,1,DU1) |
| 2:A: and load it with oranges | Cont(A,2,DU1) |
| 3:A: OK? | Ack(B,3,DU1) |
| 4:B: Corning, oranges. | Ack(B,4,DU1) |
| 5:A: Yes | Ack(A,5,DU1) |
| 6:B: OK. | Ack(B,6,DU1) |

Is Recursion Necessary?

- Recursion adds computational complexity and is expensive
- Unlimited recursion depth is psychologically unlikely
- Pushdown storage \rightarrow finite model

Finite Model (1)

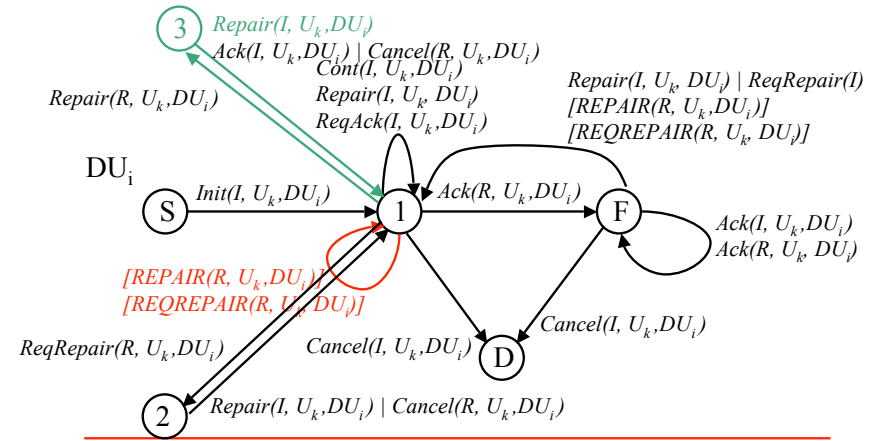


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Finite Model (2)

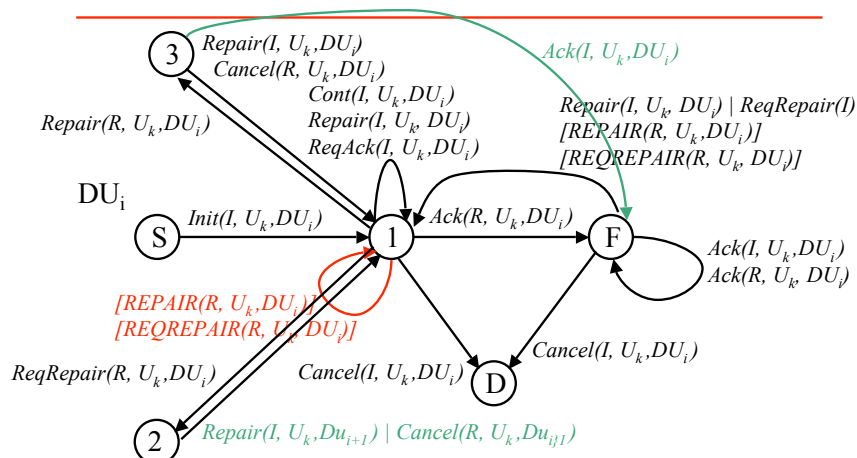


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Finite Model (3)

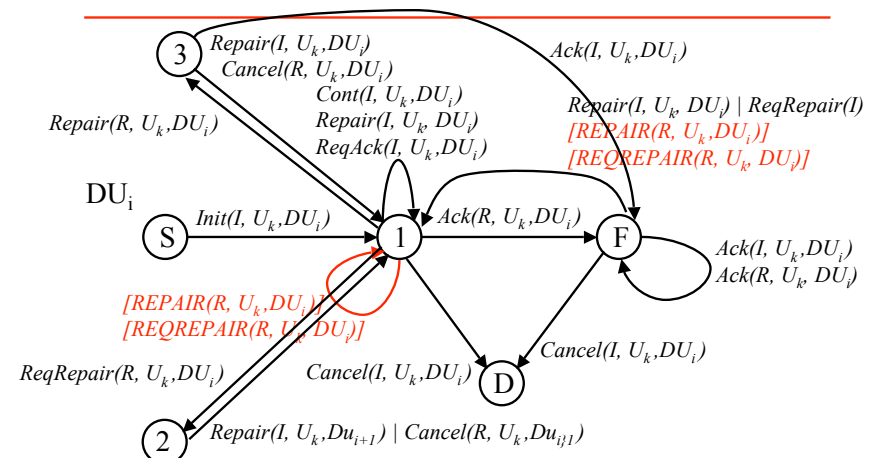


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Finite Model (4)

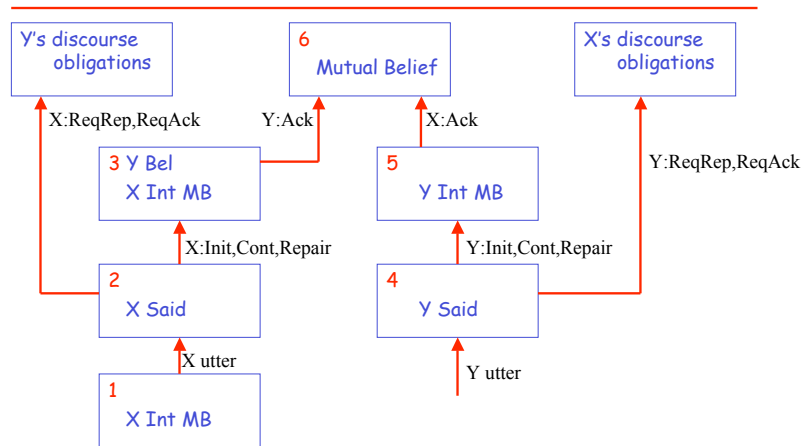


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Cognitive Model of Grounding Act Processing



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Issues / Deficiencies

- Groundedness is just binary
 - But there is evidence of graded groundedness
- Utterance unit size (cf. Ex.1)
 - Problem for coding, but any practical solution goes
- Discourse unit size
 - Center embedding (cf. Ex.1,1',2,2')
 - Partial acknowledgement (cf. Ex.7)
- Grounding act ambiguity/unspecificity
 - Representing as vagueness ?
 - Entertain multiple possibilities, eliminate later ?
 - Best-first strategy with revision/backtracking ?
- Extension to multimodal or embodied interaction?

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Questions & Discussion

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