Machine Learning in Critical Care

A Quick Note about the Course

- Session 1
 - \circ $\,$ The Nature of Medical Data $\,$
 - Data Extraction via SQL
- Session 2
 - Algorithm Construction and Application
- Session 3
 - Feature Engineering
- Session 4
 - Apply your knowledge, win a prize, start a paper!
 - Doing the homework will help with this session!

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Session 2 - Learning Objectives

- Part 1: Build an intuition for how machine learning works
 - Data Pre-processing
 - Feature Selection
 - Model Construction

Part 2: Apply a machine learning to a simple discriminative task
 Model Validation

Your Homework For This Week

• **Problem 1:** Hand-craft an algorithm for predicting mortality in the patient population

• **Problem 2:** Apply 3 machine learning techniques to predict patient mortality

Session 2, Part 1: An Introduction to Human Learning

Download Resources: http://bit.ly/1Rk0UnD

Overview of Matlab IDE

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Image: Size Image: Size	Dropbox (MIT) Machine_Learning_In_CI CRL_DoptimizingCloosterman.m CRL_Analysis.m CRL_Analysis.m CRL_Ganty.m CRL_Gl_Convert_per_hour.m CRL_Gl_Convert_per_hour.m IMPORT_GRIGHAM_DATA.m VisualizeData_1_PlotCZSpec.m artifact_Find_Vari.m artifact_Find_Eye.m EXTRACT_CELLS.m EXTRACT_CELLS.m EXTRACT_CELLS.m ImportData_3_MGH_FRONTbMAT.m importData_3_MGH_FRONTbMAT.m importData_4_FORMAT_FRONTS.m main.m	ritical_Ca > ox (MIT 1 2 3 4 5 6 7 - 8 9 10 - 11 12 13 14 15 16 17 18 - 19 20 20	<pre>re //Machine_Learning_In_Critical_Care/MLCC_Lesson1.m %% MIMIC CONNECTION in Matlab % Machine Learning in Critical Care. % Lesson #1: Connecting to the database. % Mohamad M. Ghassemi %% STEP 1: Tell Matlab where the driver is javaclasspath('/home/mohammad/Dropbox (MIT)/Machine_Learning_In_Critical_Care/p %% STEP 2: Connect to the Database conn = ConnectMIMIC; %% Step 3: Open your web-brower and let's look at the schema % https://mimic.physionet.org/about/mimic/ %% Step 4: Let's write out a query. %create a file query.sql in your folder. query = makeQuery('query.sql'); %% Step 5: Run your query and get the results.</pre>	⊙ ×	Workspace Name ∠ test	Value 100x100 double	Size 100×100	Class double	P Rar 0.9
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No detaile available	MLCC_LessonLini X makeQuery.m X + Command Window New to MATLAB? See resources for Get	tting Sta	ted.	• • ×	<pre>% 01/10/20 conn = datab 'Server','lo query = 'SEL results = fe clear all load(UNICCDA)</pre>	<pre>D16 04:25:38 PM% ase('connectdb','rod calhost'); ECT * FROM users;' tch(conn,query) ta moti)</pre>	ot','Vyax5	5amj!M3',.	
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	3	0.1270	0.3112	0.8116	0.0424	0.5985	0.8699	0.9296	0.3479	0.7227	0.2578	0.9970	0.0098	0.8770	0.9337	0.8194	0.0868	0.6944	0.9481	0.3268	0.346
	4	0.9134	0.5285	0.5328	0.0714	0.4709	0.2648	0.6967	0.4460	0.1104	0.3968	0.2242	0.8432	0.3531	0.8110	0.5319	0.4294	0.2568	0.0610	0.8803	0.418
	5	0.6324	0.1656	0.3507	0.5216	0.6959	0.3181	0.5828	0.0542	0.1175	0.0740	0.6525	0.9223	0.4494	0.4845	0.2021	0.2573	0.0098	0.5846	0.4711	0.155
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	4	0.9134	0.5285	0.5328	0.0714	0.4709	0.2648	0.6967	0.4460	0.1104	0.3968	0.2242	0.8432	0.3531	0.8110	0.5319	0.4294	0.2568	0.0610	0.8803	0.4186	0.1296	0.7203	0.6944
	5	0.6324	0.1656	0.3507	0.5216	0.6959	0.3181	0.5828	0.0542	0.1175	0.0740	0.6525	0.9223	0.4494	0.4845	0.2021	0.2573	0.0098	0.5846	0.4711	0.1557	0.2251	0.4840	0.2124
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	8	0.5469	0.6541	0.5502	0.8175	0.0336	0.6456	0.9889	0.3308	0.6538	0.9828	0.1422	0.3782	0.9730	0.9718	0.9661	0.1192	0.9462	0.1910	0.9689	0.7386	0.9275	0.1987	0.9564
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	10	0.9649	0.7482	0.5870	0.1499	0.3196	0.6393	0.8654	0.1182	0.5832	0.6207	0.4211	0.7295	0.6671	0.8641	0.6954	0.7064	0.3927	0.3934	0.8445	0.0672	0.5927	0.9922	0.0854
	11	0.1576	0.4505	0.2077	0.6596	0.5309	0.5447	0.6126	0.9884	0.7400	0.1544	0.1841	0.2243	0.5864	0.3889	0.7202	0.2436	0.0249	0.8266	0.6153	0.9508	0.1629	0.4024	0.0573
	12	0.9706	0.0838	0.3012	0.5186	0.6544	0.6473	0.9900	0.5400	0.2348	0.3813	0.7258	0.2691	0.6751	0.4547	0.3469	0.7851	0.6714	0.6769	0.3766	0.4976	0.8384	0.6589	0.6295
	13	0.9572	0.2290	0.4709	0.9730	0.4076	0.5439	0.5277	0.7069	0.7350	0.1611	0.3704	0.6730	0.3610	0.2467	0.5170	0.0741	0.8372	0.2076	0.8772	0.7551	0.1676	0.9013	0.7962
	14	0.4854	0.9133	0.2305	0.6490	0.8200	0.7210	0.4795	0.9995	0.9706	0.7581	0.8416	0.4775	0.6203	0.7844	0.5567	0.3939	0.9715	0.3181	0.7849	0.7424	0.5022	0.9954	0.6912
	15	0.8003	0.1524	0.8443	0.8003	0.7184	0.5225	0.8013	0.2878	0.8669	0.8711	0.7342	0.6237	0.8112	0.8828	0.1565	0.0034	0.0569	0.1338	0.4650	0.8311	0.9993	0.6532	0.3453
	16	0.1419	0.8258	0.1948	0.4538	0.9686	0.9937	0.2278	0.4145	0.0862	0.3508	0.5710	0.2364	0.0193	0.9137	0.5621	0.2207	0.4503	0.6715	0.8140	0.1565	0.3554	0.1084	0.9468
	17	0.4218	0.5383	0.2259	0.4324	0.5313	0.2187	0.4981	0.4648	0.3664	0.6855	0.1769	0.1771	0.0839	0.5583	0.6948	0.0013	0.5825	0.5710	0.8984	0.4573	0.0471	0.0361	0.5202
	18	0.9157	0.9961	0.1707	0.8253	0.3251	0.1058	0.9009	0.7640	0.3692	0.2941	0.9574	0.8296	0.9748	0.5989	0.4265	0.1892	0.6866	0.1698	0.4292	0.6181	0.2137	0.6181	0.9538
	19	0.7922	0.0782	0.2277	0.0835	0.1056	0.1097	0.5747	0.8182	0.6850	0.5306	0.2653	0.7669	0.6513	0.1489	0.8363	0.1425	0.7194	0.1477	0.3343	0.9322	0.3978	0.5671	0.0736
	20	0.9595	0.4427	0.4357	0.1332	0.6110	0.0636	0.8452	0.1002	0.5979	0.8324	0.9246	0.9345	0.2312	0.8997	0.7314	0.2681	0.6500	0.4761	0.5966	0.8351	0.3337	0.9620	0.2070
	21	0.6557	0.1067	0.3111	0.1734	0.7788	0.4046	0.7386	0.1781	0.7894	0.5975	0.2238	0.1079	0.4035	0.4504	0.3600	0.1749	0.7269	0.9081	0.9020	0.8954	0.2296	0.7461	0.7750
	22	0.0357	0.9619	0.9234	0.3909	0.4235	0.4484	0.5860	0.3596	0.3677	0.3353	0.3736	0.1822	0.1220	0.2057	0.4542	0.1386	0.3738	0.5522	0.7021	0.5825	0.9361	0.6625	0.9142
	23	0.8491	0.0046	0.4302	0.8314	0.0908	0.3658	0.2467	0.0567	0.2060	0.2992	0.0875	0.0991	0.2684	0.8997	0.3864	0.5989	0.5816	0.0329	0.3775	0.5827	0.6832	0.5233	0.7826
	24	0.9340	0.7749	0.1848	0.8034	0.2665	0.7635	0.6664	0.5219	0.0867	0.4526	0.6401	0.4898	0.2578	0.7626	0.7756	0.9011	0.1161	0.0539	0.7350	0.8549	0.9621	0.2599	0.2955
	25	0.6787	0.8173	0.9049	0.0605	0.1537	0.6279	0.0835	0.3358	0.7719	0.4226	0.1806	0.1932	0.3317	0.8825	0.7343	0.9394	0.0577	0.8051	0.9541	0.0349	0.4380	0.9620	0.1518
	26	0.7577	0.8687	0.9797	0.3993	0.2810	0.7720	0.6260	0.1757	0.2057	0.3596	0.0451	0.8959	0.1522	0.2850	0.4303	0.2212	0.9798	0.4514	0.5428	0.8854	0.9403	0.5402	0.8479
	27	0.7431	0.0844	0.4389	0.5269	0.4401	0.9329	0.6609	0.2089	0.3883	0.5583	0.7232	0.0991	0.3480	0.6732	0.6938	0.4827	0.2848	0.3826	0.5401	0.4077	0.0058	0.0303	0.7849
	28	0.3922	0.3998	0.1111	0.4168	0.5271	0.9727	0.7298	0.9052	0.5518	0.7425	0.3474	0.0442	0.1217	0.6643	0.9452	0.3760	0.5950	0.7896	0.3111	0.0364	0.6103	0.6963	0.2708
	29	0.6555	0.2599	0.2581	0.6569	0.4574	0.1920	0.8908	0.6754	0.2290	0.4243	0.6606	0.5573	0.8842	0.1228	0.7842	0.5238	0.9622	0.3643	0.0712	0.7461	0.8011	0.5197	0.2278
	30	0.1712	0.8001	0.4087	0.6280	0.8754	0.1389	0.9823	0.4685	0.6419	0.4294	0.3839	0.7725	0.0943	0.4073	0.7056	0.2649	0.1858	0.5323	0.1820	0.1548	0.2330	0.0590	0.3210
	31	0.7060	0.4314	0.5949	0.2920	0.5181	0.6963	0.7690	0.9121	0.4845	0.1249	0.6273	0.3119	0.9300	0.2753	0.1093	0.0684	0.1930	0.7117	0.0930	0.1439	0.9325	0.8900	0.8296
	32	0.0318	0.9106	0.2622	0.4317	0.9436	0.0938	0.5814	0.1040	0.1518	0.0244	0.0216	0.1790	0.3990	0.7167	0.3899	0.4363	0.3416	0.8715	0.4635	0.6060	0.7633	0.3302	0.8222
	33	0.2769	0.1818	0.6028	0.0155	0.6377	0.5254	0.9283	0.7455	0.7819	0.2902	0.9106	0.3390	0.0474	0.2834	0.5909	0.1739	0.9329	0.3287	0.0093	0.2545	0.8264	0.2297	0.5707
	34	0.0462	0.2638	0.7112	0.9841	0.9577	0.5303	0.5801	0.7363	0.1006	0.3175	0.8006	0.2101	0.3424	0.8962	0.4594	0.0261	0.3907	0.6501	0.9150	0.3242	0.5735	0.1139	0.5718
	35	0.0971	0.1455	0.2217	0.1672	0.2407	0.8611	0.0170	0.5619	0.2941	0.6537	0.7458	0.5102	0.7360	0.8266	0.0503	0.9547	0.2732	0.9748	0.6427	0.4018	0.7926	0.3109	0.2860
	36	0.8235	0.1361	0.1174	0.1062	0.6761	0.4849	0.1209	0.1842	0.2374	0.9569	0.8131	0.9064	0.7947	0.3900	0.2287	0.4306	0.1519	0.0760	0.0014	0.4064	0.3290	0.2284	0.6991
	37	0.6948	0.8693	0.2967	0.3724	0.2891	0.3935	0.8627	0.5972	0.5309	0.9357	0.3833	0.6289	0.5449	0.4979	0.8342	0.9616	0.3971	0.5870	0.0304	0.3862	0.2235	0.6520	0.7963
	38	0.3171	0.5797	0.3188	0.1981	0.6718	0.6714	0.4843	0.2999	0.0915	0.4579	0.6173	0.1015	0.6862	0.6948	0.0156	0.7624	0.3747	0.4139	0.2085	0.6098	0.3124	0.0662	0.4416
	39	0.9502	0.5499	0.4242	0.4897	0.6951	0.7413	0.8449	0.1341	0.4053	0.2405	0.5755	0.3909	0.8936	0.8344	0.8637	0.0073	0.1311	0.3091	0.4550	0.1669	0.5845	0.2754	0.4462
	40	0.0344	0.1450	0.5079	0.3395	0.0680	0.5201	0.2094	0.2126	0.1048	0.7639	0.5301	0.0546	0.0548	0.6096	0.0781	0.6800	0.4350	0.2638	0.1273	0.1881	0.8299	0.2818	0.4657
	41	0.4387	0.8530	0.0855	0.9516	0.2548	0.3477	0.5523	0.8949	0.1123	0.7593	0.2751	0.5013	0.3037	0.5747	0.6690	0.7060	0.0915	0.7588	0.0086	0.0946	0.2905	0.8801	0.2790
	42	0.3816	0.6221	0.2625	0.9203	0.2240	0.1500	0.6299	0.0715	0.7844	0.7406	0.2486	0.4317	0.0462	0.3260	0.5002	0.6451	0.6146	0.9952	0.7271	0.3232	0.4026	0.4443	0.6754

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plot	bar	area	pie	histo gy am	semilogx	semilogy	loglog	comet	stem	stairs	barh	O Reuso New I	e Figure Figure								
e																					
2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0.3112	0.8116	0.0424	0.5985	0.8699	0.9296	0.3479	0.7227	0.2578	0.9970	0.0098	0.8770	0.9337	0.8194	0.0868	0.6944	0.9481	0.3268	0.3463	0.2426	0.9336	0.5289
0.5285	0.5328	0.0714	0.4709	0.2648	0.6967	0.4460	0.1104	0.3968	0.2242	0.8432	0.3531	0.8110	0.5319	0.4294	0.2568	0.0610	0.8803	0.4186	0.1296	0.7203	0.6944
0.1656	0.3507	0.5216	0.6959	0.3181	0.5828	0.0542	0.1175	0.0740	0.6525	0.9223	0.4494	0.4845	0.2021	0.2573	0.0098	0.5846	0.4711	0.1557	0.2251	0.4840	0.2124

4	0.9134	0.5285	0.5328	0.0714	0.4709	0.2648	0.6967	0.4460	0.1104	0.3968	0.2242	0.8432	0.3531	0.8110	0.5319	0.4294	0.2568	0.0610	0.8803	0.4186	0.1296	0.7203	0.6944
5	0.6324	0.1656	0.3507	0.5216	0.6959	0.3181	0.5828	0.0542	0.1175	0.0740	0.6525	0.9223	0.4494	0.4845	0.2021	0.2573	0.0098	0.5846	0.4711	0.1557	0.2251	0.4840	0.2124
6	0.0975	0.6020	0.9390	0.0967	0.6999	0.1192	0.8154	0.1771	0.6407	0.6841	0.6050	0.7710	0.9635	0.7567	0.4539	0.2976	0.5323	0.2851	0.4040	0.8190	0.3500	0.6390	0.5433
7	0.2785	0.2630	0.8759	0.8181	0.6385	0.9398	0.8790	0.6628	0.3288	0.4024	0.3872	0.0427	0.0423	0.4170	0.4279	0.4249	0.2794	0.8277	0.1792	0.6249	0.2871	0.8876	0.7025
8	0.5469	0.6541	0.5502	0.8175	0.0336	0.6456	0.9889	0.3308	0.6538	0.9828	0.1422	0.3782	0.9730	0.9718	0.9661	0.1192	0.9462	0.1910	0.9689	0.7386	0.9275	0.1987	0.9564
9	0.9575	0.6892	0.6225	0.7224	0.0688	0.4795 5	5.2238e	0.8985	0.7491	0.4022	0.0251	0.7043	0.1892	0.9880	0.6201	0.4951	0.9064	0.4425	0.4075	0.8051	0.0513	0.3954	0.4445
10	0.9649	0.7482	0.5870	0.1499	0.3196	0.6393	0.8654	0.1182	0.5832	0.6207	0.4211	0.7295	0.6671	0.8641	0.6954	0.7064	0.3927	0.3934	0.8445	0.0672	0.5927	0.9922	0.0854
11	0.1576	0.4505	0.2077	0.6596	0.5309	0.5447	0.6126	0.9884	0.7400	0.1544	0.1841	0.2243	0.5864	0.3889	0.7202	0.2436	0.0249	0.8266	0.6153	0.9508	0.1629	0.4024	0.0573
12	0.9706	0.0838	0.3012	0.5186	0.6544	0.6473	0.9900	0.5400	0.2348	0.3813	0.7258	0.2691	0.6751	0.4547	0.3469	0.7851	0.6714	0.6769	0.3766	0.4976	0.8384	0.6589	0.6295
13	0.9572	0.2290	0.4709	0.9730	0.4076	0.5439	0.5277	0.7069	0.7350	0.1611	0.3704	0.6730	0.3610	0.2467	0.5170	0.0741	0.8372	0.2076	0.8772	0.7551	0.1676	0.9013	0.7962
14	0.4854	0.9133	0.2305	0.6490	0.8200	0.7210	0.4795	0.9995	0.9706	0.7581	0.8416	0.4775	0.6203	0.7844	0.5567	0.3939	0.9715	0.3181	0.7849	0.7424	0.5022	0.9954	0.6912
15	0.8003	0.1524	0.8443	0.8003	0.7184	0.5225	0.8013	0.2878	0.8669	0.8711	0.7342	0.6237	0.8112	0.8828	0.1565	0.0034	0.0569	0.1338	0.4650	0.8311	0.9993	0.6532	0.3453
16	0.1419	0.8258	0.1948	0.4538	0.9686	0.9937	0.2278	0.4145	0.0862	0.3508	0.5710	0.2364	0.0193	0.9137	0.5621	0.2207	0.4503	0.6715	0.8140	0.1565	0.3554	0.1084	0.9468
17	0.4218	0.5383	0.2259	0.4324	0.5313	0.2187	0.4981	0.4648	0.3664	0.6855	0.1769	0.1771	0.0839	0.5583	0.6948	0.0013	0.5825	0.5710	0.8984	0.4573	0.0471	0.0361	0.5202
18	0.9157	0.9961	0.1707	0.8253	0.3251	0.1058	0.9009	0.7640	0.3692	0.2941	0.9574	0.8296	0.9748	0.5989	0.4265	0.1892	0.6866	0.1698	0.4292	0.6181	0.2137	0.6181	0.9538
19	0.7922	0.0782	0.2277	0.0835	0.1056	0.1097	0.5747	0.8182	0.6850	0.5306	0.2653	0.7669	0.6513	0.1489	0.8363	0.1425	0.7194	0.1477	0.3343	0.9322	0.3978	0.5671	0.0736
20	0.9595	0.4427	0.4357	0.1332	0.6110	0.0636	0.8452	0.1002	0.5979	0.8324	0.9246	0.9345	0.2312	0.8997	0.7314	0.2681	0.6500	0.4761	0.5966	0.8351	0.3337	0.9620	0.2070
21	0.6557	0.1067	0.3111	0.1734	0.7788	0.4046	0.7386	0.1781	0.7894	0.5975	0.2238	0.1079	0.4035	0.4504	0.3600	0.1749	0.7269	0.9081	0.9020	0.8954	0.2296	0.7461	0.7750
22	0.0357	0.9619	0.9234	0.3909	0.4235	0.4484	0.5860	0.3596	0.3677	0.3353	0.3736	0.1822	0.1220	0.2057	0.4542	0.1386	0.3738	0.5522	0.7021	0.5825	0.9361	0.6625	0.9142
23	0.8491	0.0046	0.4302	0.8314	0.0908	0.3658	0.2467	0.0567	0.2060	0.2992	0.0875	0.0991	0.2684	0.8997	0.3864	0.5989	0.5816	0.0329	0.3775	0.5827	0.6832	0.5233	0.7826
24	0.9340	0.7749	0.1848	0.8034	0.2665	0.7635	0.6664	0.5219	0.0867	0.4526	0.6401	0.4898	0.2578	0.7626	0.7756	0.9011	0.1161	0.0539	0.7350	0.8549	0.9621	0.2599	0.2955
25	0.6787	0.8173	0.9049	0.0605	0.1537	0.6279	0.0835	0.3358	0.7719	0.4226	0.1806	0.1932	0.3317	0.8825	0.7343	0.9394	0.0577	0.8051	0.9541	0.0349	0.4380	0.9620	0.1518
26	0.7577	0.8687	0.9797	0.3993	0.2810	0.7720	0.6260	0.1757	0.2057	0.3596	0.0451	0.8959	0.1522	0.2850	0.4303	0.2212	0.9798	0.4514	0.5428	0.8854	0.9403	0.5402	0.8479
27	0.7431	0.0844	0.4389	0.5269	0.4401	0.9329	0.6609	0.2089	0.3883	0.5583	0.7232	0.0991	0.3480	0.6732	0.6938	0.4827	0.2848	0.3826	0.5401	0.4077	0.0058	0.0303	0.7849
28	0.3922	0.3998	0.1111	0.4168	0.5271	0.9727	0.7298	0.9052	0.5518	0.7425	0.3474	0.0442	0.1217	0.6643	0.9452	0.3760	0.5950	0.7896	0.3111	0.0364	0.6103	0.6963	0.2708
29	0.6555	0.2599	0.2581	0.6569	0.4574	0.1920	0.8908	0.6754	0.2290	0.4243	0.6606	0.5573	0.8842	0.1228	0.7842	0.5238	0.9622	0.3643	0.0712	0.7461	0.8011	0.5197	0.2278
30	0.1712	0.8001	0.4087	0.6280	0.8754	0.1389	0.9823	0.4685	0.6419	0.4294	0.3839	0.7725	0.0943	0.4073	0.7056	0.2649	0.1858	0.5323	0.1820	0.1548	0.2330	0.0590	0.3210
31	0.7060	0.4314	0.5949	0.2920	0.5181	0.6963	0.7690	0.9121	0.4845	0.1249	0.6273	0.3119	0.9300	0.2753	0.1093	0.0684	0.1930	0.7117	0.0930	0.1439	0.9325	0.8900	0.8296
32	0.0318	0.9106	0.2622	0.4317	0.9436	0.0938	0.5814	0.1040	0.1518	0.0244	0.0216	0.1790	0.3990	0.7167	0.3899	0.4363	0.3416	0.8715	0.4635	0.6060	0.7633	0.3302	0.8222
33	0.2769	0.1818	0.6028	0.0155	0.6377	0.5254	0.9283	0.7455	0.7819	0.2902	0.9106	0.3390	0.0474	0.2834	0.5909	0.1739	0.9329	0.3287	0.0093	0.2545	0.8264	0.2297	0.5707
34	0.0462	0.2638	0.7112	0.9841	0.9577	0.5303	0.5801	0.7363	0.1006	0.3175	0.8006	0.2101	0.3424	0.8962	0.4594	0.0261	0.3907	0.6501	0.9150	0.3242	0.5735	0.1139	0.5718
35	0.0971	0.1455	0.2217	0.16/2	0.2407	0.8611	0.0170	0.5619	0.2941	0.6537	0.7458	0.5102	0.7360	0.8266	0.0503	0.9547	0.2732	0.9748	0.6427	0.4018	0.7926	0.3109	0.2860
36	0.8235	0.1361	0.11/4	0.1062	0.6761	0.4849	0.1209	0.1842	0.2374	0.9569	0.8131	0.9064	0./94/	0.3900	0.2287	0.4306	0.1519	0.0760	0.0014	0.4064	0.3290	0.2284	0.6991
37	0.6948	0.8693	0.2967	0.3724	0.2891	0.3935	0.8627	0.5972	0.5309	0.9357	0.3833	0.6289	0.5449	0.4979	0.8342	0.9616	0.3971	0.5870	0.0304	0.3862	0.2235	0.6520	0.7963
38	0.3171	0.5797	0.3188	0.1981	0.6718	0.6/14	0.4843	0.2999	0.0915	0.4579	0.61/3	0.1015	0.6862	0.6948	0.0156	0.7624	0.3747	0.4139	0.2085	0.6098	0.3124	0.0662	0.4416
39	0.9502	0.5499	0.4242	0.4897	0.6951	0./413	0.8449	0.1341	0.4053	0.2405	0.5755	0.3909	0.8936	0.8344	0.8637	0.00/3	0.1311	0.3091	0.4550	0.1669	0.5845	0.2/54	0.4462
40	0.0344	0.1450	0.5079	0.3395	0.0680	0.5201	0.2094	0.2126	0.1048	0.7639	0.5301	0.0546	0.0548	0.6096	0.0781	0.6800	0.4350	0.2638	0.12/3	0.0042	0.8299	0.2818	0.4657
41	0.438/	0.8530	0.0855	0.9516	0.2548	0.3477	0.5523	0.8949	0.1123	0.7593	0.2/51	0.5013	0.303/	0.5/4/	0.6690	0.7060	0.0915	0.7588	0.0086	0.0946	0.2905	0.8801	0.2790
42	0.3816	0.6221	0.2625	0.9203	0.2240	0.1500	0.6299	0.0715	0.7844	0.7406	0.2486	0.431/	0.0462	0.3260	0.5002	0.6451	0.6146	0.9952	0./2/1	0.3232	0.4026	0.4443	0.6/54

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VARIABLE

100x100 double test x 1

3 0.1270 0.3112 0.8116

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The Human Learning Task

To the MatMobile





The Human Learning Task

- I want all of you to forget everything you ever learned about machine learning, and treat mortality prediction as a *human learning* task.
- Jim had a cardiac arrest, and is currently on life support. Nobody knows if Jim will wake up from his coma, and taking care of him is very expensive ~20K/day.
- Your boss wants you to generate a procedure to predict Jim's outcome.



The Human Learning Task

• We are going to design an algorithm together to predict the outcomes of the patients by visual inspection alone.

• We want to figure out *which features* we extracted are predictive of outcome, and *how to choose thresholds for their values*.

To the MatMobile



%% STEP 1: Let's load the data.

Code will be referenced

Load the Data

```
%% STEP 1: Let's load the data.
% you can also do this in the GUI by double clicking the '.mat' file
% on the left hand side panel. Or you can run...
load('MLCCData.mat');
```

```
%% STEP 2: Let's Unpack the Data

for i = 1:size(data,2)
    name = header{i};
    eval([name '= data(:,i);'])
end
```

Load the Data

```
%% STEP 1: Let's load the data.
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```
%% STEP 2: Let's Unpack the Data

for i = 1:size(data,2)
    name = header{i};
    eval([name '= data(:,i);'])
end
```

NOW LOOK AT YOUR WORKSPACE!

We want to find features that predict outcome

'ICUSTAYID' 'OUTCOME' 'Age' 'HeartRateMin' 'HeartRateMax' 'MeanBPMin' 'MeanBPMax' 'RespRateMin' 'RespRateMax' 'GCSMin' 'GCSMax' 'BILIRUBINmin' 'BILIRUBINmax' 'CREATININEmin 'CREATININEmax 'HEMOGLOBINmin 'HEMOGLOBINmax 'SODIUMmin' 'SODIUMmax' 'WBCmin' 'WBCmax'



%% STEP 3: Let's Visualize some features, starting with Age

Let's Look at Age



%% STEP 3: Let's Visualize some features, starting with Age

Strange Outliers



Outliers exist to protect identity of older patients



• DOB has been shifted for patients older than 89. The median age for the patients whose date of birth was shifted is 91.4.

https://mimic.physionet.org/mimictables/patients/

Corrected, the distributions of ages make sense



Much Better!

Compare histograms of each outcome class



Survival is more likely when 30 < Age < 75


What features should be considered...?



Inside The Box

prediction = death if (Age < 30 | Age > 75)

%% STEP 6: The Ageist Algorithm

Confusion Matrix 2789 762 78.5% 0 43.5% 11.9% 21.5% Output Class **762** 11.9% 2104 26.6% 32.8% 73.4% 57.0% 50.0% 55.3% 43.0% 50.0% 44.7% 0 1

Target Class

%% STEP 6: The Ageist Algorithm

Confusion Matrix 2789 762 78.5% 0 43.5% 11.9% 21.5% Output Class **762** 11.9% 2104 26.6% 32.8% 73.4% 57.0% 50.0% 55.3% 43.0% 50.0% 44.7% 0 1

Target Class

What features should be considered...?

'ICUSTAYID' 'OUTCOME' 'Age' -'HeartRateMin' 'HeartRateMax' 'MeanBPMin' 'MeanBPMax' 'RespRateMin' 'RespRateMax' 'GCSMin' A Black Box 'GCSMax' (Literally) 'BILIRUBINmin' 'BILIRUBINmax' 'CREATININEmin 'CREATININEmax 'HEMOGLOBINmin 'HEMOGLOBINmax 'SODIUMmin' 'SODIUMmax' 'WBCmin' 'WBCmax'

What features should be considered...?



We can do better!



HeartRatemin

What would the histograms of a perfect feature look like?

Let's Make a Better Black Box



Inside The Better Black Box

prediction = death if WBCmax > 15 & WBCmin > 15 & HeartRateMin > 100





Victory!

Or is it...?

STEP 9: The Optimist's Algorithm

Let's Try The Optimist's Algorithm



Everyone Always Survives!

% STEP 9: The Optimist's Algorithm

Confusion Matrix 4893 1524 76.3% 0 76.3% 23.7% 23.7% **Output Class** 0.0% **0** 0.0% NaN% 1 NaN% 100% 76.3% 23.7% 0.0% 100% 1 0 **Target Class**

Oh dear... 0.3% better...





Why is this happening?



Accuracy may not be a good measure of performance when you have uneven class sizes.



Specificity

• Specificity= true survivors/(true survivors + false deaths)

• <u>Given that a person is going to survive</u>, how often will the test indicate survival?





Sensitivity

• Sensitivity=true deaths/(true deaths + false survivors)

• <u>Given that a person is going to die</u>, how often will the test indicate death?





Negative Predictive value:

• *PV-= true survivals/(true survivals + false deaths)*

• <u>Given that the test predicts survival</u>, what is the probability that the patient actually survives?

4805 74.9%	1454 22.7%	negative predictive value 76.8% 23.2%



Positive Predictive value (PV+):

• *PV*+= true deaths / (true deaths +false deaths)

• <u>Given that the test predicts death</u>, what is the probability that the patient will die?

		positive predictive value
88	70	44.3%
1.4%	1.1%	55.7%

If we compare our approach against the Optimistic Approach, using these other metrics, how do we do?





Output Class

Given all the options, what is the standard performance metric when working with medical data?

• A good algorithm is both **sensitive** and **specific**.

• But deciding relative importance can be tricky

- Is it as bad to
 - o predict survival given death, as it is to
 - o predict death given survival?



What is the value of a life?

What is the value of a life?
- If everyone has an opinion about the relative importance of predicting survival vs. death, then let's add a range of biases to our predictions and see how it does.
- We can do this, by adding or subtracting a constant value from our predictions

Let's Bias The Optimist's Algorithm

Optimist's Original Prediction	Slight Bias	Modified Prediction	Modified Prediction > 0.5	Outcome
0	.1	0.1	0	1
0	.1	0.1	0	0
0	.1	0.1	0	1
0	.1	0.1	0	0

Optimist's Original Prediction	Pessimist Bias	Modified Prediction	Modified Prediction > 0.5	Outcome
0	1	1	1	1
0	1	1	1	0
0	1	1	1	1
0	1	1	1	0

Optimist's Original Prediction	Optimist Bias	Modified Prediction	Modified Prediction > 0.5	Outcome
0	-1	-1	0	1
0	-1	-1	0	0
0	-1	-1	0	1
0	-1	-1	0	0

The Optimist's Algorithm

- Bias create two distinct predictions
- All 1s, or all 0s



The Optimist's Algorithm



If predicting death given death is infinitely valuable.

If predicting survival given survival is infinitely valuable.

What about our Algorithm?

Our Original Prediction	Bias	Modified Prediction	Modified Prediction > 0.5	Outcome
1	.1	1.1	1	1
1	.1	1.1	1	0
0	.1	0.1	0	1
0	.1	0.1	0	0

Our Original Prediction	Pessimist Bias	Modified Prediction	Modified Prediction > 0.5	Outcome
1	1	2	1	1
1	1	2	1	0
0	1	1	1	1
0	1	1	1	0

Our Original Prediction	Optimist Bias	Modified Prediction	Modified Prediction > 0.5	Outcome
1	-1	0	0	1
1	-1	0	0	0
0	-1	-1	0	1
0	-1	-1	0	0

Our Algorithm: Three Options



If predicting death given death is infinitely valuable.

If predicting survival given survival is infinitely valuable.

How do we know which is better?

Compare Every Option via Area Under the Curve



Compare Using the Area Under the Curve



Compare Using the Area Under the Curve





Wait... Why are we so similar to the optimist's algorithm?





Output Class

Requiring all conditions to be satisfied is too rare.

Democracy to the rescue!

Let's Make a <u>BETTER</u> Better Black Box



Inside The <u>BETTER</u> Better Black Box

votes = ((Age < 30) +(Age > 75) +(WBCmax > 15) +(WBCmin > 15) + (HeartRateMax > 125) +(HeartRateMin > 100) + (HeartRateMin < 40))/7 prediction = death if votes > ...



How many votes are enough?

How many votes are enough?

The Democracy Algorithm



But can we do better...

Perhaps not all features are created equal.

<u>Aristocracy?</u>

Let's Make a Philosopher King Black Box



Inside The Philosopher King's Black Box

- votes = 4 * ((Age < 30) +
 - 1 * (Age > 75) +
 - 1 * (WBCmax > 15) +
 - 1 * (WBCmin > 15) +
 - 1 * (HeartRateMax > 125) +
 - 3 * (HeartRateMin > 100) +
 - 3 * (HeartRateMin < 40)) / 14

prediction = 1 if votes > ...

The Philosopher King Algorithm... Plato was right...



What can we conclude

- The Optimist's Approach
 - \circ Area under the curve = 0.50
- Our First Approach
 - Area under the curve = 0.51
- Democracy
 - \circ Area under the curve = 0.62
- Aristocracy
 - Area under the curve = 0.64

What can we conclude

- The Optimist's Approach
 - Area under the curve = 0.50
- Our First Approach
 - Area under the curve = 0.51
- Democracy
 - \circ Area under the curve = 0.62
- Aristocracy
 - Area under the curve = 0.64



Before we get carried away...

What Has Human Learning Taught Us?

• Features with distributions that separate the outcomes of interest do a good job in classification.

• If done correctly, combining multiple weak features can make for a strong classifier.

• Not all features are equally important, some should be considered more strongly than others.

Here's how it connects to Machine Learning

• ML Identifies features that separate the cases of interest, <u>automatically</u>!

• ML combines multiple weak features, <u>automatically</u>.

• ML considered some features more strongly than others, <u>automatically</u>!

Are we done?


Wait! What about Jim!

Jim's ICUSTAY_ID - 290851

- Prediction is 0?
 - Could there be a bug?

• Let's Investigate