

Deep Learning for Ultrasound Image Analysis

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4Catalyzer

With results and help from 4Catalyzer
and Butterfly Network colleagues

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Need for Low-cost Diagnostic Tools



Camman's Model 1900



Hertz with the 1953 ultrasound reflectoscope on the left and the Sonoline CD on the right, 1985

Ultrasound is used more often by doctors than any other type of imaging test.

Barriers to Use of Ultrasound

Low- and middle-income countries

- lack of training (60%)
- lack of equipment (45%)
- ultrasound machine malfunction (37%)
- lack of ultrasound maintenance capability (47%)

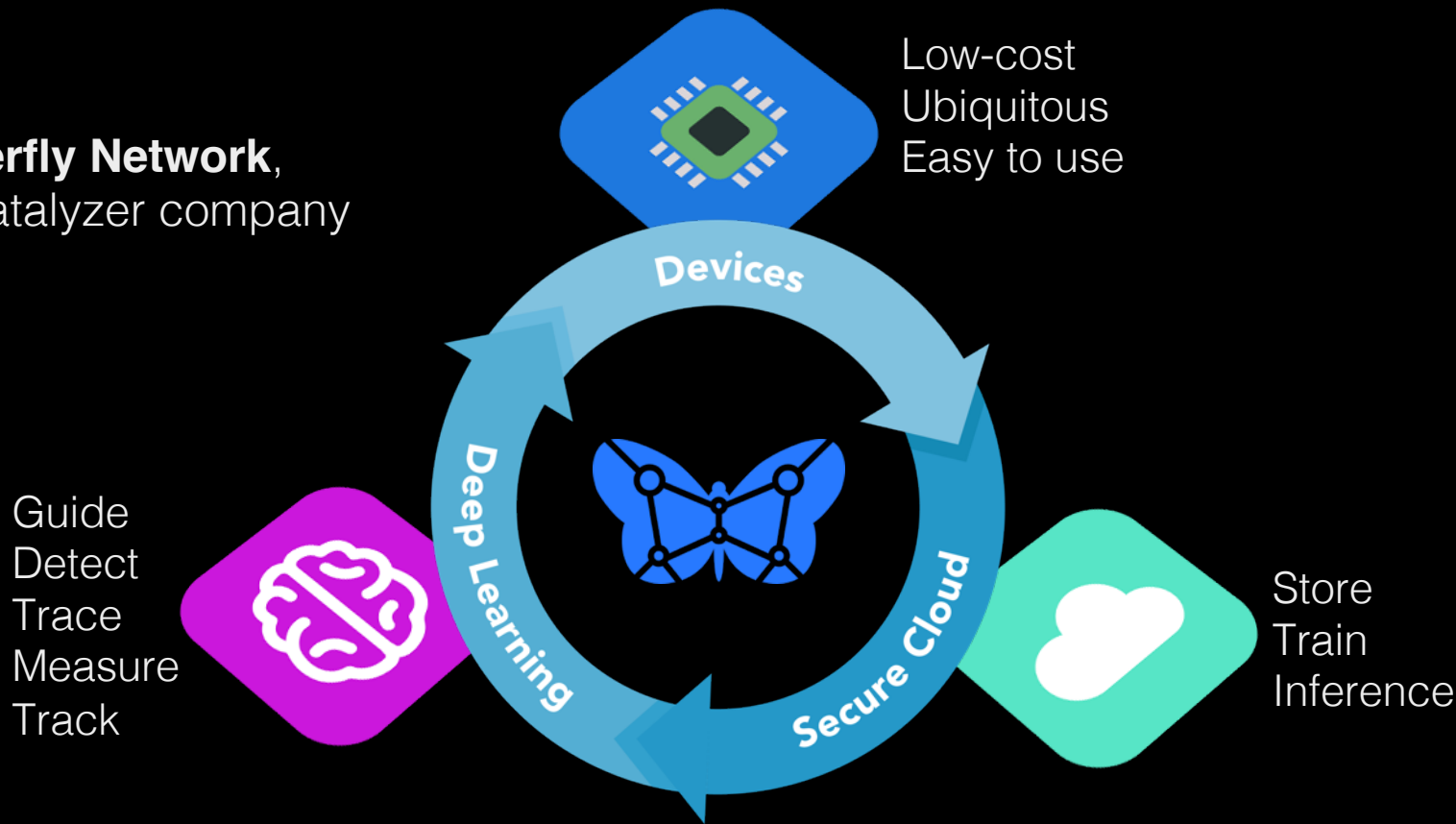


United States

- available between 40-80% of emergency departments
- barriers to use: limited training (70%), expense (39%), and limited need (32%)

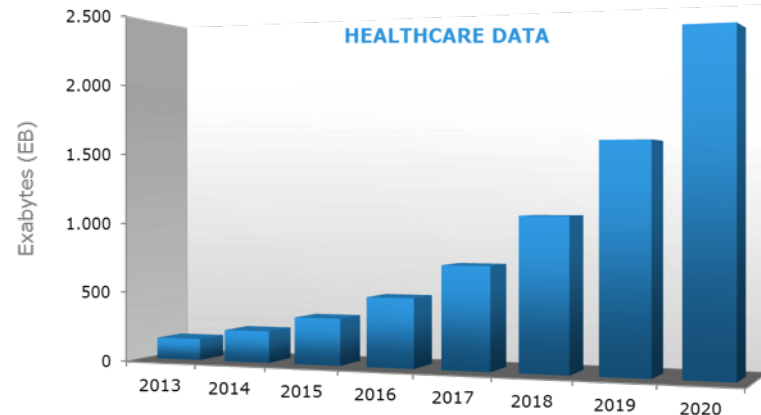
A Complete Ecosystem in One Company

Butterfly Network,
a 4Catalyzer company



Data Explosion

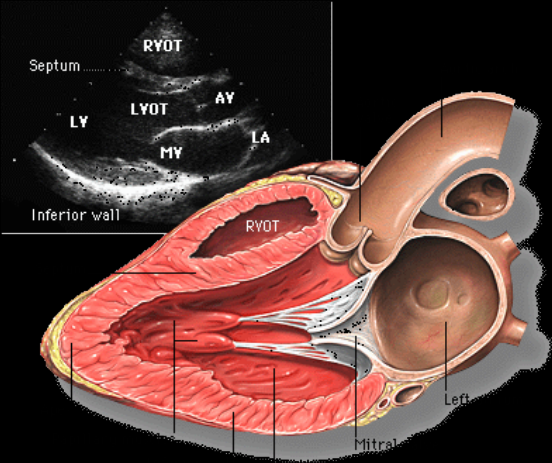
“Radiology field will change as a result of deep learning. The systems aren’t threat but benefit to radiologists.”



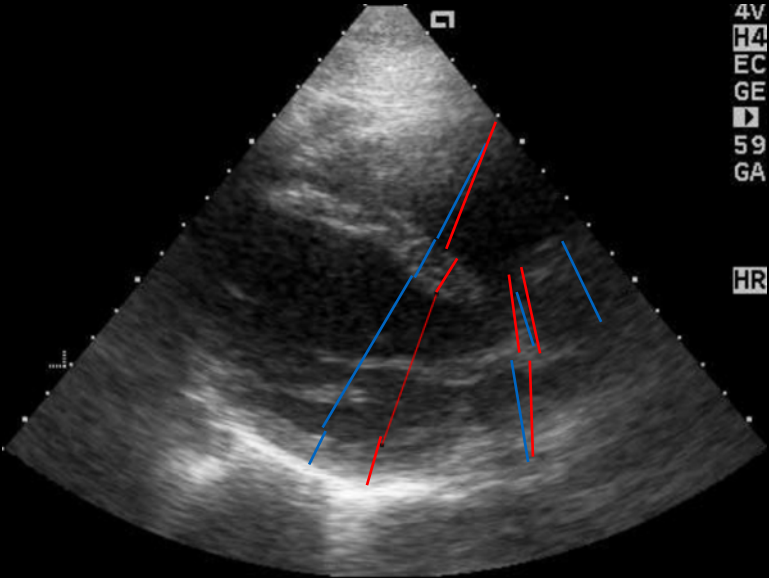
Source: EMC Digital Universe with Research & Analysis by IDC

	num cines	patients	patients annotated	num annotations	cine labels
data set 1	706	10	10	5166	0
data set 2	712	10	10	2328	0
data set 3	151368	6777	271	3210	4169
data set 4	63245	2498	181	2188	1281
data set 5	45562	1999	85	1007	894
data set 6	168	10	10	611	0

Parasternal Long Axis View



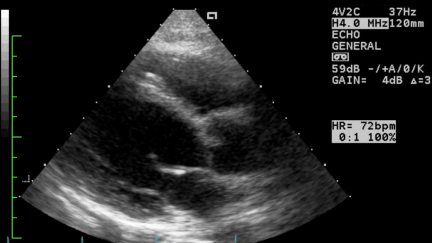
LV	interuser [%]	number
user 1	2.10	502
user 2	3.16	252
user 3	3.92	294



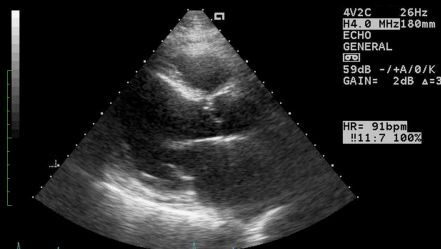
	user error [%]	length [cm]
ALHP	4.24	2.45
AORTA	4.20	3.90
IVS	6.44	1.54
LA	3.80	4.29
LV	3.56	4.60
PW	7.17	1.47
RVOT	5.29	3.18



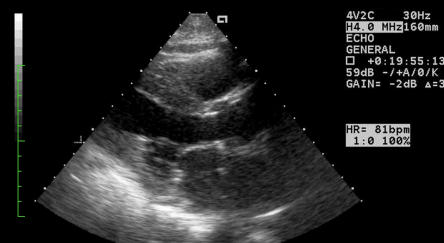
Data Variation



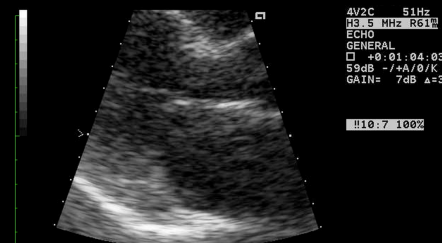
normal 43%



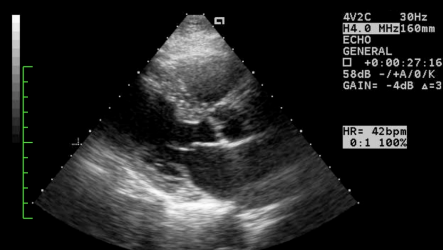
dilated 13%



LV hypertrophy 9%



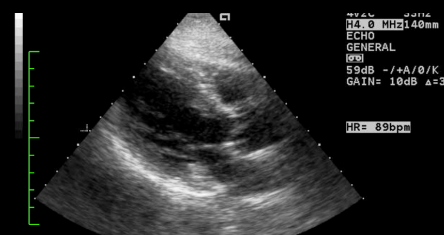
cutoff_lv 14%



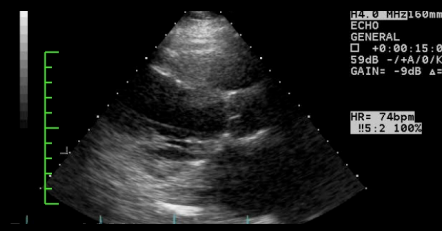
sigmoid septum 8%



banana 6%

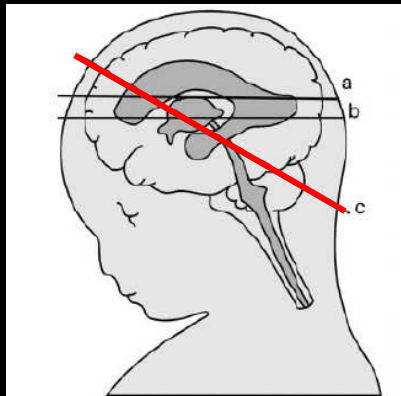


cavity obliteration 5%

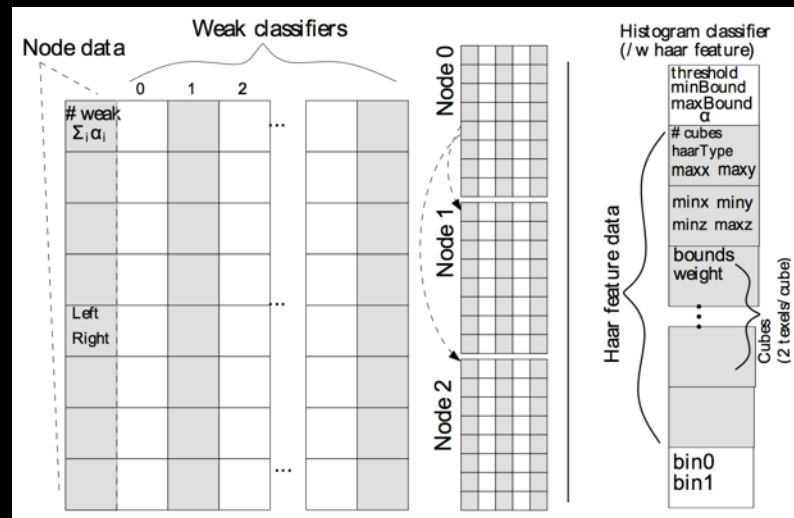
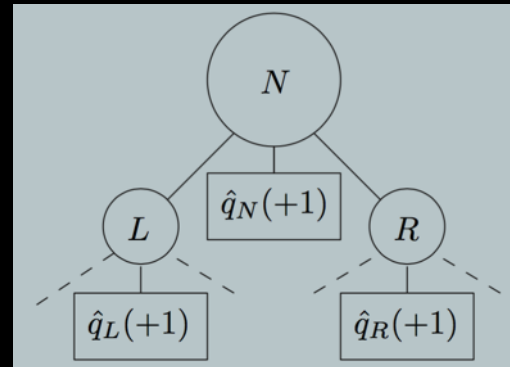
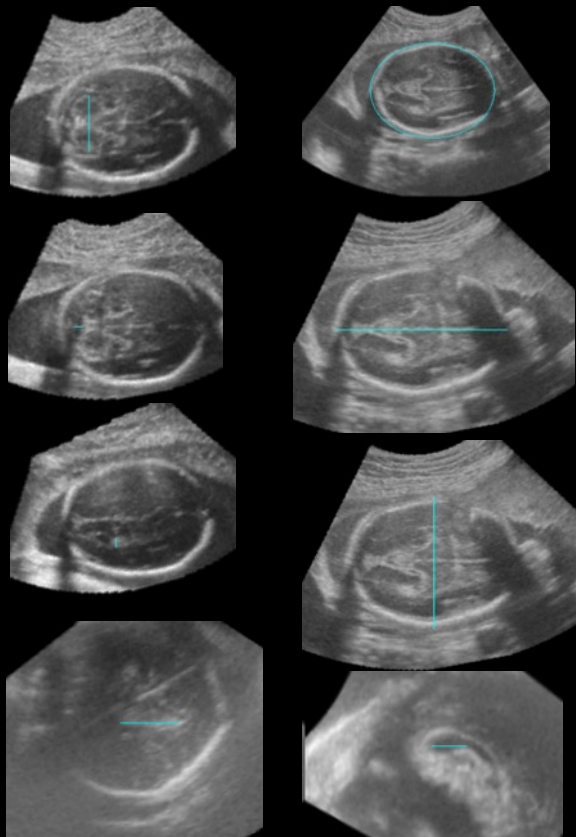


foreshortened 9%

Before: Probabilistic Boosting Trees on a GPU

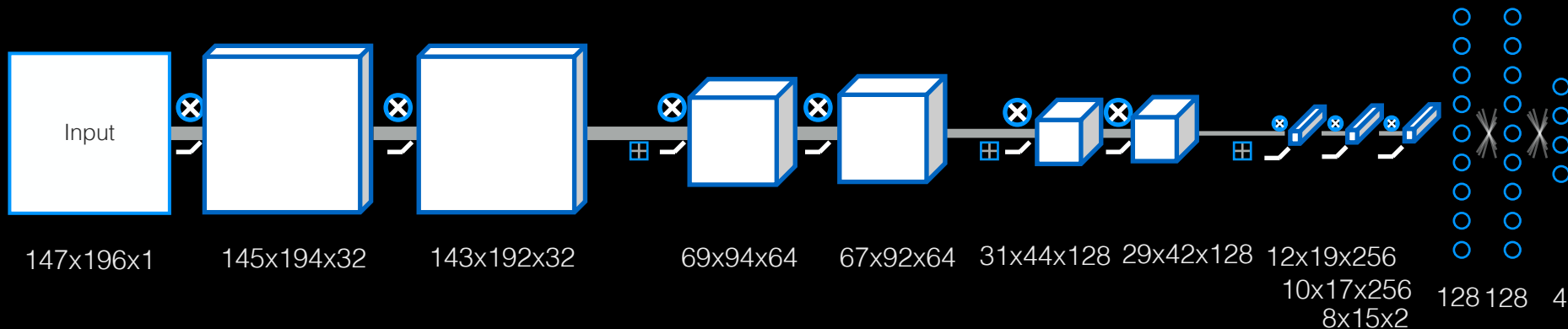


Sofka et al. *TMI* 2014.



Fast Boosting Trees for Classification, Pose Detection, and Boundary Detection on a GPU. *Birkbeck, Sofka, Zhou, ECCVW 2011.*

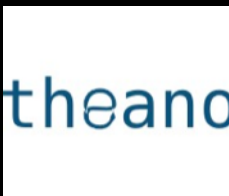
Now: Network Architecture



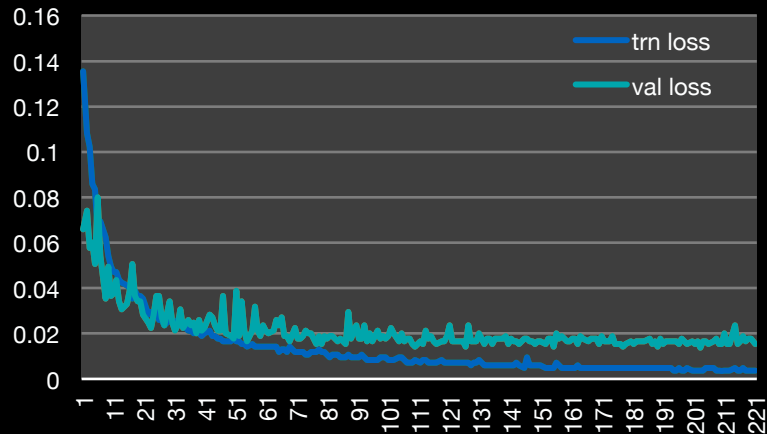
- ▣ Max pooling
- ⊗ Convolution
- ✓ ReLU nonlinearity

nVidia® Tesla™ K80 GPU accelerated cloud computing

epoch	trn loss	val loss	trn/val	ptdT	ptdV	lndV	dur
1	0.94281	0.07557	12.47633	0.59839	0.20127	0.13372	43.92s
2	0.13544	0.06610	2.04896	0.28076	0.19044	0.12857	28.07s
3	0.10777	0.07404	1.45554	0.24289	0.20755	0.13289	28.26s
4	0.10169	0.05809	1.75035	0.23713	0.18333	0.09826	28.30s
5	0.08568	0.05945	1.44126	0.21424	0.18644	0.10525	28.32s
6	0.08393	0.05038	1.66600	0.21097	0.16676	0.09850	28.30s
7	0.06500	0.07998	0.81261	0.18527	0.21875	0.10196	28.36s
8	0.06909	0.05371	1.28634	0.19155	0.17395	0.09522	28.33s
9	0.06272	0.03499	1.79216	0.18450	0.13900	0.08591	28.32s
10	0.05391	0.04973	1.08416	0.17369	0.15565	0.12774	28.36s
11	0.04887	0.03599	1.35797	0.16199	0.14317	0.08492	28.72s
12	0.04674	0.03749	1.24684	0.15958	0.14839	0.08033	28.70s
13	0.04742	0.04372	1.08482	0.16046	0.17410	0.07708	28.33s
14	0.04410	0.03395	1.29888	0.15481	0.13273	0.08422	28.32s
15	0.04253	0.03048	1.39558	0.15296	0.13123	0.07450	28.33s
16	0.04128	0.03301	1.25038	0.14976	0.13602	0.07123	28.30s
17	0.03995	0.03941	1.01375	0.14747	0.14504	0.08227	28.72s
18	0.03493	0.05043	0.69272	0.13720	0.16334	0.08704	28.73s
19	0.03882	0.03676	1.05599	0.14485	0.14133	0.08534	28.73s
20	0.03636	0.03426	1.06104	0.13945	0.13485	0.07684	28.71s
21	0.03658	0.03421	1.06951	0.13818	0.14559	0.07332	28.43s
22	0.03513	0.02822	1.24485	0.13547	0.12011	0.07662	28.33s
23	0.02870	0.02491	1.15232	0.12357	0.11188	0.07587	28.30s
24	0.02932	0.02272	1.29056	0.12677	0.10930	0.06601	28.34s
25	0.02848	0.02782	1.02365	0.12417	0.12367	0.07612	28.35s
26	0.02979	0.03691	0.80701	0.12859	0.14446	0.09057	28.29s
27	0.02624	0.03610	0.72678	0.12020	0.13106	0.10619	28.31s
28	0.02570	0.02720	0.94467	0.11703	0.11768	0.07893	28.33s
29	0.02338	0.02385	0.98043	0.11300	0.11714	0.05975	28.33s
30	0.02575	0.03408	0.75568	0.11708	0.13882	0.07876	28.32s
31	0.02471	0.02444	1.01088	0.11515	0.11472	0.06563	28.39s
32	0.02406	0.02109	1.14054	0.11313	0.10742	0.06103	28.32s
33	0.02626	0.02302	1.14080	0.11889	0.10552	0.07413	28.29s
34	0.02319	0.03026	0.76640	0.11113	0.12732	0.07217	28.41s
35	0.02315	0.02284	1.01352	0.11177	0.11448	0.06044	28.29s
36	0.02072	0.02592	0.79936	0.10516	0.11400	0.07897	28.67s
37	0.02151	0.02367	0.90838	0.10755	0.11513	0.06694	28.57s
38	0.02006	0.02432	0.82484	0.10144	0.11355	0.05938	28.34s
39	0.02169	0.02021	1.07337	0.10848	0.10687	0.05704	28.28s
40	0.02021	0.02620	0.77121	0.10377	0.11785	0.06714	28.34s
41	0.01941	0.02142	0.90632	0.10299	0.10924	0.06349	28.33s
42	0.01980	0.02208	0.89647	0.10401	0.10415	0.06780	28.32s
43	0.02082	0.02887	0.72105	0.10608	0.11548	0.08040	28.45s
44	0.01858	0.02715	0.68457	0.09943	0.12133	0.07072	28.33s
45	0.01863	0.02306	0.80789	0.09936	0.10779	0.07517	28.35s
46	0.01831	0.02172	0.84304	0.09854	0.10793	0.06150	28.31s
47	0.01828	0.02094	0.87315	0.09840	0.10415	0.06706	28.29s
48	0.01703	0.03595	0.47377	0.09505	0.12689	0.10824	28.34s
49	0.01673	0.01983	0.84366	0.09524	0.09728	0.06416	28.35s
50	0.01695	0.01919	0.88344	0.09541	0.10518	0.05867	28.39s



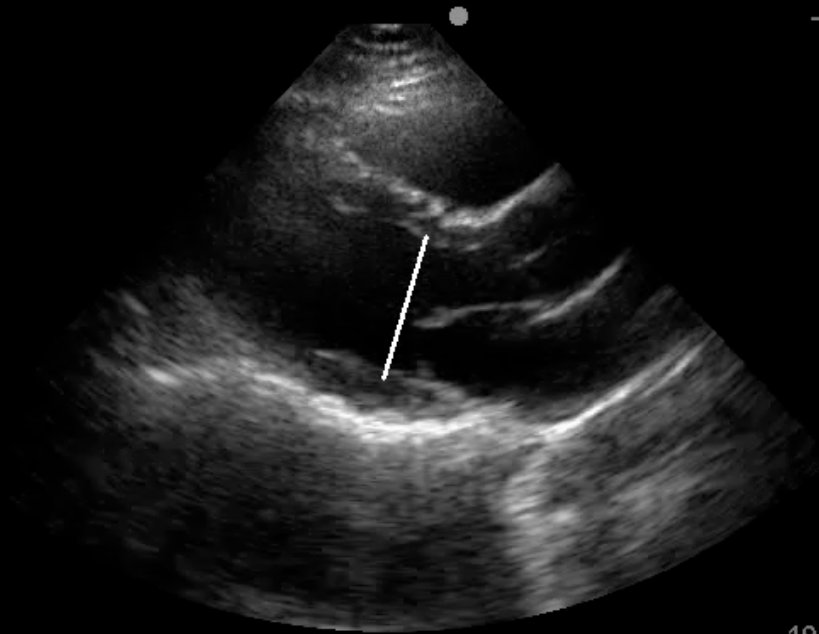
Training



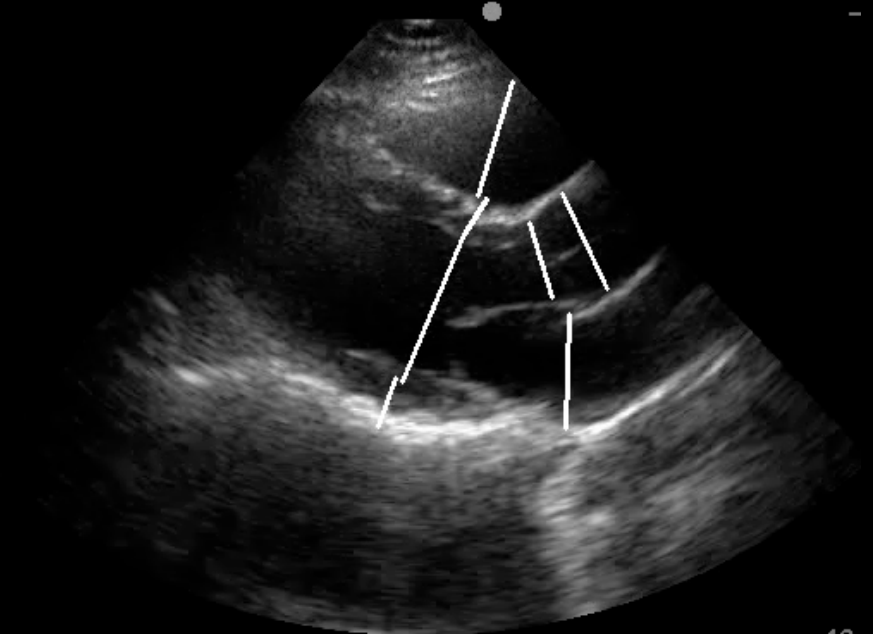
Michal Sofka, msofka@4catalyzer.com



Cardiology: Parasternal Long Axis View



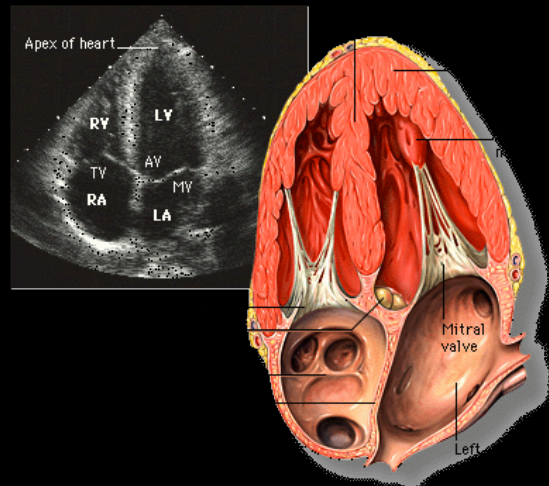
19



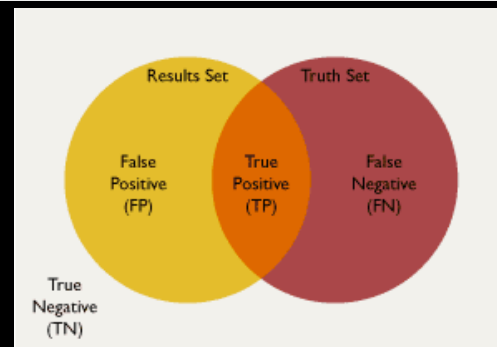
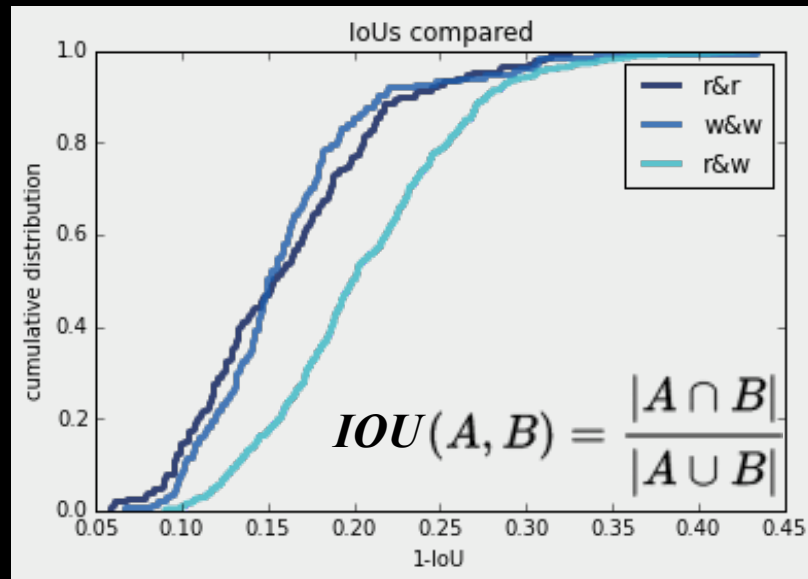
19

Four Chamber Apical View

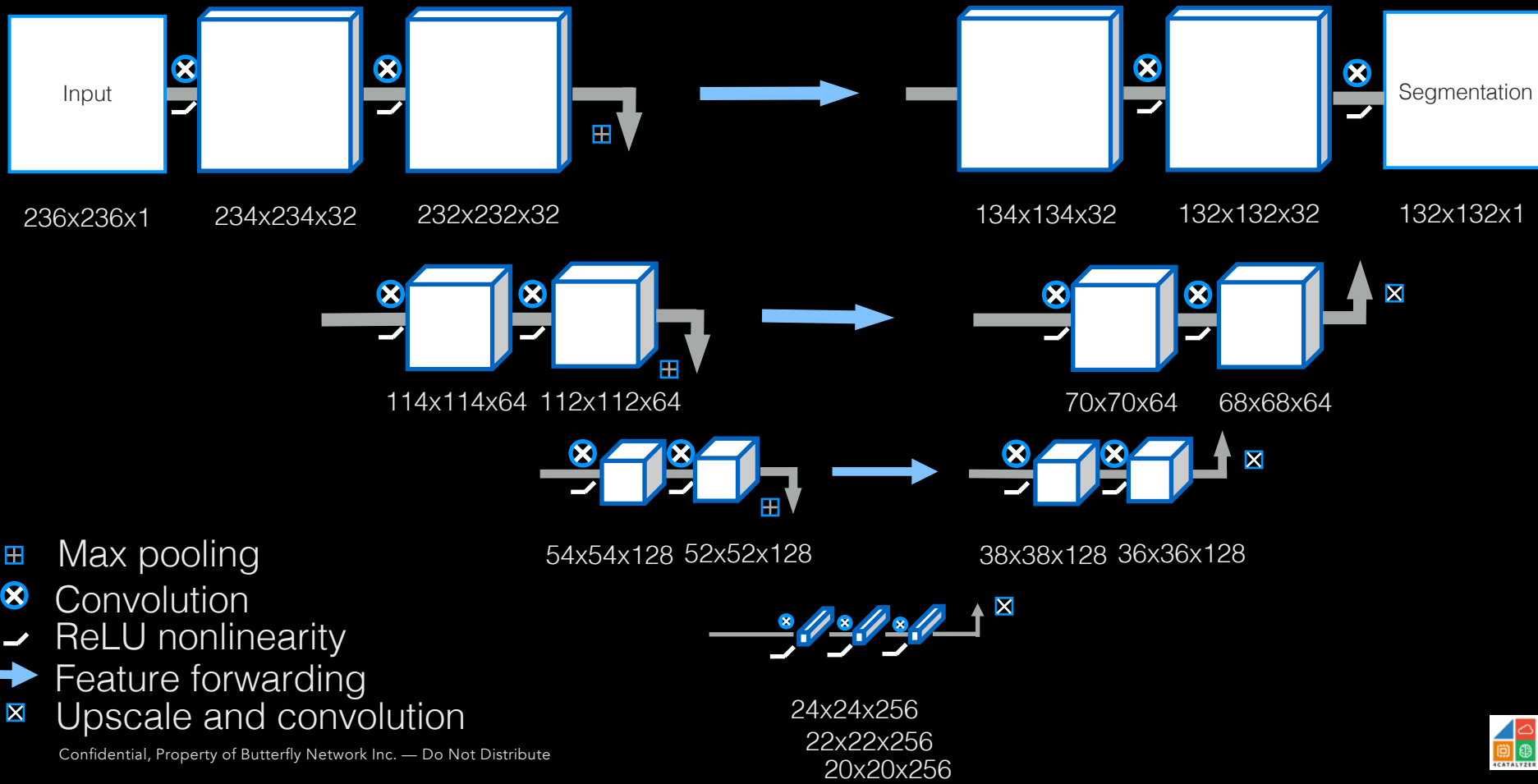
Segment LV



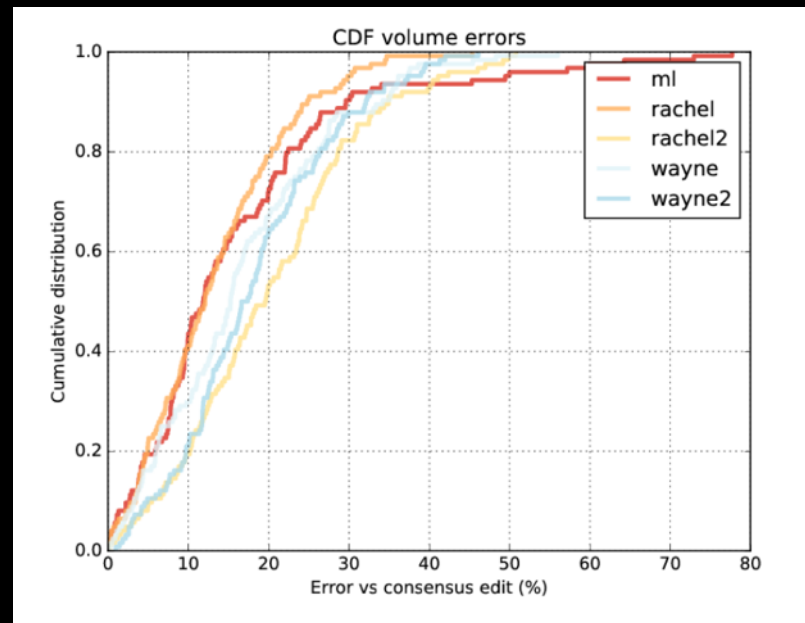
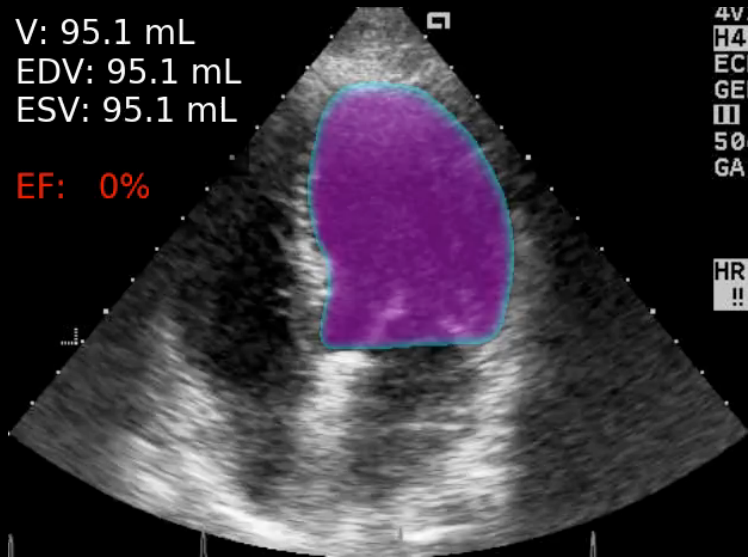
IOU	mean	std	min	25%	50%	75%	max	count
1 vs. 1	0.84	0.05	0.57	0.82	0.85	0.87	0.93	138
2 vs. 2	0.84	0.06	0.67	0.80	0.85	0.88	0.94	151
1 vs. 2	0.79	0.06	0.57	0.76	0.80	0.83	0.91	572

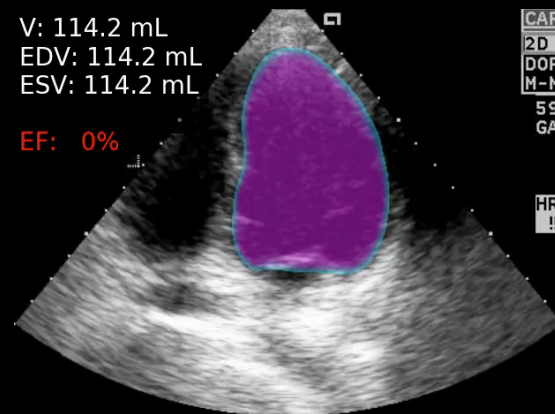
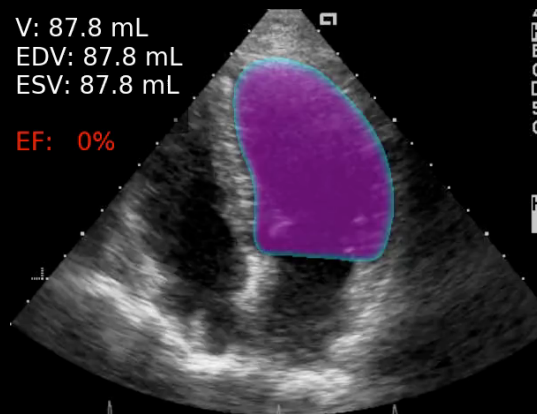
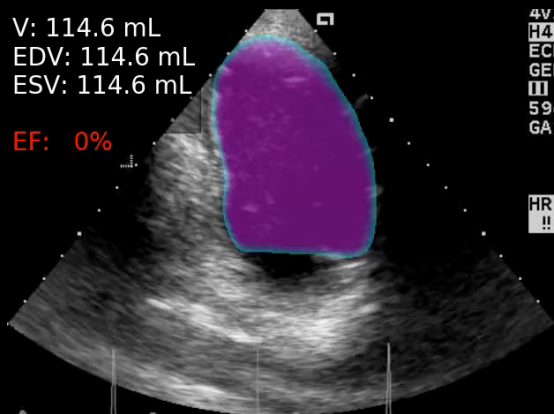
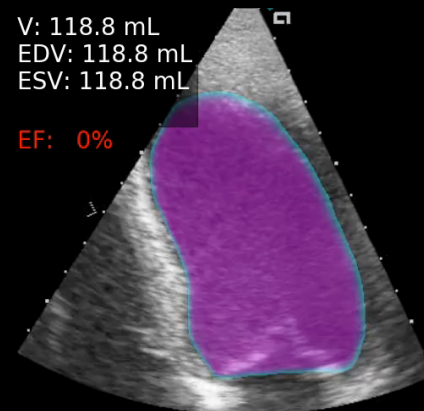
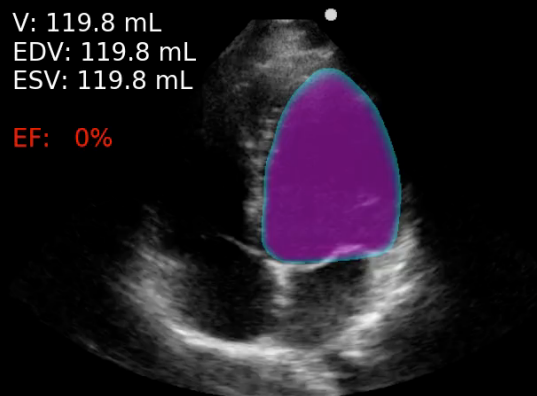
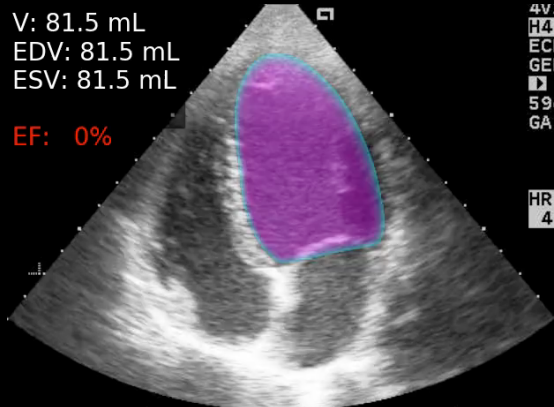


Network Architecture



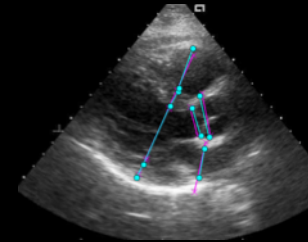
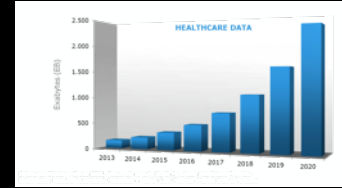
Cardiology: Apical View





Deep Learning in Ultrasound Imaging

- Data explosion
- Domain knowledge critical
- No single source of truth



- New devices will yield new applications
- Decentralized medicine
- Cloud based and real-time running on a device

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