

Fuzzy inference system to identify mobile fraudulent transactions

CRISTIAN ALZATE URREA

Motivation

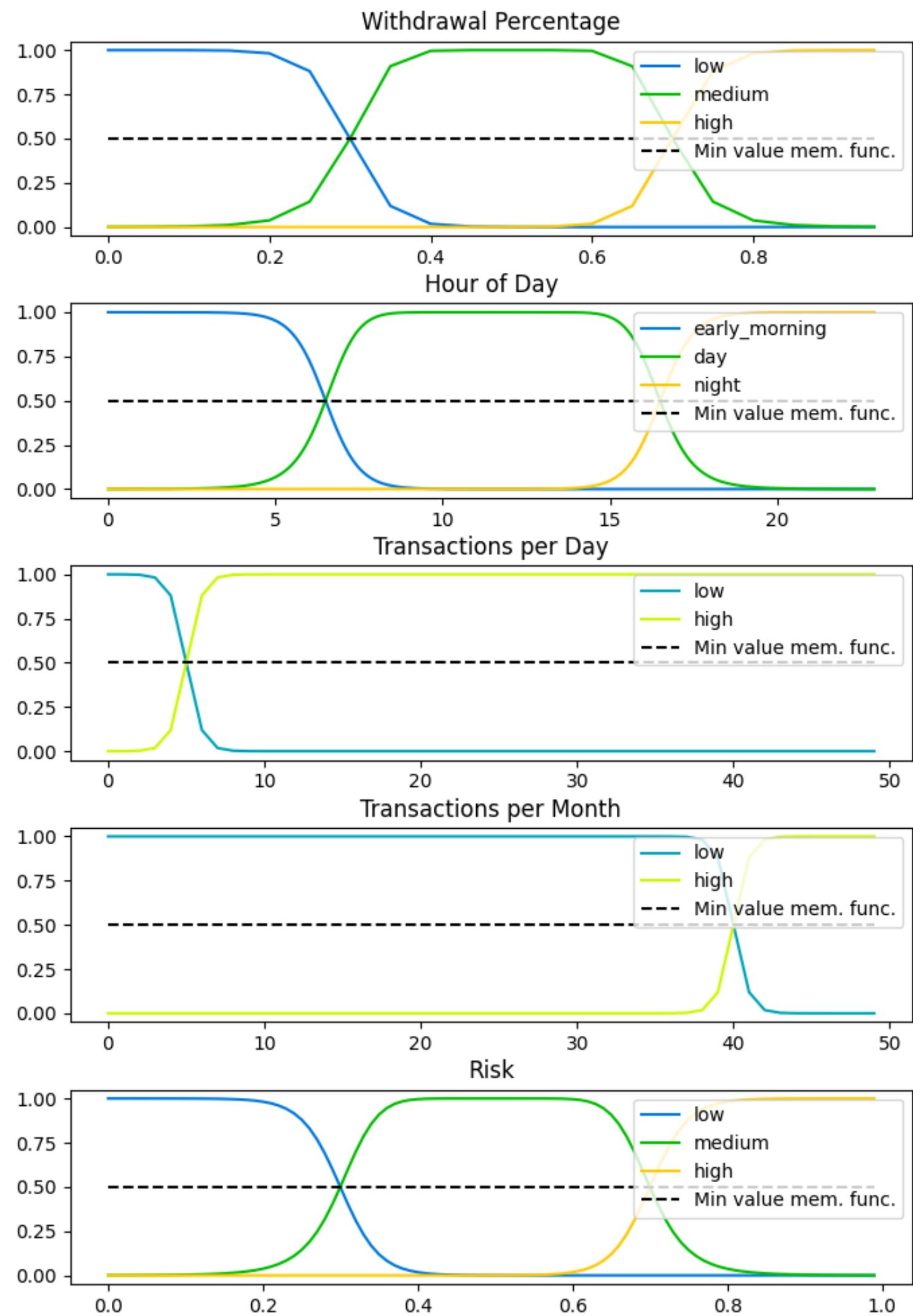
- **Problem:** Mobile fraudulent transactions are a growing threat affecting individuals, businesses, and financial institutions.
- **Challenge:** imbalanced data distributions, where fraudulent cases are significantly fewer.
- **Approach:** Fuzzy systems offer promise by leveraging expert knowledge



System variable

	Universe discourse	Categories
Withdrawal percentage	[0,1]	Low: [0,0.3) Medium: [0.3,0.7) High: [0.7,1]
Hour	[0, 24)	Early Morning: [0,6.5) Day: [6.5,16.5) Night: [16.5,24)
Transactions per day	[0, 50]	Low: [0,5] High: (5,50]
Transactions per month	[0, 50]	Low: [0,40) High: [40,50]
Risk	[0,1]	Low: [0,0.3) Medium: [0.3,0.7) High: [0.7,1]

Membership function



T-norms: min, algebraic product.

S-norms: max, algebraic sum

36 Rules

Rules definition

Rules	Withdrawal percentage			Hour of day			Transactions per day		Transaction per month		Risk Final			
	Low	Medium	High	Early morning	Day	Night	Low	High	Low	High	Low	Medium	High	
Rule 1	Yellow						Yellow		Yellow			Yellow		
Rule 2	Yellow			Yellow			Yellow			Yellow		Yellow		
Rule 3	Yellow			Yellow				Yellow				Yellow		Blue
Rule 4	Yellow			Yellow				Yellow				Yellow		
Rule 5	Yellow				Yellow		Yellow		Yellow		Yellow			
Rule 6	Yellow				Yellow		Yellow		Yellow		Yellow			
Rule 7	Yellow				Yellow			Yellow		Yellow			Yellow	Blue
Rule 8	Yellow				Yellow			Yellow		Yellow				
Rule 9	Yellow					Yellow	Yellow		Yellow		Yellow			
Rule 10	Yellow						Yellow		Yellow		Yellow			
Rule 11	Yellow						Yellow		Yellow		Yellow		Yellow	Blue
Rule 12	Yellow						Yellow		Yellow		Yellow			
Rule 13		Yellow		Yellow			Yellow		Yellow			Yellow		
Rule 14		Yellow		Yellow			Yellow		Yellow			Yellow		
Rule 15		Yellow		Yellow				Yellow		Yellow			Yellow	Blue
Rule 16		Yellow		Yellow				Yellow		Yellow			Yellow	
Rule 17		Yellow			Yellow		Yellow		Yellow		Yellow			
Rule 18		Yellow			Yellow		Yellow		Yellow		Yellow			
Rule 19		Yellow			Yellow			Yellow		Yellow			Yellow	Blue
Rule 20		Yellow			Yellow			Yellow		Yellow				
Rule 21		Yellow				Yellow	Yellow		Yellow		Yellow			
Rule 22		Yellow					Yellow		Yellow		Yellow			
Rule 23		Yellow					Yellow		Yellow		Yellow		Yellow	Blue
Rule 24		Yellow					Yellow		Yellow		Yellow			
Rule 25			Yellow					Yellow		Yellow			Yellow	
Rule 26			Yellow					Yellow		Yellow				
Rule 27			Yellow					Yellow		Yellow			Yellow	Blue
Rule 28			Yellow					Yellow		Yellow			Yellow	
Rule 29			Yellow		Yellow		Yellow		Yellow		Yellow			
Rule 30			Yellow		Yellow		Yellow		Yellow		Yellow			
Rule 31			Yellow		Yellow			Yellow		Yellow			Yellow	Blue
Rule 32			Yellow		Yellow			Yellow		Yellow				
Rule 33			Yellow			Yellow	Yellow		Yellow		Yellow			
Rule 34			Yellow			Yellow	Yellow		Yellow		Yellow			
Rule 35			Yellow			Yellow		Yellow		Yellow				Blue
Rule 36			Yellow			Yellow		Yellow		Yellow				

Rules definition

23 Rules

	Withdrawal percentage			Hour of day			Transactions per day		Transaction per month		Risk Final		
Rules	Low	Medium	High	Early morning	Day	Night	Low	High	Low	High	Low	Medium	High
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Rule 3				Yellow			Yellow		Yellow			Yellow	
Rule 4					Yellow		Yellow		Yellow		Yellow		
Rule 5					Yellow		Yellow		Yellow		Yellow		
Rule 6					Yellow		Yellow		Yellow		Yellow		
Rule 7						Yellow	Yellow		Yellow		Yellow		
Rule 8						Yellow	Yellow		Yellow		Yellow		
Rule 9						Yellow	Yellow		Yellow			Yellow	
Rule 10		Yellow		Yellow			Yellow		Yellow			Yellow	
Rule 11		Yellow		Yellow			Yellow		Yellow			Yellow	
Rule 12		Yellow		Yellow			Yellow		Yellow			Yellow	
Rule 13		Yellow											
Rule 14		Yellow											
Rule 15		Yellow											
Rule 16		Yellow											
Rule 17		Yellow											
Rule 18		Yellow					Yellow		Yellow			Yellow	
Rule 19			Yellow		Yellow		Yellow		Yellow		Yellow		
Rule 20			Yellow		Yellow		Yellow		Yellow		Yellow		
Rule 21			Yellow		Yellow		Yellow		Yellow		Yellow		
Rule 22				Orange	Orange		Orange		Orange				Orange
Rule 23							Orange		Orange				Orange

If the withdrawal percentage is **high** and the hour is **early morning or night**, then the risk is **high**.



Rules definition

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	Withdrawal percentage			Hour of day			Transactions per day		Transaction per month		Risk Final		
Rules	Low	Medium	High	Early morning	Day	Night	Low	High	Low	High	Low	Medium	High
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Rule 12		Yellow		Yellow				Yellow		Yellow			Yellow
Rule 13		Yellow			Yellow			Yellow					
Rule 14		Yellow											
Rule 15		Yellow											
Rule 16		Yellow											
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Rule 18		Yellow											
Rule 19			Yellow										
Rule 20			Yellow		Yellow			Yellow		Yellow		Yellow	
Rule 21			Yellow		Yellow			Yellow		Yellow			
Rule 22			Yellow		Yellow			Yellow		Yellow			Yellow
Rule 23			Yellow		Yellow			Yellow		Yellow		Yellow	Yellow

If transactions per day is **high** and transactions per month is **low**, then the risk is **high**.



Comparion of decision surface

T-norms: min, algebraic produc

S-norm: max, algebraic sum

Inputs: 0.7, 9, 5, 20

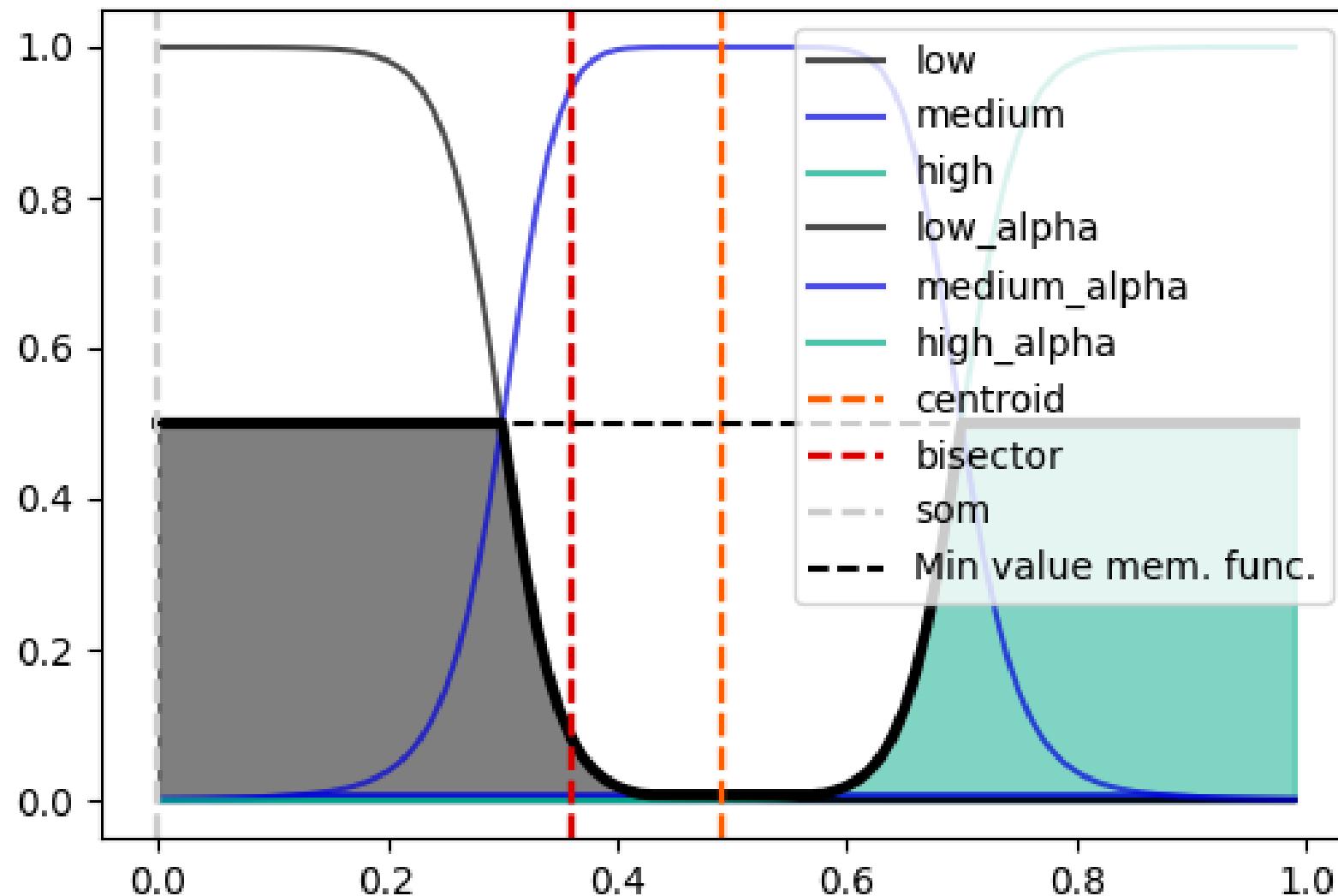
Comparion of decision surface

T-norms: min, algebraic produc

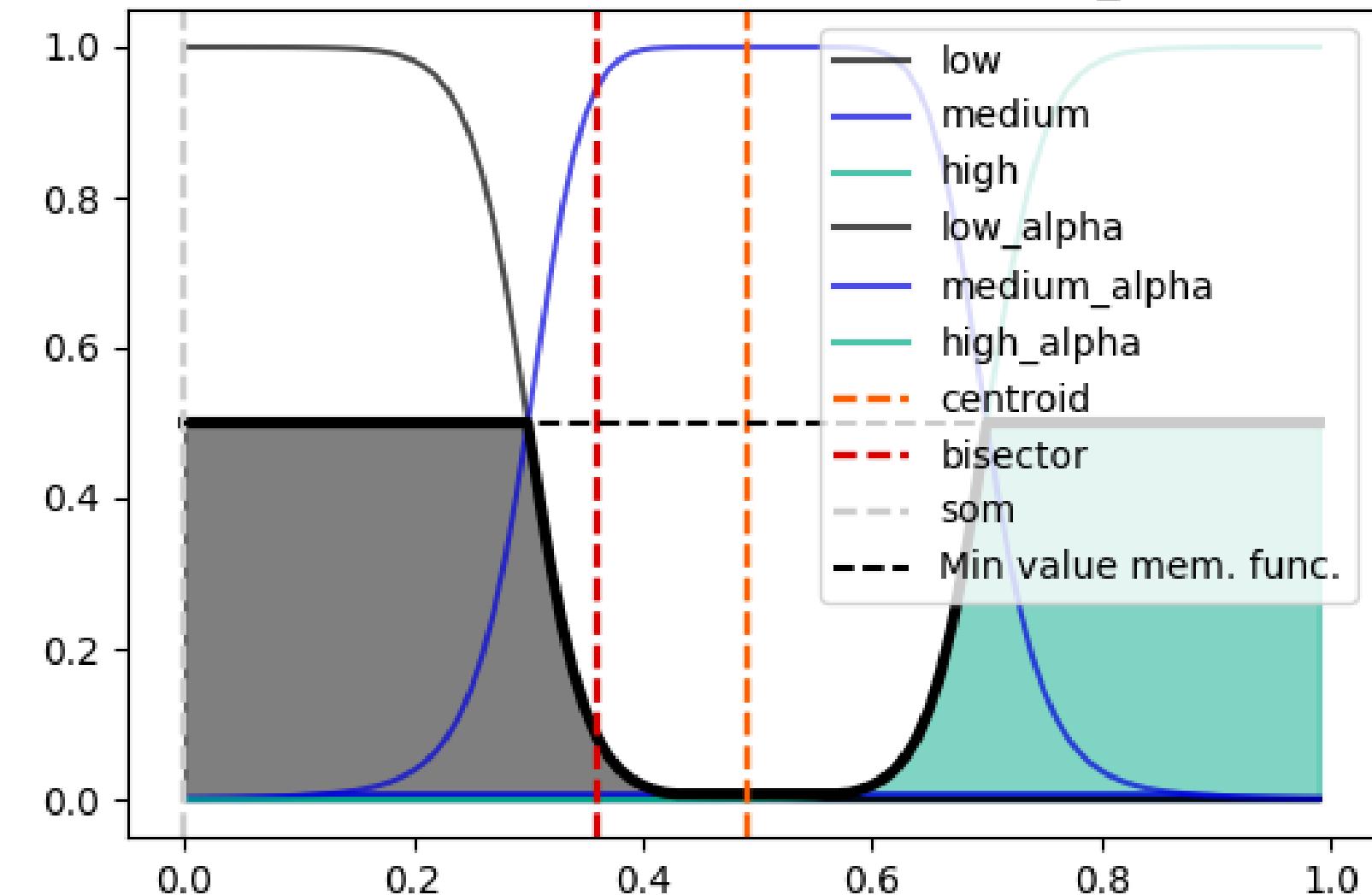
S-norm: max, algebraic sum

Inputs: 0.7, 9, 5, 20

Risk with different defuzzification methods
and t-norm: fmin, s-norm: fmax



Risk with different defuzzification methods
and t-norm: fmin, s-norm: algebraic_sum

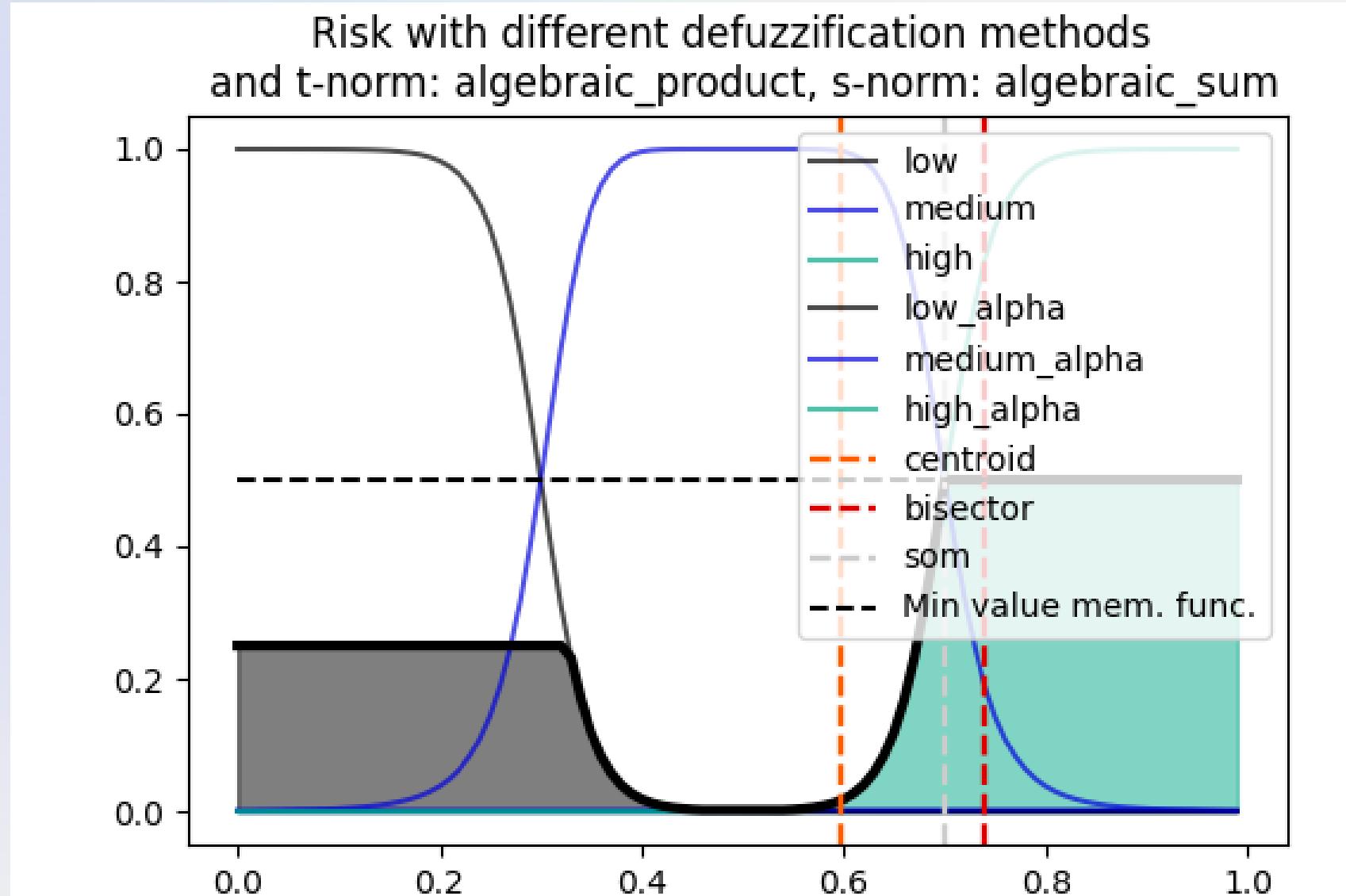
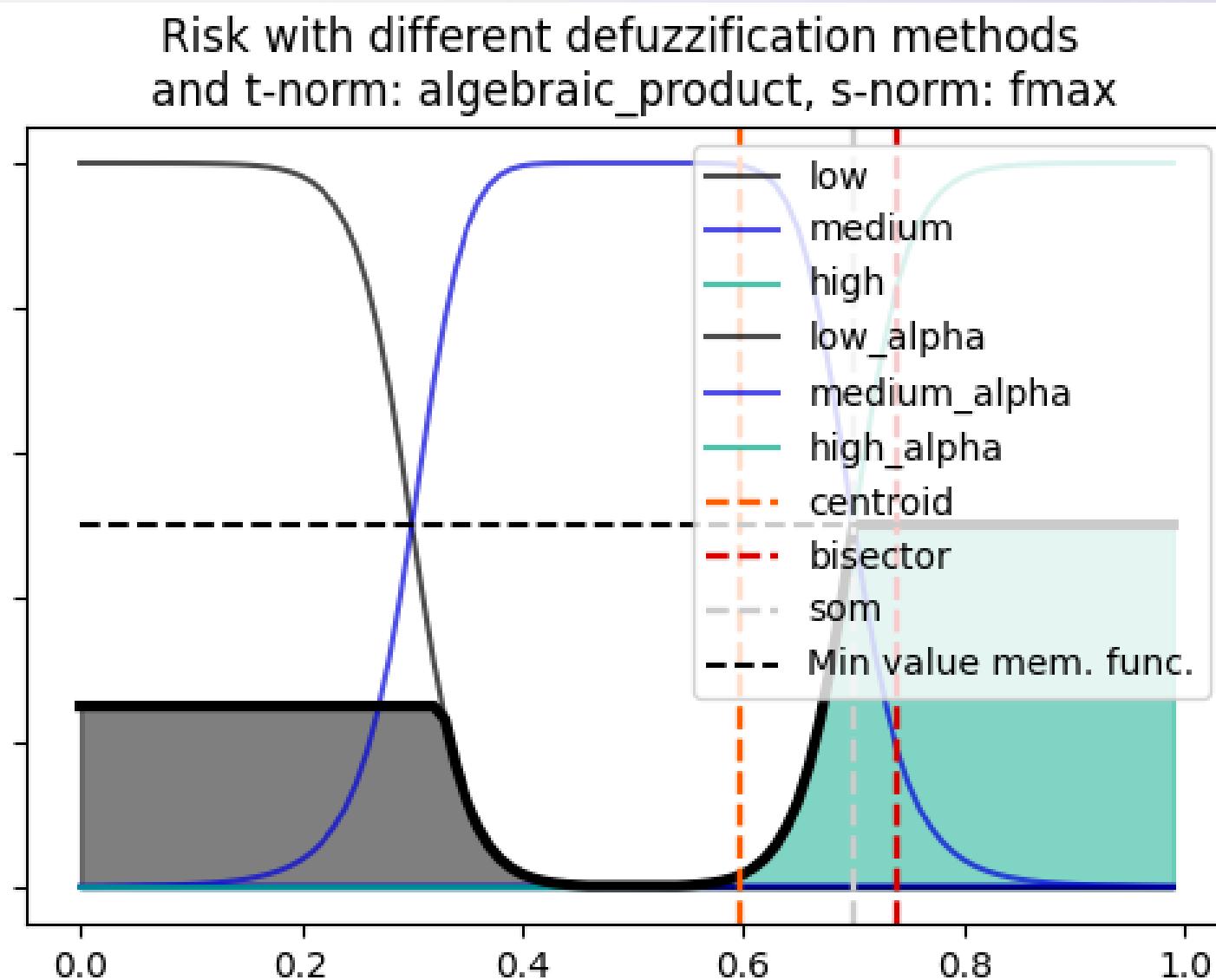


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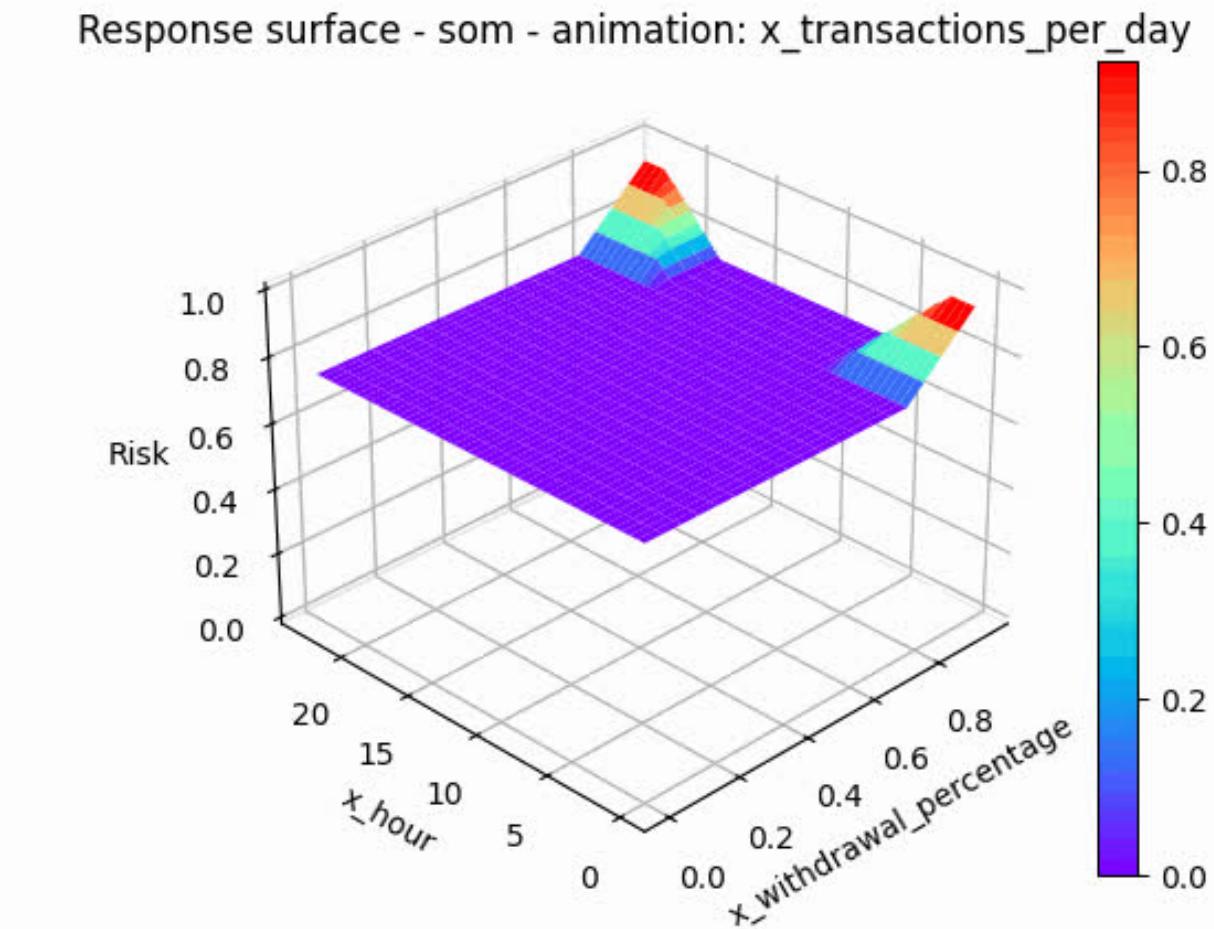
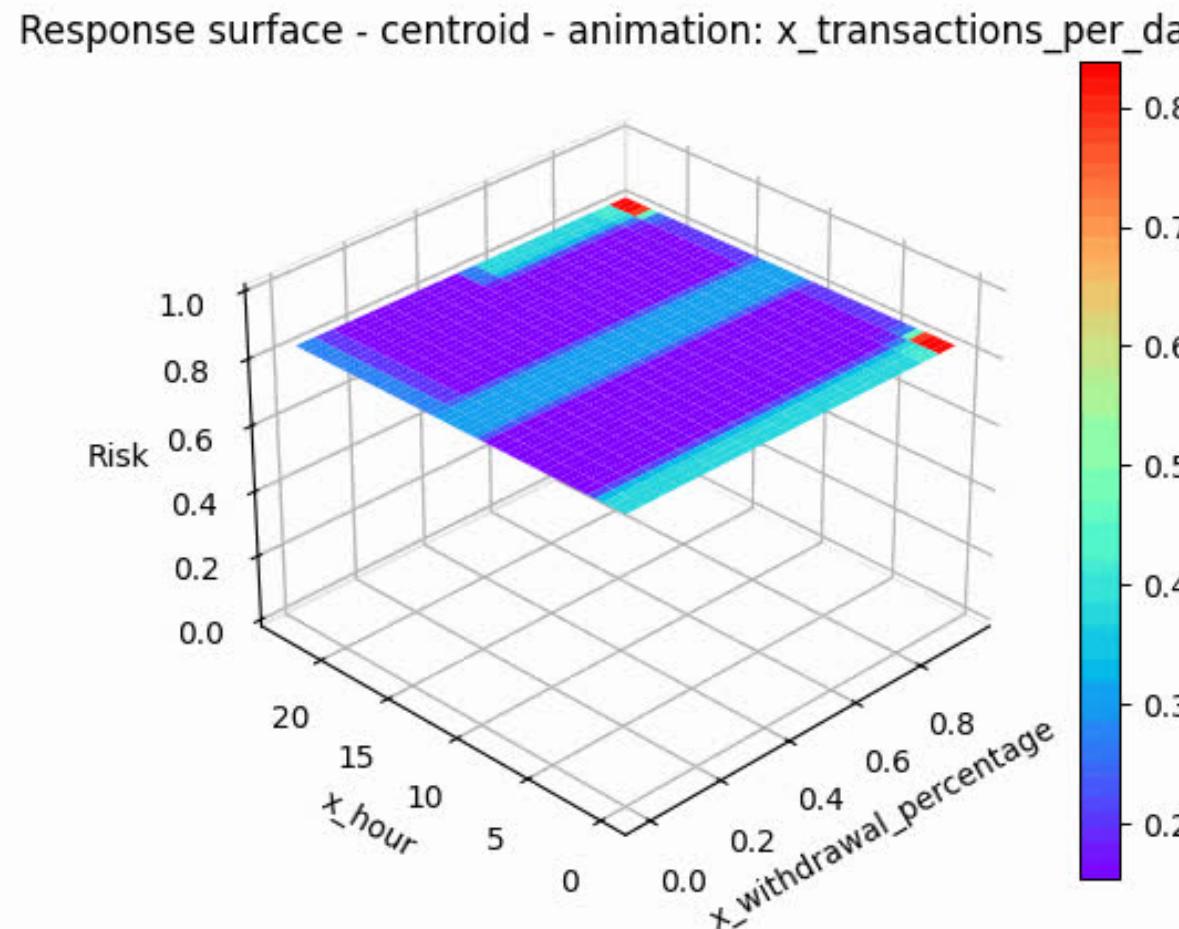
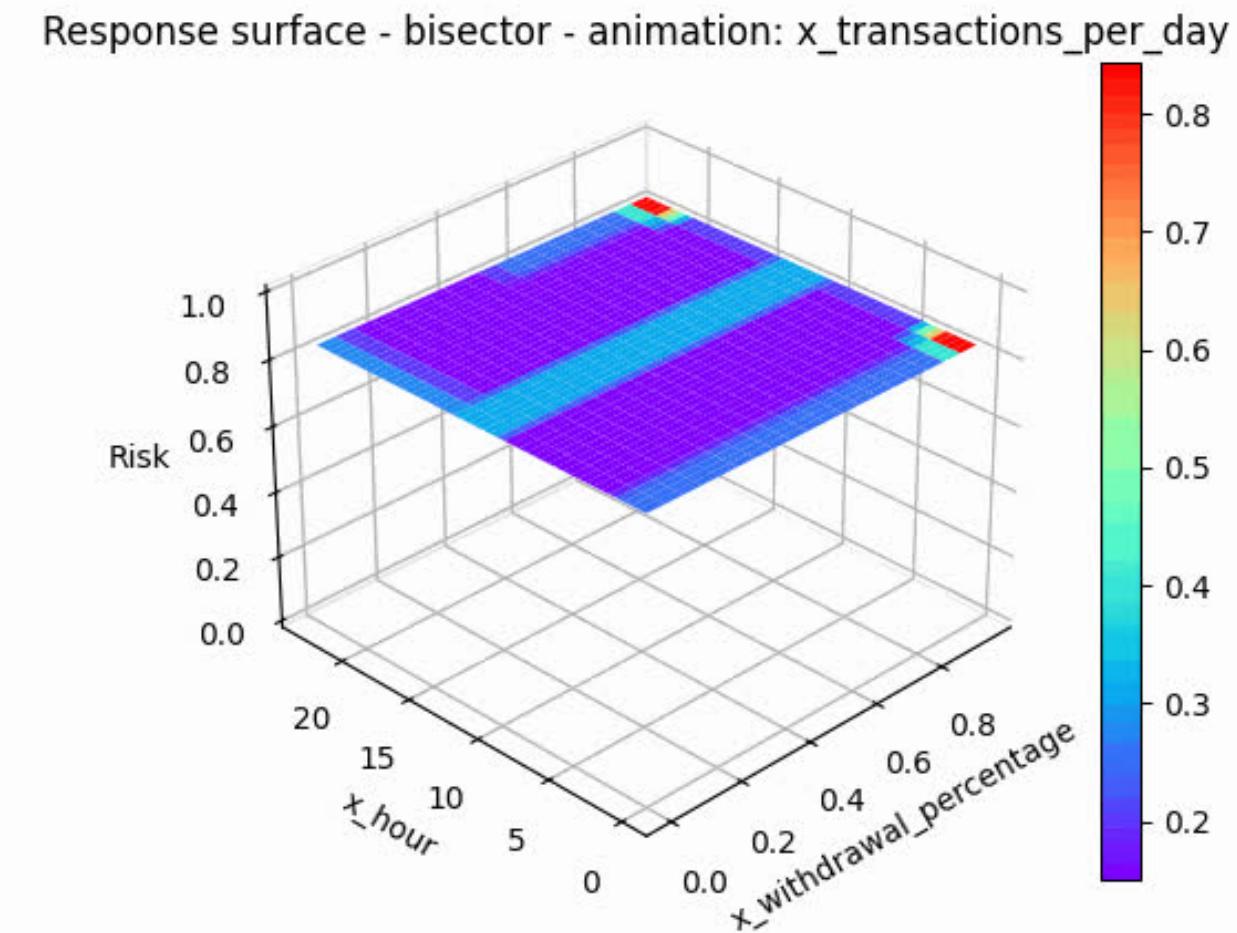


Comparion of response surface

Comparison of response surface

T-norms: fmin

S-norm: algebraic sum

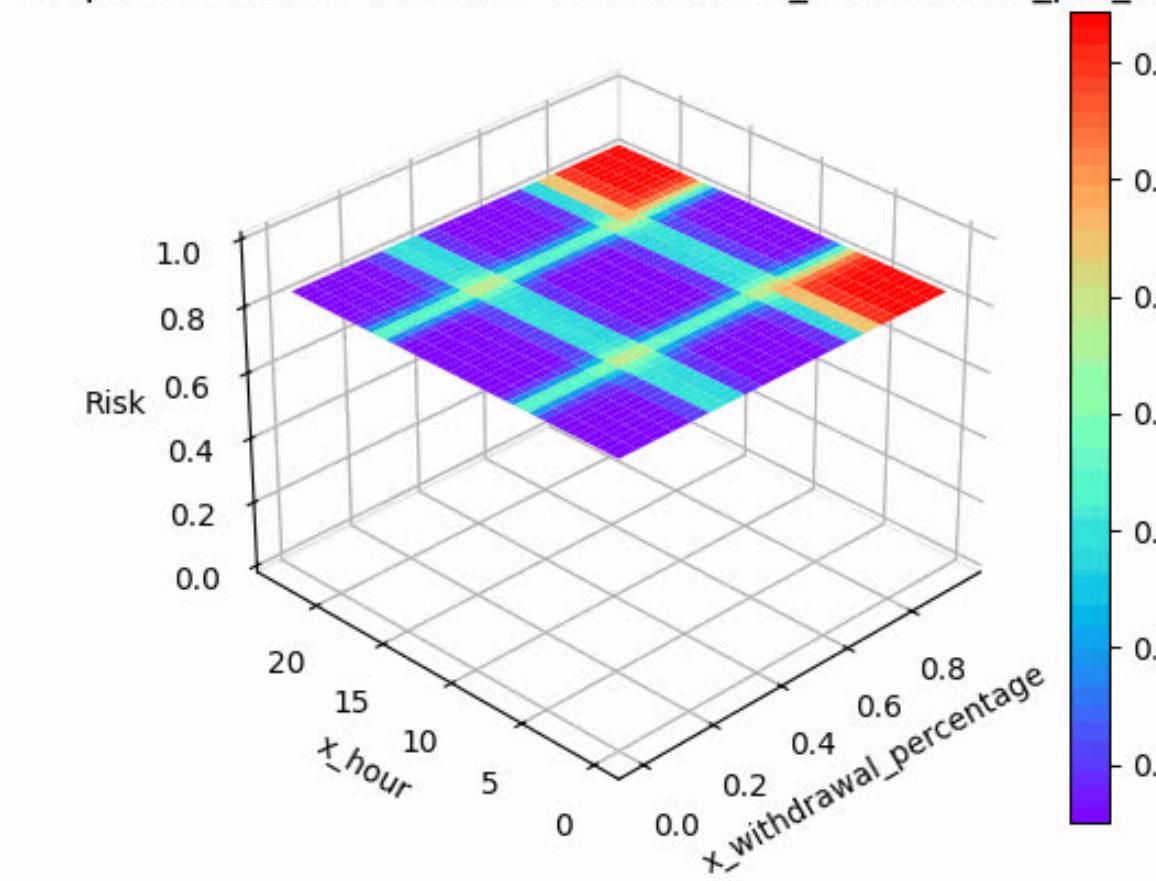


Comparison of response surface

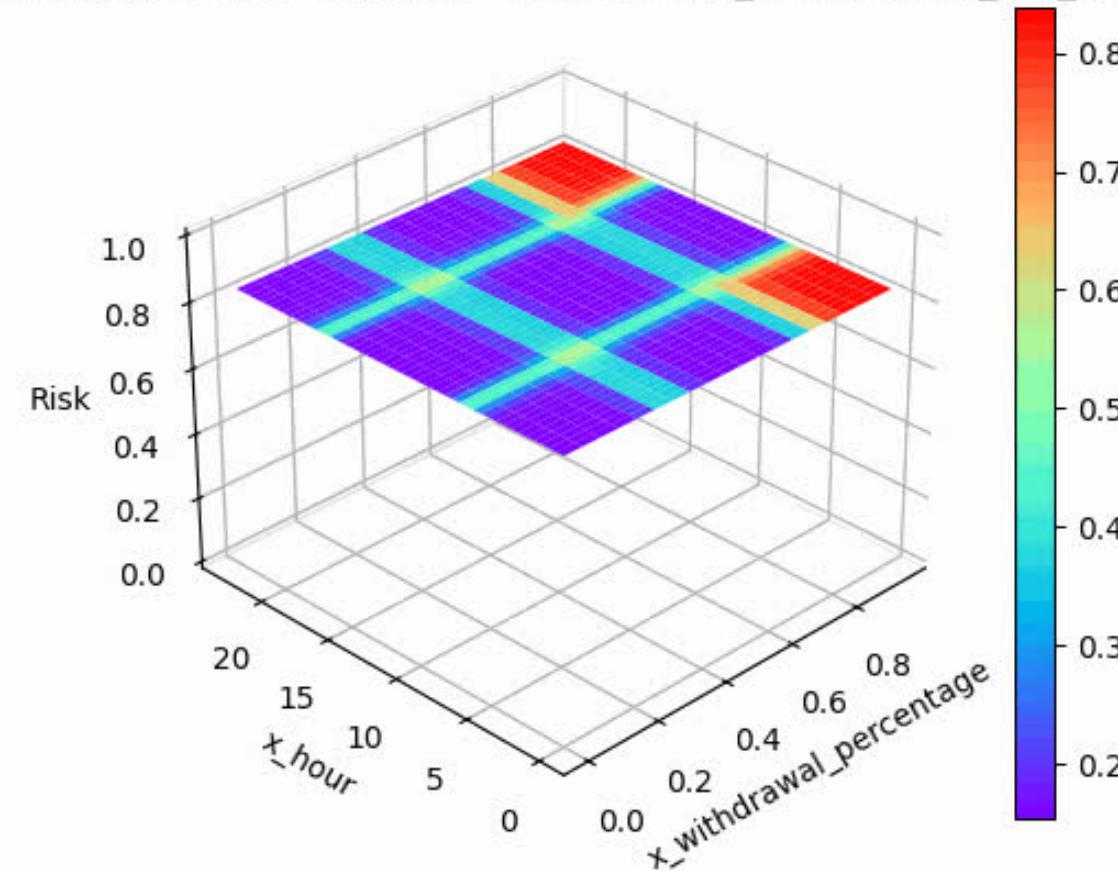
T-norms: algebraic product

S-norm: algebraic sum

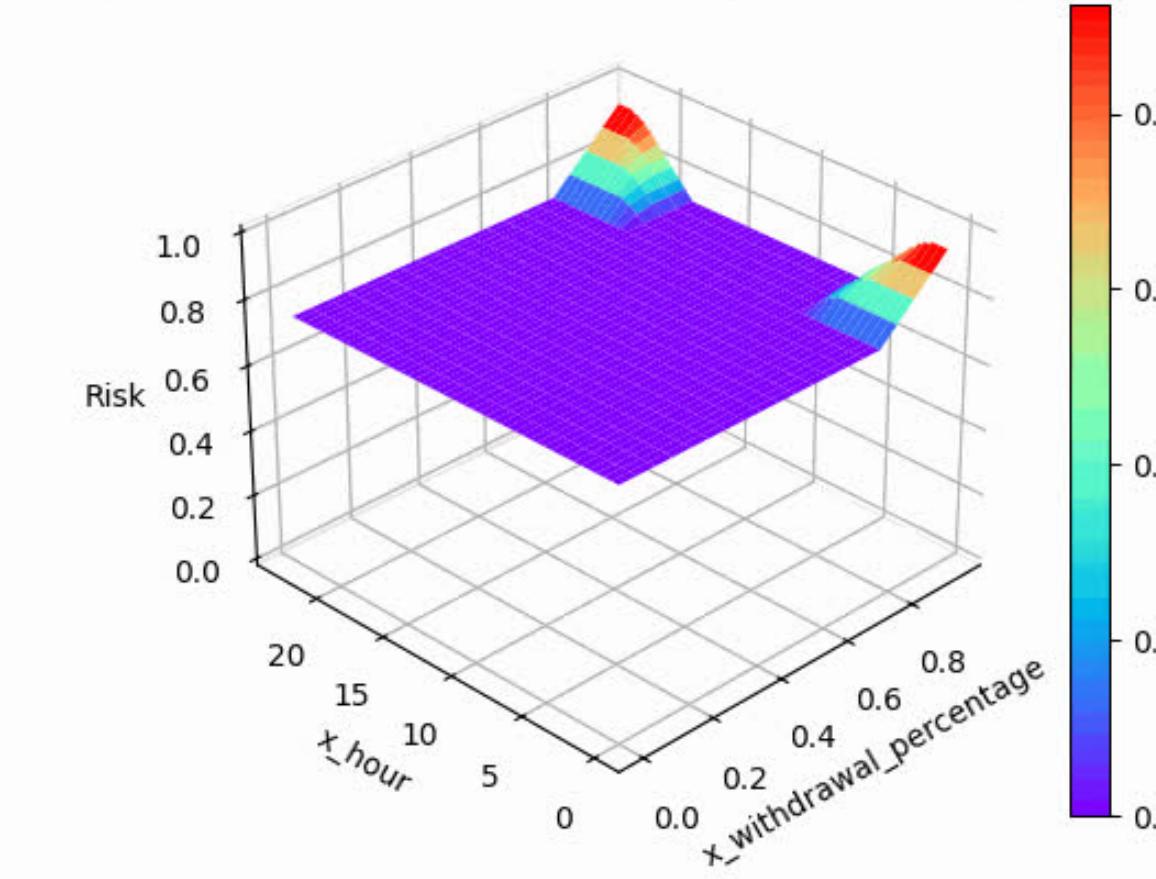
Response surface - bisector - animation: `x_transactions_per_day`



Response surface - centroid - animation: `x_transactions_per_day`



Response surface - som - animation: `x_transactions_per_day`

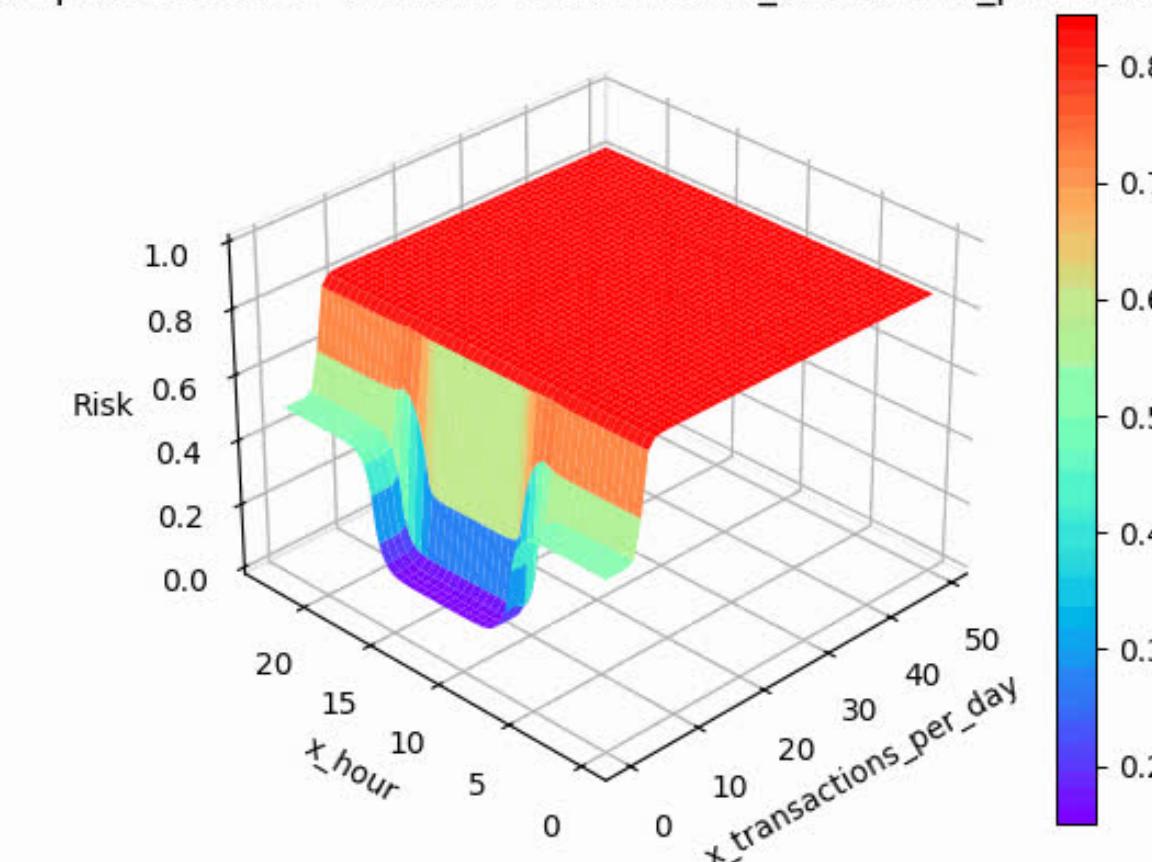


Comparison of response surface

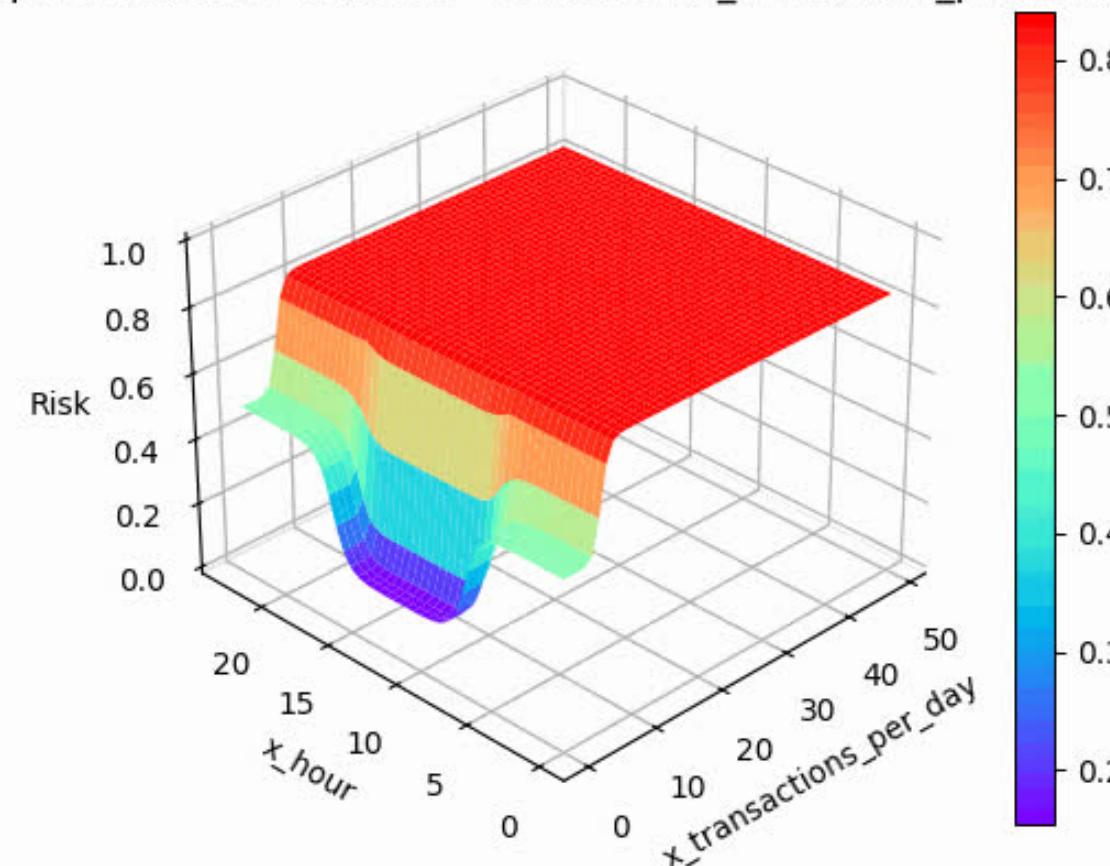
T-norms: algebraic product

S-norm: algebraic sum

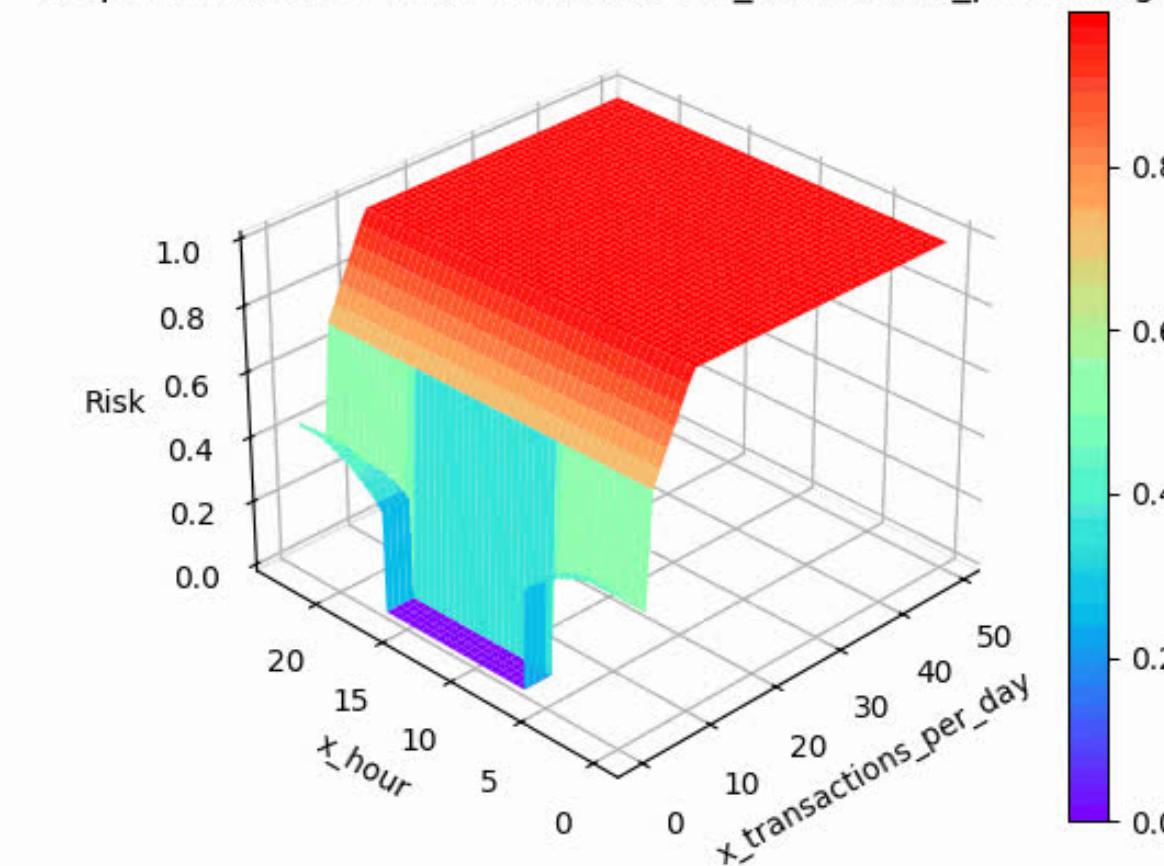
Response surface - bisector - animation: `x_withdrawal_percentage`



Response surface - centroid - animation: `x_withdrawal_percentage`



Response surface - som - animation: `x_withdrawal_percentage`



CONCLUSION

- Changing the defuzzification method alters the model estimation.
- Variables such as transactions per day or hour have a strong influence on risk.
- The work can be extended to the Neuro-Fuzzy Expert System, as it can improve the identification of unusual behaviors.

REFERENCES

- Monto máximo de pagos - centro de ayuda bancolombia.<https://www.bancolombia.com/centro-de-ayuda/preguntas-recuentes/monto-maximo-pagos>. Accessed: February 18, 2024.
- Sikdar Md S Askari and Md Anwar Hussain. Ifdtc4. 5: Intuitionistic fuzzy logic based decision tree for e-transactional fraud detection. Journal of Information Security and Applications, 52:102469, 2020.
- Tanmay Kumar Behera and Suvasini Panigrahi. Credit card fraud detection using a neuro-fuzzy expert system. In Computational Intelligence in Data Mining: Proceedings of the International Conference on CIDM, 10-11 December 2016, pages 835–843. Springer, 2017.
- Jisha Shaji and Dakshata Panchal. Improved fraud detection in ecommerce transactions. In 2017 2nd International Conference on Communication Systems, Computing and IT Applications (CSCITA), pages 121–126. IEEE, 2017.