Generalized Universality

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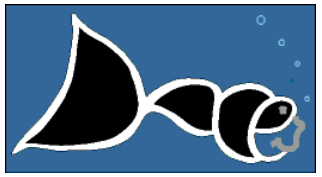



Lausanne
Vevey
Villeneuve
Nyon
Genève

Act 1
Classical Universality

Act 2
Modern Universality

Act 3
Generalized Modern Universality


ПОЧТА СССР
4к
1983
1200
ЛЕТ
Мухаммед
аль-Хорезми

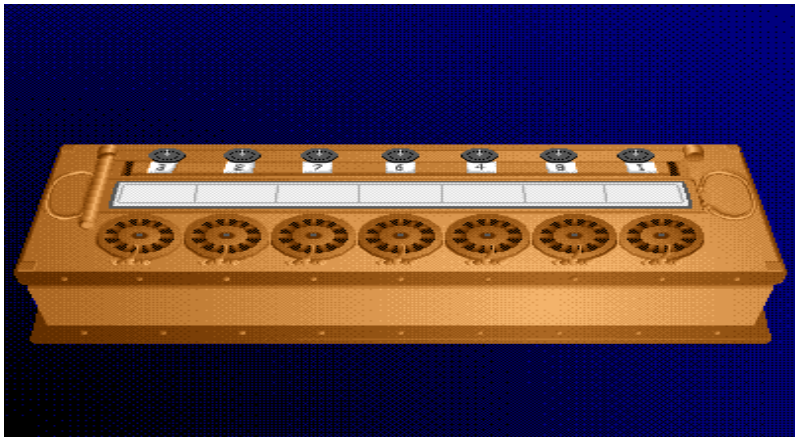
Algorithm

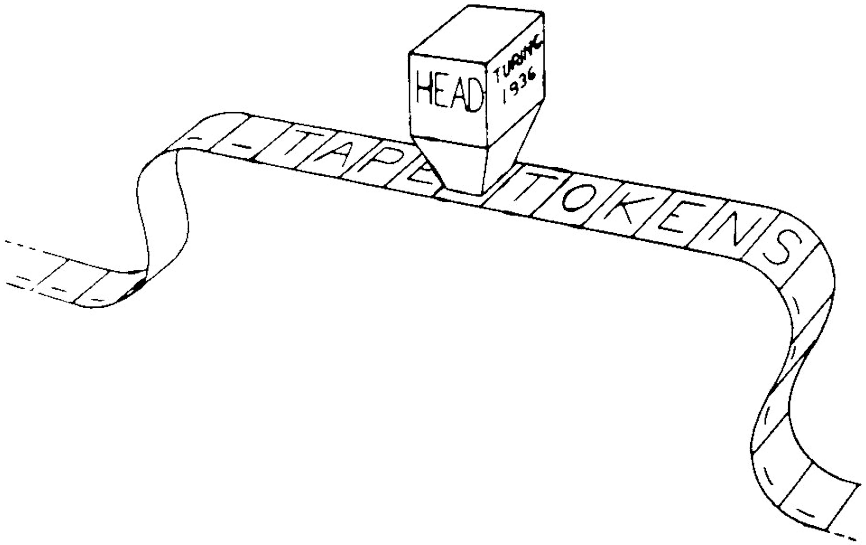
A finite set of precise instructions

The only intelligence required is to compute the instructions

Must always produce a result

Which machine enables to compute everything?





Universality

Act 1
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Act 2
Modern Universality

Act 3
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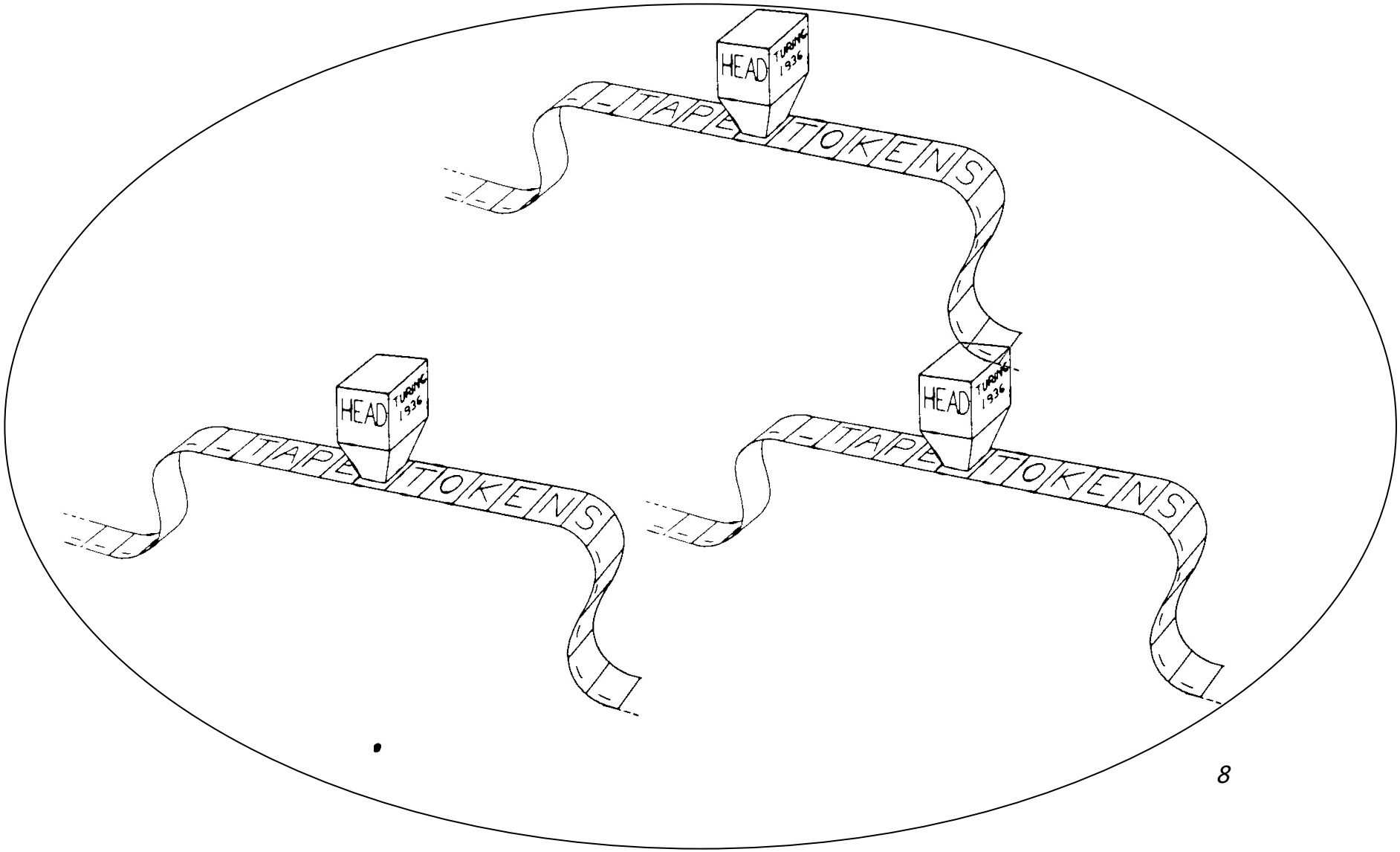
The Network is the Computer



Algorithm

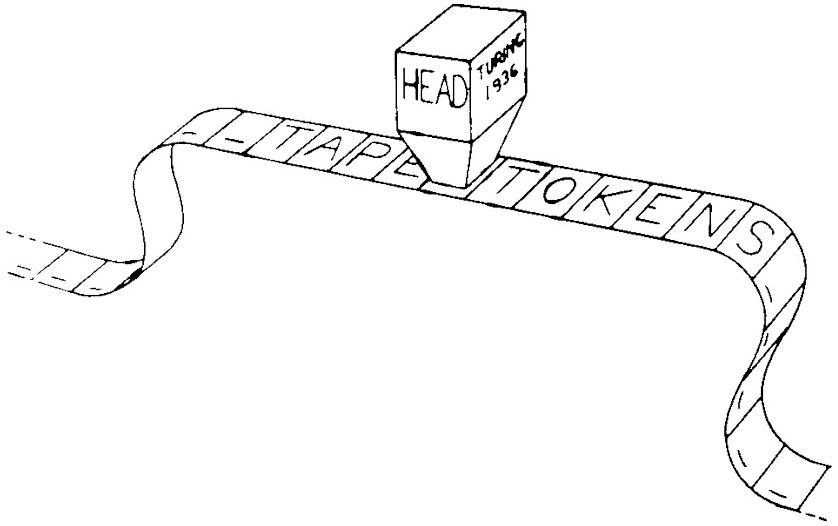
A finite set of precise instructions

The only intelligence required is to compute the instructions

Must **always** produce a result

NB. Despite concurrency and failures

Which network enables to compute everything?



Linearizable

Highly-available

Universality of consensus [L-L-S-H-CT]

Message Passing?

Register?

Test&Set?

Consensus C&S Abcast

Consensus

Processes propose each a value and ***agree*** on one of those values

same-output = ***propose(***input***)***

Universal construction

A state machine of which each process holds a copy

A list of commands local to each process

A list of consensus objects shared by the processes

Universal construction

- while(true)

- c = commands.next()
- cons = Consensus.next()

- c’ = cons.***propose***(c)
- sM.***perform***(c’)

Act 1
Classical Universality

Act 2
Modern Universality

Act 3
Generalized Universality

Generalized Universality

Consensus is the particular case of k-consensus

K-consensus [C, AGK]

- Every process proposes a vector of k values and returns a value at some position

- (value,position) = propose(kVect)

K-consensus

- ***Validity***: the value returned at some position has been proposed at that position
- ***Agreement***: no two values returned at the same position are different
- ***Termination***: every correct process that proposes eventually returns

What form of universality with K-consensus?

With consensus

Processes implement a highly-available state machine

With k-consensus

Processes implement k state machines of which ***at least one*** is highly-available

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Act 1
Classical Universality

Act 2
Modern Universality

Act 3
Generalized Universality

Generalized universality

k state machines: each process holding a copy of each (sM(i))

k lists of commands local to each process

A list of k-vector consensus objects (kVectCons)

Reads and writes in shared memory

Universal construction

- while(true)
- c = commands.next()
- cons = consensus.next()

- c’ = cons.propose(c)
- sM.perform(c’)

Generalized universality?

- while(true)
- for j = 1 to k: com(j) = commands(j).next()
- kVectC = kVectCons.next()

- (c,i) = kVectC.propose(com)
- sM(i).perform(c)

Generalized universality?

- while(true)
- for j = 1 to k: com(j) = commands(j).next()
- kVectC = kVectCons.next()

- (c,i) = kVectC.propose(com)
- read shared memory and update any missing c’
- sM(i).perform(c)
- write (c,i) in shared memory

Key idea

- ***Safety (commitment)***: a process does not perform a command unless all others know the command

Commitment

write (c) at level 1
let V1 be the set of values at level 1
if V1 has only c, write (commit, c) at level 2

let V2 be the set of values at level 2
if V2 has only (commit, c) then return(commit, c)
if V2 has some (commit, c') then return(adopt, c')
else return (adopt, c)

Commitment

- ***Invariant (1)***: if a value v is committed then no other value is returned

- ***Invariant (2)***: if all processes propose the same command then the command is committed

Generalized universality (step 0)

- newCom = commands.next()
- while(true)
- kVectC = kVectCons.next()

Generalized universality (step 1)

- …
- (c,i) = kVectC.propose(newCom)
- …

Generalized universality (step1-2)

- …
- (c,i) = kVectC.propose(newCom)
- vect(i) = commitment(i,c)
- …

Generalized universality (step1-2-2’)

- …
- (c,i) = kVectC.propose(newCom)
- vect(i) = commitment(i,c)
- for j = 1 to k except i:
  - vect(j) = commitment(newCom(j))

  …

Generalized universality (step 3)

…

for i = 1 to k

- if ok(vect(i)) then
  - sM(i).perform(vect(i))
  - newCom(i) = commands(i).next()
- else
  - newCom(i) = vect(i)

Key ideas

- ***Safety (commitment)***: a process does not perform a command unless all others know the command

- ***Liveness (success first)***: at least one process executes a command in every round

Generalized universality (step 3’)

…

for i = 1 to k

- If older(newCom(i),vect(i)) then
  sM(i).perform(newCom(i))
- If no(vect(i)) then newCom(i) = vect(i)
- else
- sM(i).perform(vect(i))
- If vect(i) = newCom(i) then
  - newCom(i) = commands(i).next()
- add(newCom(i),vect(i))

3 Key ideas

- ***Safety (commitment)***: a process does not perform a command unless all others know the command

- ***Liveness (success first)***: at least one process executes a command in every round

- ***Safety (old promises)***: a process might execute two commands at the same round

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Act 2
Modern Universality

Act 3
Generalized Universality

Generalized Universality

Consensus is the particular case of k-consensus

What if consensus is not available? Mistakes? Partitions?

Generalized Universality

With consensus

Processes implement a highly-available state machine

With k-consensus

Processes implement k state machines of which ***at least one*** is highly-available