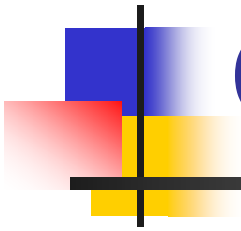
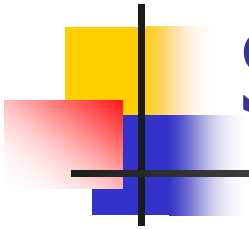


Subjective Logic and Other Challenges

A Human-centric Sensing Perspective



Subjective Logic

- The question it addresses is how trust (or uncertainty) “composes”.
  - Your friend X said they heard their friend Y say that m might have happened.
  - What should be your estimate of the likelihood of m based on this evidence?

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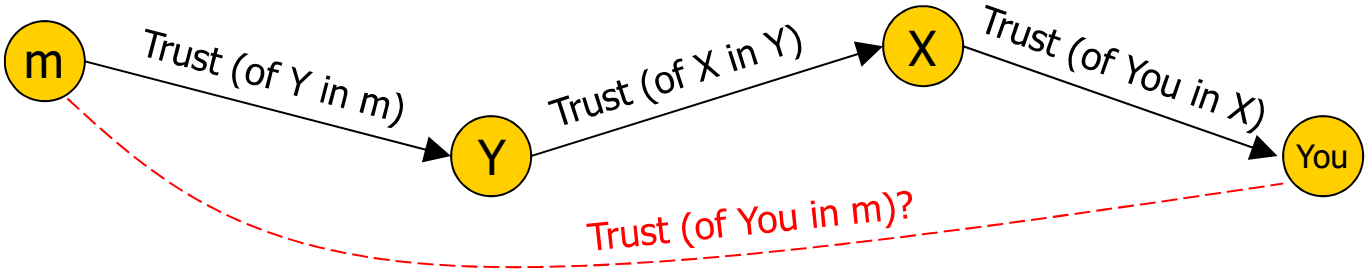
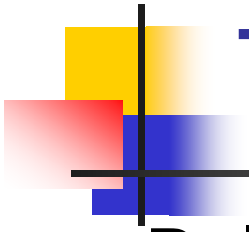
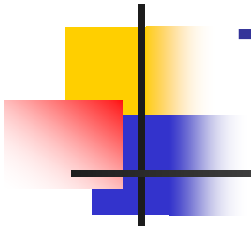




The Subjective Opinion

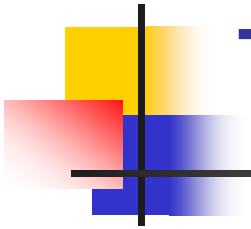
- Belief, Disbelief, and Uncertainty.
- Example: You asked John 100 questions.
  - He replied to 30 correctly
  - 20 incorrectly
  - 50 you could not tell if they were correct or not
- Your opinion of John's correctness is:
  - Belief (b) = 30/100
  - Disbelief (d) = 20/100
  - Uncertainty (u) = 50/100



The "Discount" Operator

- Your opinion of John is
  - (b=0.3, d=0.2, u=0.5)
- John's opinion of Sally is
  - (b=0.7, d=0.05, u=0.25)
- What should your opinion be of Sally?

The "Discount" Operator



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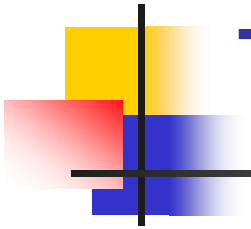
  - (b=0.3, d=0.2, u=0.5)
- John's opinion of Sally is
  - (b=0.7, d=0.05, u=0.25)
- What should your opinion be of Sally?
  - One possibility (max uncertainty):
    - Belief (at least) = 0.3 * 0.7
    - Disbelief (at least) = 0.3 * 0.05
    - Uncertainty (at most) = 1 – 0.3 (0.7 + 0.05)



The "Discount" Operator

Another possibility: Divide uncertainty proportionally then continue as before

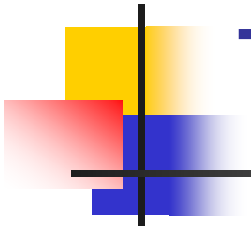
- Your opinion of John is
  - (b=0.3, d=0.2, u=0.5) → approx: (0.6, 0.4)
- John's opinion of Sally is
  - (b=0.7, d=0.05, u=0.25) → approx: (0.9333, 0.0667)
- What should your opinion be of Sally?
  - Belief = 0.6 * 0.9333 = 0.56
  - Disbelief = 0.6 * 0.0667 = 0.04
  - Uncertainty = 1 – 0.56 – 0.04 = 0.4

The "Discount" Operator

Another possibility: Divide uncertainty in half among belief and disbelief then continue as before

- Your opinion of John is
  - (b=0.3, d=0.2, u=0.5) → approx: (0.55, 0.45)
- John's opinion of Sally is
  - (b=0.7, d=0.05, u=0.25) → approx: (0.825, 0.175)
- What should your opinion be of Sally?
    - Belief = 0.55 * 0.825 = 0.45375
    - Disbelief = 0.55 * 0.175 = 0.09625
    - Uncertainty = 1 – 0.45375 – 0.09625 = 0.45

The "Discount" Operator



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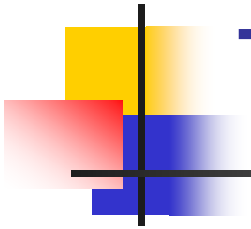
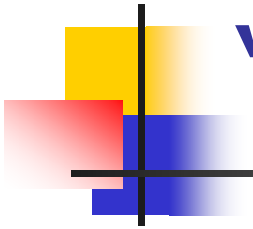


The "Discount" Operator

Other possibilities?

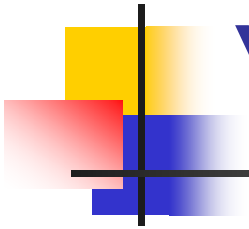
- Your opinion of John is
  - (b=0.3, d=0.2, u=0.5)
- John's opinion of Sally is
  - (b=0.7, d=0.05, u=0.25)
- Difficulties:
  - We have finite samples, not actual probabilities
  - We have uncertainty (unobserved samples)
  - We do not know the error distribution when someone is wrong: What do instances when John is wrong tell us about Sally?

Requirements of the "Discount" Operator



- Rd1: If John has pure belief in Sally, your belief in her should be equal to your belief in John.
- Example:
  - Your opinion of John is
    - (b=0.3, d=0.2, u=0.5)
  - John's opinion of Sally is
  - (b=1, d=0, u=0)
- What should your opinion be of Sally?
  - My belief in Sally should be 0.3

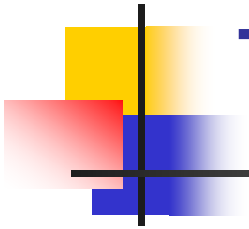
Requirements of the "Discount" Operator



- Rd2: If John is completely uncertain in Sally, you should be completely uncertain in her too.
- Example:
  - Your opinion of John is
    - (b=0.3, d=0.2, u=0.5)
  - John's opinion of Sally is
  - (b=0, d=0, u=1)
- What should your opinion be of Sally?
  - It should be (b=0, d=0, u=1)

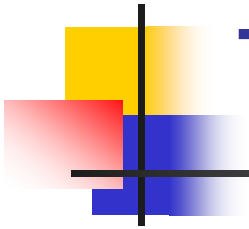
Requirements of the "Discount" Operator

- Rd3: Your belief in Sally (from John's input alone) should never be higher than your belief in John
- Example:
  - Your opinion of John is
    - (b=0.3, d=0.2, u=0.5)
  - John's opinion of Sally is
  - $(b_{John}, d_{John}, u_{John})$
- What should your opinion be of Sally?
  - Rule says that my belief in her should not exceed 0.3



The Fusion Operator

- Given n opinions about Sally that you formed from talking to n sources, how do you fuse them into one overall opinion?



The Fusion Operator

- Given n opinions about Sally that you formed from talking to n sources, how do you fuse them into one overall opinion?
  - Let *your* opinion about Sally that you formed from talking to source *i* be given by (b_i, d_i, u_i)
  - The overall opinion is the weighted average of opinions (b_i, d_i, u_i) each weighted by your effective belief in source *i* (actual belief plus half the uncertainty)

Main Results

- Paper derived a discounting operator and a fusion operator that outperform others in estimating ground truth credibility of sources in the presence of reporting chains

Operator	Md* $d_E(O^{a_z}_{a_{S\,|\circ}}, O^{a_z}_{Exp})$	Md* $d_E(O^{a_z}_{a_{S\,|J}}, O^{a_z}_{Exp})$	s^- ($\times 10^{10}$)	s^+ ($\times 10^{10}$)	z	Incr. Performance†
$\circ_1$	0.141	0.144	4.11	4.53	$-27.457^\ddagger$	$\approx +5\%$
$\circ_n$	0.156	0.155	4.40	3.95	$-29.586^\ddagger$	$\approx -5\%$
$\circ_2$	0.143	0.142	4.58	3.89	$-45.559^\ddagger$	$\approx -8\%$
$\circ_3$	0.163	0.145	5.12	3.51	$-104.098^\ddagger$	$\approx -19\%$

Subjective Logic Operators in Trust Assessment: An Empirical Study