Modelling the Interaction Levels in HCI using an Intelligent Hybrid System with Interactive Agents: A Case Study of an Interactive Museum Exhibition Module in Mexico

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1. FIS Configurations

1.1. Empirical FIS Configuration

1.1.1. Empirical FIS inputs setup

Table S1. Inputs configuration of the empirical FIS. s= standard deviation, m= average

Input	Type Member Function	Linguistic Variable [params]
Presence	Gauss Member Function	Very Bad : [s=0.085, m=3.47e-18] Bad : [s=0.085, m=0.2] Regular : [s=0.085, m=0.4] Good : [s=0.085, m=0.6] Very Good : [s=0.085, m=0.8] Excellent : [s=0.085, m=1]
Interactivity	Gauss Member Function	Very Bad : [s=0.085, m=3.47e-18] Bad : [s=0.085, m=0.2] Regular : [s=0.085, m=0.4] Good : [s=0.085, m=0.6] Very Good : [s=0.085, m=0.8] Excellent : [s=0.085, m=1]
Control	Gauss Member Function	Very Bad : [s=0.085, m=3.47e-18] Bad : [s=0.085, m=0.2] Regular : [s=0.085, m=0.4] Good : [s=0.085, m=0.6] Very Good : [s=0.085, m=0.8] Excellent : [s=0.085, m=1]
FeedBack	Gauss Member Function	Very Bad : [s=0.085, m=3.47e-18] Bad : [s=0.085, m=0.2] Regular : [s=0.085, m=0.4] Good : [s=0.085, m=0.6] Very Good : [s=0.085, m=0.8] Excellent : [s=0.085, m=1]
Creativity	Gauss Member Function	Very Bad : [s=0.085, m=3.47e-18] Bad : [s=0.085, m=0.2]

		Regular : [s=0.085, m=0.4]
		Good : [s=0.085, m=0.6]
		Very Good : [s=0.085, m=0.8]
		Excellent : [s=0.085, m=1]
Productivity	Gauss Member Function	Very Bad : [s=0.085, m=3.47e-18]
		Bad : [s=0.085, m=0.2]
		Regular : [s=0.085, m=0.4]
		Good : [s=0.085, m=0.6]
		Very Good : [s=0.085, m=0.8]
		Excellent : [s=0.085, m=1]
Communication	Gauss Member Function	Very Bad : [s=0.085, m=3.47e-18]
		Bad : [s=0.085, m=0.2]
		Regular : [s=0.085, m=0.4]
		Good : [s=0.085, m=0.6]
		Very Good : [s=0.085, m=0.8]
		Excellent : [s=0.085, m=1]
Adaptation	Gauss Member Function	Very Bad : [s=0.085, m=3.47e-18]
		Bad : [s=0.085, m=0.2]
		Regular : [s=0.085, m=0.4]
		Good : [s=0.085, m=0.6]
		Very Good : [s=0.085, m=0.8]
		Excellent : [s=0.085, m=1]

1.1.2. Empirical FIS outputs setup

Table S2. Outputs configuration of the empirical FIS. s= standard deviation, m= average

Output	Type Member Function	Linguistic Variable [params]
ELI (Level 0)	Gauss Member Function	Low : [s=0.05, m=0] High : [s=0.3, m=1]
VLI (Level 1)	Gauss Member Function	Low : [s=0.05, m=0] High : [s=0.3, m=1]
LI (Level 2)	Gauss Member Function	Low : [s=0.025, m=0] High : [s=0.3, m=1]
MI (Level 3)	Gauss Member Function	Low : [s=0.025, m=0] High : [s=0.5, m=1]
HI (Level 4)	Gauss Member Function	Low : [s=0.025, m=0] High : [s=0.5, m=1]
EHI (Level 5)	Gauss Member Function	Low : [s=0.05, m=0] High : [s=0.3, m=1]

1.1.3. Empirical FIS Rules Setup

Table S3. Inference Fuzzy Rules of the Empirical FIS.

No	Inference Fuzzy Rules
1	If (Presence is Very Bad) and (Interactivity is Very Bad) and (Control is Very Bad) and (FeedBack is Very Bad) and (Creativity is Very Bad) and (Productivity is Very Bad) and (Communication is Very BAD) and (Adaptation is Very Bad) then (Level 0 is High)(Level 1 is Low)(Level 2 is Low)(Level 3 is Low)(Level 4 is Low)(Level 5 is Low).
2	If (Presence is Bad) and (Interactivity is Bad) and (Control is Bad) and (FeedBack is Bad) and (Creativity is Bad) and (Productivity is Bad) and (Communication is Bad) and (Adaptation is Bad)

	then (Level 0 is Low)(Level 1 is High)(Level 2 is Low)(Level 3 is Low)(Level 4 is Low)(Level 5 is Low).
3	If (Presence is Regular) and (Interactivity is Regular) and (Control is Regular) and (FeedBack is Regular) and (Creativity is Regular) and (Productivity is Regular) and (Communication is Regular) and (Adaptation is Regular) then (Level 0 is Low)(Level 1 is Low)(Level 2 is High)(Level 3 is Low)(Level 4 is Low)(Level 5 is Low).
4	If (Presence is Good) and (Interactivity is Good) and (Control is Good) and (FeedBack is Good) and (Creativity is Good) and (Productivity is Good) and (Communication is Good) and (Adaptation is Good) then (Level 0 is Low)(Level 1 is Low)(Level 2 is Low)(Level 3 is High)(Level 4 is Low)(Level 5 is Low).
5	If (Presence is Very Good) and (Interactivity is Very Good) and (Control is Very Good) and (FeedBack is Very Good) and (Creativity is Very Good) and (Productivity is Very Good) and (Communication is Very Good) and (Adaptation is Very Good) then (Level 0 is Low)(Level 1 is Low)(Level 2 is Low)(Level 3 is Low)(Level 4 is High)(Level 5 is Low).
6	If (Presence is Excellent) and (Interactivity is Excellent) and (Control is Excellent) and (FeedBack is Excellent) and (Creativity is Excellent) and (Productivity is Excellent) and (Communication is Excellent) and (Adaptation is Excellent) then (Level 0 is Low)(Level 1 is Low)(Level 2 is Low)(Level 3 is Low)(Level 4 is Low)(Level 5 is High).

1.2. Data Mined Type-1 FIS Configuration

1.2.1. Data Mined Type-1 FIS inputs setup

Table S4. Inputs configuration of the Data Mined Type-1 FIS. s= standard deviation, m= average

Input	Type Member Function	Linguistic Variable [params]
Presence	Gauss Member Function	Very Bad : [s=0.1942, m=0.2569] Bad : [s=0.1327, m=0.5009] Regular : [s=0.086, m=0.7002] Good : [s=0.0832, m=0.7204] Very Good : [s=0.1108, m=0.8619] Excellent : [s=0.1042, m=0.9747]
Interactivity	Gauss Member Function	Very Bad : [s=0.1945, m=0.2510] Bad : [s=0.1417, m=0.4659] Regular : [s=0.0856, m=0.6975] Good : [s=0.0854, m=0.7067] Very Good : [s=0.1149, m=0.8526] Excellent : [s=0.1010, m=0.9814]
Control	Gauss Member Function	Very Bad : [s=0.1883, m=0.2807] Bad : [s=0.1347, m=0.4951] Regular : [s=0.0864, m=0.7105] Good : [s=0.084, m=0.7249] Very Good : [s=0.1122, m=0.8699] Excellent : [s=0.1033, m=0.9753]
FeedBack	Gauss Member Function	Very Bad : [s=0.1899, m=0.2039] Bad : [s=0.1586, m=0.3795] Regular : [s=0.14, m=0.4805] Good : [s=0.1213, m=0.6069]

Output	Type Member Function	Linguistic Variable [params]
		Very Good : [s=0.1527, m=0.879] Excellent : [s=0.1132, m=0.9879]
Creativity	Gauss Member Function	Very Bad : [s=0.1668, m=0.1337] Bad : [s=0.1291, m=0.306] Regular : [s=0.1127, m=0.4037] Good : [s=0.1002, m=0.4832] Very Good : [s=0.1229, m=0.6677] Excellent : [s=0.19, m=0.8881]
Productivity	Gauss Member Function	Very Bad : [s=0.1758, m=0.0795] Bad : [s=0.1431, m=0.2477] Regular : [s=0.1127, m=0.3926] Good : [s=0.1069, m=0.4389] Very Good : [s=0.1214, m=0.6402] Excellent : [s=0.2031, m=0.863]
Communication	Gauss Member Function	Very Bad : [s=0.1939, m=0.2543] Bad : [s=0.1608, m= 0.4169] Regular : [s=0.1273, m=0.5786] Good : [s=0.1141, m=0.6588] Very Good : [s=0.1322, m=0.9113] Excellent : [s=0.1008, m=0.9862]
Adaptation	Gauss Member Function	Very Bad : [s=0.1985, m=0.2385] Bad : [s=0.1616, m=0.4129] Regular : [s=0.1045, m=0.6581] Good : [s=0.0994, m=0.6789] Very Good : [s=0.1242, m=0.851] Excellent : [s=0.1063, m=0.981]

1.2.2. Data Mined Type-1 FIS outputs setup

Table S5. Outputs configuration of the Data Mined Type-1 FIS. s= standard deviation, m= average

Output	Type Member Function	Linguistic Variable [params]
ELI (Level 0)	Gauss Member Function	Very Bad : [s=0.0093, m=0.0004] Bad : [s=0.0098, m=0.0007] Regular : [S=0.0136, m=0.0076] Good : [s=0.0155, m=0.0122] Very Good : [s=0.0189, m=0.0156] Excellent : [s=0.0387, m=0.0643]
VLI (Level 1)	Gauss Member Function	Very Bad : [s=0.0138, m= 4.627e-05] Bad : [s=0.0143, m=7.975e-05] Regular : [s=0.0153, m=0.0008] Good : [s=0.0157, m=0.0013] Very Good : [s=0.0165, m=0.0014] Excellent : [s=0.3187, m=0.9099]
LI (Level 2)	Gauss Member Function	Very Bad : [s=0.0365, m=0.0005] Bad : [s=0.038, m=0.0008] Regular : [s=0.0425, m=0.0078] Good : [s=0.0439, m=0.0123] Very Good : [s=0.0445, m=0.0124] Excellent : [s=0.3240, m=0.9695]
MI (Level 3)	Gauss Member Function	Very Bad : [s=0.075, m=0.0008] Bad : [s=0.0773, m=0.0012] Regular : [s=0.0789, m=0.0055]

		Good : [s=0.0757, m=0.0055]
		Very Good : [s=0.2927, m=0.9497]
		Excellent : [s=0.2967, m=0.9651]
HI (Level 4)	Gauss Member Function	Very Bad : [s=0.1439, m=0.0032]
		Bad : [s=0.1285, m=0.0069]
		Regular : [s=0.1352, m=0.0074]
		Good : [s=0.1444, m=0.0172]
		Very Good : [s=0.144, m=0.0227]
		Excellent : [s=0.2372, m=0.9966]
EHI (Level 5)	Gauss Member Function	Very Bad : [s=0.0882, m=0.0004]
		Bad : [s=0.099, m=0.0005]
		Regular : [s=0.0914, m=0.00052]
		Good : [s=0.0961, m=0.0014]
		Very Good : [s=0.0952, m=0.0017]
		Excellent : [s=0.2769, m=0.9951]

1.2.3. Data Mined Type-1 FIS rules setup

Table S6. Rules configuration of the Data Mined Type-1 FIS.

No	Inference Fuzzy Rules
1	If (Presence is Very Good) and (Interactivity is Very Good) and (Control is Very Good) and (FeedBack is Very Good) and (Creativity is Very Good) and (Productivity is Very Good) and (Communication is Very Good) and (Adaptation is Very Good) then (ELI(Level 0) is Bad)(VLI(Level 1) is Bad)(LI(Level 2) is Bad)(M I(Level 3) is Bad)(HI(Level 4) is Excellent)(EHI(Level 5) is Bad).
2	If (Presence is Excellent) and (Interactivity is Excellent) and (Control is Excellent) and (FeedBack is Excellent) and (Creativity is Excellent) and (Productivity is Excellent) and (Communication is Excellent) and (Adaptation is Excellent) then (ELI(Level 0) is Very Bad)(VLI(Level 1) is Very Bad)(LI(Level 2) is Very Bad)(MI(Level 3) is Very Bad)(HI(Level 4) is Very Bad)(EHI(Level 5) is Excellent).
3	If (Presence is Good) and (Interactivity is Regular) and (Control is Good) and (FeedBack is Regular) and (Creativity is Regular) and (Productivity is Regular) and (Communication is Regular) and (Adaptation is Good) then (ELI(Level 0) is Good)(VLI(Level 1) is Good)(LI(Level 2) is Very Good)(MI(Level 3) is Very Good)(HI(Level 4) is Very Good)(EHI(Level 5) is Very Good).
4	If (Presence is Bad) and (Interactivity is Bad) and (Control is Bad) and (FeedBack is Bad) and (Creativity is Bad) and (Productivity is Bad) and (Communication is Bad) and (Adaptation is Bad) then (ELI(Level 0) is Very Good)(VLI(Level 1) is Very Good)(LI(Level 2) is Excellent)(MI(Level 3) is Regular)(HI(Level 4) is Regular)(EHI(Level 5) is Regular).
5	If (Presence is Very Bad) and (Interactivity is Very Bad) and (Control is Very Bad) and (FeedBack is Very Bad) and (Creativity is Very Bad) and (Productivity is Very Bad) and (Communication is Very Bad) and (Adaptation is Very Bad) then (ELI(Level 0) is Excellent)(VLI(Level 1) is Excellent)(LI(Level 2) is Good)(M I(Level 3) is Good)(HI(Level 4) is Bad)(EHI(Level 5) is Very Bad).
6	If (Presence is Regular) and (Interactivity is Good) and (Control is Regular) and (FeedBack is Good) and (Creativity is Good) and (Productivity is Good) and (Communication is Good) and (Adaptation is Regular) then (ELI(Level 0) is Regular)(VLI(Level 1) is Regular)(LI(Level 2) is Regular)(M I(Level 3) is Excellent)(HI(Level 4) is Good)(EHI(Level 5) is Good)

1.3. Neuro-Fuzzy FIS Configuration

1.3.1. Neuro-Fuzzy FIS inputs setup

Table S7. Inputs configuration of the Neuro-Fuzzy FIS. s= standard deviation, m= average

Input	Type Member Function	Linguistic Variable [params]
Presence	Gauss Member Function	Very Bad : [s=0.0356], m=0.2435] Bad : [s=0.0396, m=0.4896] Regular : [s=0.0363, m=0.6918] Good : [s=0.0431, m=0.7077] Very Good : [s=0.0315, m=0.8568] Excellent : [s=0.0167, m=0.9717]
Interactivity	Gauss Member Function	Very Bad : [s=0.0409, m=0.2356] Bad : [s=0.0393, m=0.4547] Regular : [s=0.0412, m=0.6858] Good : [s=0.0355, m=0.6981] Very Good : [s=0.0325, m=0.8475] Excellent : [s=0.0147, m=0.9790]
Control	Gauss Member Function	Very Bad : [s=0.0376, m=0.2665] Bad : [s=0.0417, m=0.4833] Regular : [s=0.0383, m=0.7013] Good : [s=0.0435, m=0.7125] Very Good : [s=0.0324, m=0.8648] Excellent : [s=0.0181, m=0.9723]
FeedBack	Gauss Member Function	Very Bad : [s=0.0372, m=0.1899] Bad : [s=0.0452, m=0.3666] Regular : [s=0.0567, m=0.4663] Good : [s=0.0525, m=0.5929] Very Good : [s=0.0434, m=0.8721] Excellent : [s=0.0152, m=0.9854]
Creativity	Gauss Member Function	Very Bad : [s=0.0261, m=0.1238] Bad : [s=0.0309, m=0.2971] Regular : [s=0.0437, m=0.3928] Good : [s=0.0403, m=0.4723] Very Good : [s=0.0336, m=0.6624] Excellent : [s=0.0324 m=0.8827]
Productivity	Gauss Member Function	Very Bad : [s=0.0244, m=0.0703] Bad : [s=0.0346, m=0.2378] Regular : [s=0.0481, m=0.38] Good : [s=0.0413, m=0.428] Very Good : [s=0.0324, m=0.6351] Excellent : [s=0.0365, m=0.8569]
Communication	Gauss Member Function	Very Bad : [s=0.0476, m=0.2364] Bad : [s=0.0475, m= 0.4033] Regular : [s=0.0653, m=0.5605] Good : [s=0.0509, m=0.6464] Very Good : [s=0.0383, m=0.9052] Excellent : [s=0.0155, m=0.9836]
Adaptation	Gauss Member Function	Very Bad : [s=0.0505, m=0.2195] Bad : [s=0.0585, m=0.3961] Regular : [s=0.0474, m=0.6474] Good : [s=0.058, m=0.6616] Very Good : [s=0.0358, m=0.8453]

| | | Excellent : [s=0.0172, m=0.9782] |

1.3.2. Neuro-Fuzzy FIS outputs setup

Table S8. Outputs configuration of the Neuro-Fuzzy FIS. s= standard deviation, m= average

Output	Type Member Function	Linguistic Variable [params]
ELI (Level 0)	Gauss Member Function	Very Bad : [s=0.0088, m=0.0003] Bad : [s=0.0095, m=0.0012] Regular : [S=0.0101, m=0.0022] Good : [s=0.0217, m=0.0271] Very Good : [s=0.0264, m=0.0413] Excellent : [s=0.0303, m=0.0469]
VLI (Level 1)	Gauss Member Function	Very Bad : [s=0.0137, m= 4.084e-05] Bad : [s=0.0141, m=0.0002] Regular : [s=0.0143, m=0.0003] Good : [s=0.0167, m=0.0027] Very Good : [s=0.0173, m=0.0045] Excellent : [s=0.3165, m=0.9322]
LI (Level 2)	Gauss Member Function	Very Bad : [s=0.0341, m=0.0002] Bad : [s=0.0352, m=0.0007] Regular : [s=0.0359, m=0.0014] Good : [s=0.0385, m=0.0051] Very Good : [s=0.2982, m=0.8837] Excellent : [s=0.3095, m=0.9418]
MI (Level 3)	Gauss Member Function	Very Bad : [s=0.0801, m=0.0016] Bad : [s=0.0833, m=0.0055] Regular : [s=0.0858, m=0.0102] Good : [s=0.0876, m=0.0226] Very Good : [s=0.0973, m=0.0568] Excellent : [s=0.2850, m=0.9925]
HI (Level 4)	Gauss Member Function	Very Bad : [s=0.1307, m=0.0011] Bad : [s=0.1297, m=0.0024] Regular : [s=0.1192, m=0.0024] Good : [s=0.1272, m=0.0114] Very Good : [s=0.2394, m=0.9843] Excellent : [s=0.2382, m=0.9913]
EHI (Level 5)	Gauss Member Function	Very Bad : [s=0.0879, m=0.0005] Bad : [s=0.0952, m=0.0006] Regular : [s=0.0910, m=0.0010] Good: [s=0.0986, m=0.0016] Very Good : [s=0.0925, m=0.0023] Excellent : [s=0.2662, m=0.9967]

1.3.3. Neuro-Fuzzy FIS rules setup

Table S9. Rules configuration of the Neuro-Fuzzy FIS.

No	Inference Fuzzy Rules
1	If (Presence is Very Good) and (Interactivity is Very Good) and (Control is Very Good) and (FeedBack is Very Good) and (Creativity is Very Good) and (Productivity is Very Good) and (Communication is Very Good) and (Adaptation is Very Good) then (ELI(Level 0) is Bad)(VLI(Level 1) is Bad)(LI(Level 2) is Bad)(M I(Level 3) is Bad)(HI(Level 4) is Excellent)(EHI(Level 5) is Bad).

2	If (Presence is Excellent) and (Interactivity is Excellent) and (Control is Excellent) and (FeedBack is Excellent) and (Creativity is Excellent) and (Productivity is Excellent) and (Communication is Excellent) and (Adaptation is Excellent) then (ELI(Level 0) is Very Bad)(VLI(Level 1) is Very Bad)(LI(Level 2) is Very Bad)(MI(Level 3) is Very Bad)(HI(Level 4) is Very Bad)(EHI(Level 5) is Excellent).
3	If (Presence is Good) and (Interactivity is Regular) and (Control is Good) and (FeedBack is Regular) and (Creativity is Regular) and (Productivity is Regular) and (Communication is Regular) and (Adaptation is Good) then (ELI(Level 0) is Good)(VLI(Level 1) is Good)(LI(Level 2) is Very Good)(MI(Level 3) is Very Good)(HI(Level 4) is Very Good)(EHI(Level 5) is Very Good).
4	If (Presence is Bad) and (Interactivity is Bad) and (Control is Bad) and (FeedBack is Bad) and (Creativity is Bad) and (Productivity is Bad) and (Communication is Bad) and (Adaptation is Bad) then (ELI(Level 0) is Very Good)(VLI(Level 1) is Very Good)(LI(Level 2) is Excellent)(MI(Level 3) is Regular)(HI(Level 4) is Regular)(EHI(Level 5) is Regular).
5	If (Presence is Very Bad) and (Interactivity is Very Bad) and (Control is Very Bad) and (FeedBack is Very Bad) and (Creativity is Very Bad) and (Productivity is Very Bad) and (Communication is Very Bad) and (Adaptation is Very Bad) then (ELI(Level 0) is Excellent)(VLI(Level 1) is Excellent)(LI(Level 2) is Good)(M I(Level 3) is Good)(HI(Level 4) is Bad)(EHI(Level 5) is Very Bad).
6	If (Presence is Regular) and (Interactivity is Good) and (Control is Regular) and (FeedBack is Good) and (Creativity is Good) and (Productivity is Good) and (Communication is Good) and (Adaptation is Regular) then (ELI(Level 0) is Regular)(VLI(Level 1) is Regular)(LI(Level 2) is Regular)(M I(Level 3) is Excellent)(HI(Level 4) is Good)(EHI(Level 5) is Good).