

作業二

TOTAL POINTS 200

1.	Questions 1-2 are about noisy targets.	10 points
	Consider the bin model for a hypothesis h that makes an error with probability μ in approximating a deterministic target function f (both h and f outputs $\{-1, +1\}$). If we use the same h to approximate a noisy version of f given by	
	$P(\mathbf{x},y) = P(\mathbf{x})P(y \mathbf{x})$	
	$P(y \mathbf{x}) = \begin{cases} \lambda & y = f(\mathbf{x}) \\ 1 - \lambda & \text{otherwise} \end{cases}$	
	What is the probability of error that h makes in approximating the noisy target y ?	
	what is the probability of error that n -makes in approximating the noisy target g : $\bigcirc 1 - \lambda$	
	Ο μ	
	$ \bigcap_{\mu} \lambda(1-\mu) + (1-\lambda)\mu $	
	$ \lambda(1-\mu) + (1-\lambda)\mu $ $ \lambda\mu + (1-\lambda)(1-\mu) $	
	$\lambda \mu + (1 - \lambda)(1 - \mu)$ none of the other choices	
	of note of the other choices	
2.	Following Question 1, with what value of λ will the performance of \hbar be independent of μ ?	10 points
	○ 0	
	O 1	
	○ 0 or 1	
	onne of the other choices	
3.	Questions 3-5 are about generalization error, and getting the feel of the bounds numerically. Please use the simple upper	10 points
	bound $N^{d_{ m rc}}$ on the growth function $m_{\mathcal H}(N)$, assuming that $N\geq 2$ and $d_{ m rc}\geq 2$.	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
	For an \mathcal{H} with $d_{q_c}=10$. If you want 95% confidence that your generalization error is at most 0.05 , what is the closest numerical approximation of the sample size that the VC generalization bound predicts?	
	420,000	
	○ 440,000	
	460,000460,000	
	○ 480,000 ○ 500,000	
	500,000	
4.	There are a number of bounds on the generalization error ϵ , all holding with probability at least $1-\delta$. Fix $d_{vc}=50$ and $\delta=0.05$ and plot these bounds as a function of N . Which bound is the tightest (smallest) for very large N , say $N=10,000$?	10 points
	Note that Devroye and Parrondo & Van den Broek are implicit bounds in $\varepsilon.$	
	\bigcirc Original VC bound: $\epsilon \leq \sqrt{\frac{8}{N} \ln \frac{4 m_{\rm R}(2N)}{\delta}}$	
	$\bigcirc \ \ \text{Rademacher Penalty Bound: } \epsilon \leq \sqrt{\frac{2\ln(2Nm_{\text{\tiny NL}}(N))}{N}} + \sqrt{\frac{2}{N}\ln\frac{1}{\delta}} + \frac{1}{N}$	
	\bigcirc Parrondo and Van den Broek: $\epsilon \leq \sqrt{rac{1}{N}(2\epsilon + \lnrac{6m_{ m N}(2N)}{\delta})}$	
	$leftlefte$ Devroye: $\epsilon \leq \sqrt{rac{1}{2N}(4\epsilon(1+\epsilon) + \lnrac{4m_{ m R}(N^2)}{\delta})}$	
	\bigcirc Variant VC bound: $\epsilon \leq \sqrt{rac{16}{N} \ln rac{2m_{ m K}(N)}{\sqrt{\delta}}}$	
_	Continuing from Question 4 for small N and N = 5 which housed in the kinkhoot (smallest)?	
5.	Continuing from Question 4, for small N , say $N=5$, which bound is the tightest (smallest)?	10 points
	Original VC bound	
	Rademacher Penalty Bound	
	Parrondo and Van den Broek	
	Devroye Variant VC bound	
6.	In Questions 6-11, you are asked to play with the growth function or VC-dimension of some hypothesis sets.	10 points
	What is the growth function $m_{\mathcal{H}}(N)$ of "positive-and-negative intervals on \mathbb{R}^n ? The hypothesis set \mathcal{H} of "positive-and-negative intervals" contains the functions which are $+1$ within an interval $[\ell,r]$ and -1 elsewhere, as well as the functions which are -1 within an interval $[\ell,r]$ and $+1$ elsewhere.	
	For instance, the hypothesis $h_1(x)=\mathrm{sign}(x(x-4))$ is a negative interval with -1 within $[0,4]$ and $+1$ elsewhere, and hence belongs to $\mathcal H$. The hypothesis $h_2(x)=\mathrm{sign}((x+1)(x)(x-1))$ contains two positive intervals in $[-1,0]$ and $[1,\infty)$ and hence does not belong to $\mathcal H$.	
	\bigcirc N^2	
	\bigcirc $N^2 + 1$	
	onne of the other choices.	
	$\bigcirc N^2 + N + 2$	
7.	Continuing from the previous problem, what is the VC-dimension of the hypothesis set of "positive-and-negative intervals on \mathbb{R}^n ?	10 points
	W11 M2 1	

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$ \begin{array}{c} 0 & 0 \\ 0 & 0 $		O 4	
what is the growth function $m_{\rm th}(N)$ of "postible distinct." Online in \$\mathbb{R}^{N\gamma}\$ The hypothesis set N of "postible distinct." Online in \$\mathbb{R}^{N\gamma}\$ The hypothesis set N of "postible distinct." Online in \$\mathbb{R}^{N\gamma}\$ The hypothesis set N of "postible distinct." Online in \$\mathbb{R}^{N\gamma}\$ The hypothesis set N of "postible distinct." Online in \$\mathbb{R}^{N\gamma}\$ The hypothesis set N of "postible distinct." Online in \$\mathbb{R}^{N\gamma}\$ The hypothesis is each within a "short of region of $a^2 \le q^2 + a^2 \le b^2$ and -1 elsewhere. Without less of generally set N of N		O 5	
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generally, we assume $0 < a < b < \infty$. $N = 1$ \emptyset $\binom{N+1}{2} + 1$ 0 none of the other choices. $\binom{N+1}{2} + 1$ 0 none of the other choices. $\binom{N+1}{2} + 1$ $\binom{N+1}{2} + $			
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On none of the other choices. $ \binom{n}{2}+1 $ 1. Consider the "polynomial discriminant" hypothesis set of degree D on \mathbb{R} , which is given by $ \mathcal{H} = \left\{h_e \ \middle \ h_e(x) = \operatorname{sign}\left(\sum_{i=0}^D c_ix^2\right)\right\} $ What is the V-Colmension of such an $\mathcal{H}2$: $ D$			
Consider the 'polynomial discriminant' hypothesis set of degree D on \mathbb{R} , which is given by $\mathcal{H} = \left\{h_{\mathbb{R}}\left[h_{\mathbb{R}}(x) = \operatorname{sign}\left(\sum_{i=0}^{D} \operatorname{cu}^{x}\right)\right\}\right\}$ What is the VC-dimension of such an \mathcal{H} ? D 0 $D + 1$ ∞ 0 0 10 0 0 10 0 0 0 0 0 0 0 0 0		$\binom{N+1}{3} + 1$	
Consider the "polynomial discriminant" hypothesis set of degree D on \mathbb{R} , which is given by $\mathcal{H} = \left\{h_{e} \left[h_{e}(x_{e}) = \operatorname{sign}\left(\sum_{i=0}^{D} c_{i}x^{i}\right)\right\}\right\}$ What is the VC-dimension of such an \mathcal{H} ? D D D D D $H = \left\{h_{e}[h_{e}(x_{e}) = \operatorname{high}\left(\sum_{i=0}^{D} c_{i}x^{i}\right)\right\}$ None of the other choices. $D + 2$ D $Consider the "simplified decision trees" hypothesis set on \mathbb{R}^{d}, which is given by \mathcal{H} = \left\{h_{e}[h_{e}(x_{e}) = 2] \mathbf{v} \in S]\right\} - 1, where \mathbf{v}_{e} = \left[\left[x_{e} > h_{e}\right]\right], and so collection of vectors in (0, 1)^{d}, it is \mathbb{R}^{d}. That is, each hypothesis makes a pradiction by first using the d three-holds t_{e} = 1 to c = 1. What is the VC-dimension of the "simplified decision trees" hypothesis set? 2^{d-1} = 3 0 0 none of the other choices. 2^{d-1} = 3 0 0 none of the other choices. 2^{d-1} = 3 0 0 none of the other choices. 2^{d-1} = 3 0 0 0 none of the other choices. 2^{d-1} = 3 0 0 0 0 0 0 0 0 0 0$		onne of the other choices.	
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What is the VC-dimension of such an \mathcal{H} ? D $D + 1$ ∞ ∞ none of the other choices. $D + 2$ 0. Consider the "simplified decision trees" hypothesis set on \mathbb{R}^d , which is given by $\mathcal{H} = \{h_{1,\mathbf{S}} \mid h_{1,\mathbf{S}}(\mathbf{x}) = 2[\mathbf{v} \in S] - 1$, where $\mathbf{s}_1 = [\mathbf{z}_1 > b_1]$, $\mathbf{S}_1 = \mathbf{s}_2 = \mathbf{s}_3 = \mathbf{s}$		$\mathcal{H} = \left\{ h_{c} \left \ h_{c}(x) = \mathrm{sign} \left(\sum^{D} c_{i} x^{i} ight) ight\}$	
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ⓐ $D+1$ ○ ∞ ○ none of the other choices. ○ $D+2$ ○ Consider the "simplified decision trees" hypothesis set on \mathbb{R}^d , which is given by $\mathcal{H}=\{h_{t,S}\mid h_{t,S}(x)=2 v\in S -1, \text{ where } v_t= x_t>t_t , S a collection of vectors in \{0,1\}^d, t\in \mathbb{R}^d ○ That is, each hypothesis makes a precision by fex using the directions for yet one of the thresholds, to be until none of the 2^d hyperrectangular regions, and looking up S to decide whether the region should be +1 or -1. What is the V-climension of the "simplified decision trees" hypothesis set? ○ 2^d ○ 2^d$			
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Once of the other choices. $D+2$ O. Consider the "simplified decision trees" hypothesis set on \mathbb{R}^d , which is given by $\mathcal{H} = \{h_{1S} \mid h_{LS}(\mathbf{x}) = 2 \mathbf{v} \in S - 1, \text{ where } \mathbf{v}_1 = \mathbf{x}_1 > t_1 , \\ \mathbf{S} \text{ a collection of vectors in } \{0, 1\}^d, \mathbf{t} \in \mathbb{R}^d \}$ That is, each hypothesis makes a prediction by first using the differential state is to boate \mathbf{x} to be within one of the 2^d hyperexectangular regions, and looking up \mathbf{S} to decide whether the region should be $+1$ or -1 . What is the V-C-dimension of the "simplified decision trees" hypothesis set? ② 2^d ② $2^{d-1} - 3$ ③ ∞ ① none of the other choices. ② 2^{d-1} 1. Consider the "triangle waves" hypothesis set on \mathbb{R} , which is given by $\mathcal{H} = \{h_{1S} \mid h_{1S}(\mathbf{x}) = \text{sign}(\ (\mathbf{x})\ \text{ mod } 4 - 2 - 1), \alpha \in \mathbb{R}\}$ Here ($\mathbf{z} \text{ mod } 4$) is a number $\mathbf{z} - 4k$ for some integer k such that $\mathbf{z} - 4k \in [0, 4]$. For instance, (11.26 $\mathbf{mod } 4$) is 3.26 , and ($-11.26 \mathbf{mod } 4$) is 0.74 what is the V-C-dimension of such an \mathcal{H} ? 1 2 ② ∞ ② ∞ Once of the other choices. 3 2. In Questions 12-15. you are asked to verify some properties or bounds on the growth function and V-C-dimension. Which of the following is an upper bounds of the growth function $m_K(N)$ for $N \geq d_{vc} \geq 2$? $m_K(\{\frac{N}{2}\})$ 2^{d-1} $m_K(\{\frac{N}{2}\})$ 2^{d-1} 2			
0. Consider the "simplified decision trees" hypothesis set on \mathbb{R}^d , which is given by $\mathcal{H} = \{h_{\text{LS}} \mid h_{\text{LS}}(x) = 2\ Y \in S\ - 1, \text{ where } v_1 = \ x_1 > t_1\ , \\ S \text{ a collection of vectors in } [0,1]^d, \mathbf{t} \in \mathbb{R}^d - 1 $ That is, each hypothesis makes a prediction by first using the d thresholds t_1 to locate x to be within one of the 2^d hyper-rectangular regions, and looking up S to decide whether the region should be $+1$ or -1 . What is the VC-dimension of the "simplified decision trees" hypothesis set? ② 2^d ② $2^d = 1$ ③ ∞ ② none of the other choices. ② 2^{d+1} ③ 1. Consider the "triangle waves" hypothesis set on \mathbb{R} , which is given by $\mathcal{H} = \{h_{\text{LS}} \mid h_{\text{LS}}(x) = \text{sign}([\alpha x) \text{ mod } 4 - 2] - 1\}, \alpha \in \mathbb{R}\}$ Here $(x \text{ mod } 4)$ is a number $x = 4k$ for some integer k such that $x = 4k \in [0, 4]$. For instance, $(11.26 \text{ mod } 4)$ is 3.25 . and $(-11.26 \text{ mod } 4)$ is 0.74 , what is the VC-dimension of such an \mathcal{H} ? ① 1 ② 2 ③ ∞ ③ none of the other choices. ③ 3 2. In Questions 12.15. In polarize asked to verify some properties or bounds on the growth function and VC-dimension and VC-dimension and VC-dimension and VC-dimension of $(x, y) = (x + 1)$ and $(x, y) = (x + 1)$ and $(x + 1) = (x + 1)$ a			
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$\mathcal{H} = \{h_{\mathbf{t},\mathbf{S}} \mid h_{\mathbf{t},\mathbf{S}}(\mathbf{x}) = 2[\mathbf{v} \in S] - 1, \text{ where } v_{\mathbf{t}} = [x_{\mathbf{t}} > t_{\mathbf{t}}] , \\ \mathbf{S} \text{ a collection of vectors in } \{0,1\}^d, \mathbf{t} \in \mathbb{R}^d \times \mathbb{R}^$		○ D+2	
$\mathcal{H} = \{h_{\mathbf{t},\mathbf{S}} \mid h_{\mathbf{t},\mathbf{S}}(\mathbf{x}) = 2[\mathbf{v} \in S] - 1, \text{ where } v_{\mathbf{t}} = [x_{\mathbf{t}} > t_{\mathbf{t}}] , \\ \mathbf{S} \text{ a collection of vectors in } \{0,1\}^d, \mathbf{t} \in \mathbb{R}^d \times \mathbb{R}^$	10	Concider the "simplified decision treas" hypothesis set on Td which is niver by	40
S a collection of vectors in $\{0,1\}^d$, $t \in \mathbb{R}^d$ } That is, each hypothesis makes a prediction by first using the d thresholds t_1 to locate x to be within one of the 2^d hyperrectangular regions, and looking up S to decide whether the region should be $+1$ or -1 . What is the VC-dimension of the "simplified decision trees" hypothesis set? ② 2^d $2^{d+1} - 3$ ∞ on one of the other choices. ② 2^{d+1} 1. Consider the "triangle waves" hypothesis set on \mathbb{R} , which is given by $\mathcal{H} = \{h_n \mid h_n(x) = \text{signt}((\alpha x) \text{ mod } 4 - 2 - 1), \alpha \in \mathbb{R}\}$ Here $(x \text{ mod } 4)$ is a number $x - 4k$ for some integer k such that $x - 4k \in [0, 4]$. For instance, $(11.26 \text{ mod } 4)$ is 3.26 , and $(-11.26 \text{ mod } 4)$ is 0.74 . What is the VC-dimension of such an \mathcal{H} ? 1 1 2 2 3 ∞ none of the other choices. 3 3 2. In Questions 12-15. you are asked to verify some properties or bounds on the growth function and VC-dimension. Which of the following is an upper bounds of the growth function $m_R(N)$ for $N \ge d_{nx} \ge 2$? $m_R(\{\frac{N}{2}\})$ 0.2^{d-1} $m_R(\{\frac{N}{2}\})$ 0.2^{d-1} none of the other choices 3. Which of the following is not a possible growth functions $m_R(N)$ for some hypothesis set? 2 N 3 N 4 N 4 N 5 N 5 N 6 N 7 N 6 N 7 N 7 N 7 N 7 N 9 N	U.		10 points
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$\mathcal{H} = \{h_{\alpha} \mid h_{\alpha}(x) = \operatorname{sign}((\alpha x) \mod 4 - 2 - 1), \alpha \in \mathbb{R}\}$ Here $(z \mod 4)$ is a number $z - 4k$ for some integer k such that $z - 4k \in [0, 4)$. For instance, $(11.26 \mod 4)$ is 3.26 , and $(-11.26 \mod 4)$ is 0.74 . What is the VC-dimension of such an \mathcal{H} ? 1 2 3 2. In Questions 12-15. you are asked to verify some properties or bounds on the growth function and VC-dimension. Which of the following is an upper bounds of the growth function $m_{\mathcal{H}}(N)$ for $N \ge d_{vc} \ge 2$? $m_{\mathcal{H}}\left(\lfloor \frac{N}{2} \rfloor\right)$ $2^{d_{vc}}$ 1 $2^{d_{vc}}$ $2^{d_{vc}}$ onne of the other choices 3. Which of the following is not a possible growth functions $m_{\mathcal{H}}(N)$ for some hypothesis set? 2^{N} 2^{V} 2		O 2 ⁿ⁻¹	
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● ∞ onone of the other choices. onone of the other choices. 2. In Questions 12-15, you are asked to verify some properties or bounds on the growth function $m_H(N)$ for $N \ge d_{nc} \ge 2$? $m_H(\lfloor \frac{N}{2} \rfloor)$ $2^{d_{nc}}$ $m_H(\lfloor \frac{N}{2} \rfloor)$ $2^{d_{nc}}$ $m_H(N-i)$ $\sqrt{N^{d_{nc}}}$ onone of the other choices 3. Which of the following is not a possible growth functions $m_H(N)$ for some hypothesis set? 2^N 2^{l_N}		O 1	
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$\begin{array}{c} m_{\mathcal{H}}\left(\left\lfloor\frac{N}{2}\right\rfloor\right) \\ 2^{d_{-}} \\ \hline \bullet & \min_{1\leq i\leq N-1} 2^{i} m_{\mathcal{H}}(N-i) \\ \hline \bigcirc \sqrt{N^{d_{-i}}} \\ \hline \bigcirc & \text{none of the other choices} \\ \\ 3. \text{ Which of the following is not a possible growth functions } m_{\mathcal{H}}(N) \text{ for some hypothesis set?} \\ \hline \bigcirc 2^{N} \\ \hline \bullet & 2^{ N } \\ \hline \bigcirc 1 \\ \hline \bigcirc N^{2}-N+2 \\ \hline \bigcirc & \text{none of the other choices} \\ \\ 4. \text{ For hypothesis sets } \mathcal{H}_{1},\mathcal{H}_{2},,\mathcal{H}_{K} \text{ with finite, positive VC-dimensions } d_{ve}(\mathcal{H}_{k}), \text{ some of the following bounds are correct and some are not.} \end{array}$	12	you are asked to verify some properties or bounds on the growth function	10 points
$ 2^{d_w} $	12.	Which of the following is an upper bounds of the growth function $m_{\mathcal{H}}(N)$ for $N \geq d_{vc} \geq 2$?	
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$\sqrt{N^{d_{vc}}}$	12		
none of the other choices $3. \ \text{Which of the following is not a possible growth functions} m_{\mathcal{H}}(N) \text{for some hypothesis set?} $	12.	○ 2 ^d ···	
3. Which of the following is not a possible growth functions $m_{\mathcal{H}}(N)$ for some hypothesis set? $2^{N} $	12.	$\bigcirc \ 2^{d_{in}}$ $\bigcirc \ \min_{1 \le i \le N-1} 2^i m_{\mathcal{H}}(N-i)$	
$\begin{array}{c} 2^N \\ \bullet \ \ 2^{\lfloor \sqrt{N} \rfloor} \\ \bullet \ \ 1 \\ \ \ N^2 - N + 2 \\ \ \ \ \ \ \text{none of the other choices} \end{array}$ 4. For hypothesis sets $\mathcal{H}_1, \mathcal{H}_2,, \mathcal{H}_K$ with finite, positive VC-dimensions $d_{ve}(\mathcal{H}_k)$, some of the following bounds are correct and some are not.	12.	$\bigcirc \ 2^{d_{n\epsilon}}$ $ullet \min_{1 \leq i \leq N-1} 2^i m_{\mathcal{H}}(N-i)$ $\bigcirc \sqrt{N^{d_{n\epsilon}}}$	
	12.	$\bigcirc \ 2^{d_{n\epsilon}}$ $ullet \min_{1 \leq i \leq N-1} 2^i m_{\mathcal{H}}(N-i)$ $\bigcirc \sqrt{N^{d_{n\epsilon}}}$	
$\begin{array}{c} \bigcirc \ 1 \\ \bigcirc \ N^2-N+2 \\ \bigcirc \ \text{none of the other choices} \end{array}$ 4. For hypothesis sets $\mathcal{H}_1,\mathcal{H}_2,,\mathcal{H}_K$ with finite, positive VC-dimensions $d_{ve}(\mathcal{H}_k)$, some of the following bounds are correct and some are not.		$ 2^{d_{or}} \\ \min_{1 \le i \le N-1} 2^i m_{\mathcal{H}}(N-i) \\ \sqrt{N^{d_{or}}} \\ \text{none of the other choices} $	10 points
$\begin{array}{c} \bigcirc \ 1 \\ \bigcirc \ N^2-N+2 \\ \bigcirc \ \text{none of the other choices} \end{array}$ 4. For hypothesis sets $\mathcal{H}_1,\mathcal{H}_2,,\mathcal{H}_K$ with finite, positive VC-dimensions $d_{vc}(\mathcal{H}_k)$, some of the following bounds are correct and some are not.		$ 2^{d_{or}} $ $ \min_{1 \le i \le N-1} 2^i m_{\mathcal{H}}(N-i) $ $ \sqrt{N^{d_{or}}} $ none of the other choices $ \text{ which of the following is not a possible growth functions } m_{\mathcal{H}}(N) \text{ for some hypothesis set?} $	10 points
$\bigcirc N^2-N+2$ \bigcirc none of the other choices $ 4. \ \text{For hypothesis sets} \ \mathcal{H}_1,\mathcal{H}_2,,\mathcal{H}_K \ \text{with finite, positive VC-dimensions} \ d_{vc}(\mathcal{H}_k), \text{some of the following bounds are correct and some are not.} $		$ 2^{d_w} $ $ \min_{1 \leq i \leq N-1} 2^i m_{\mathcal{H}}(N-i) $ $ \sqrt{N^{d_w}} $ none of the other choices $ \text{Which of the following is not a possible growth functions } m_{\mathcal{H}}(N) \text{ for some hypothesis set?} $ $ 2^N $	10 points
on none of the other choices $4. \ \text{For hypothesis sets} \ \mathcal{H}_1, \mathcal{H}_2,, \mathcal{H}_K \ \text{with finite, positive VC-dimensions} \ d_{vc}(\mathcal{H}_k), \text{some of the following bounds are correct and some are not.}$		$ 2^{d_m} $ $ \min_{1 \le i \le N-1} 2^i m_{\mathcal{H}}(N-i) $ $ \sqrt{N^{d_m}} $ none of the other choices $ \text{Which of the following is not a possible growth functions } m_{\mathcal{H}}(N) \text{ for some hypothesis set?} $ $ 2^N $ $ 2^{ N } $	10 points
4. For hypothesis sets $\mathcal{H}_1, \mathcal{H}_2,, \mathcal{H}_K$ with finite, positive VC-dimensions $d_{vc}(\mathcal{H}_k)$, some of the following bounds are correct and some are not.		$\bigcirc 2^{d_w}$ $\bigcirc \min_{1 \le i \le N-1} 2^i m_{\mathcal{H}}(N-i)$ $\bigcirc \sqrt{N^{d_w}}$ $\bigcirc \text{none of the other choices}$ $\text{Which of the following is not a possible growth functions } m_{\mathcal{H}}(N) \text{ for some hypothesis set?}$ $\bigcirc 2^N$ $\bigcirc 2^{ \mathcal{N} }$ $\bigcirc 1$	10 points
correct and some are not.		$ 2^{d_{vv}} $ $ \min_{1 \le i \le N-1} 2^i m_{\mathcal{H}}(N-i) $ $ \sqrt{N^{d_{vv}}} $ none of the other choices $ \text{Which of the following is not a possible growth functions } m_{\mathcal{H}}(N) \text{ for some hypothesis set?} $ $ 2^N $ $ 2^{ \sqrt{N} } $ $ 1 $ $ N^2 - N + 2 $	10 points
		$ 2^{d_{vv}} $ $ \min_{1 \le i \le N-1} 2^i m_{\mathcal{H}}(N-i) $ $ \sqrt{N^{d_{vv}}} $ none of the other choices $ \text{Which of the following is not a possible growth functions } m_{\mathcal{H}}(N) \text{ for some hypothesis set?} $ $ 2^N $ $ 2^{ \sqrt{N} } $ $ 1 $ $ N^2 - N + 2 $	10 points
	113	2^{d_w} $\min_{1\leq i\leq N-1} 2^i m_{\mathcal{H}}(N-i)$ $\sqrt{N^{d_w}}$ $\text{none of the other choices}$ Which of the following is not a possible growth functions $m_{\mathcal{H}}(N)$ for some hypothesis set? 2^N $2^{\lfloor \sqrt{N} \rfloor}$ $2^{\lfloor \sqrt{N} \rfloor}$ 1 $N^2 - N + 2$ $\text{none of the other choices}$ For hypothesis sets $\mathcal{H}_1, \mathcal{H}_2,, \mathcal{H}_K$ with finite, positive VC-dimensions $d_{v_{\mathcal{E}}}(\mathcal{H}_k)$, some of the following bounds are	

$igcirc$ $0 \leq d_{vc}(igcap_{k=1}^K \mathcal{H}_k) \leq \sum_{k=1}^K d_{vc}(\mathcal{H}_k)$	
$igotimes 0 \ \le \ d_{vc}(igcap_{k=1}^K \mathcal{H}_k) \ \le \ \min\{d_{vc}(\mathcal{H}_k)\}_{k=1}^K$	
$igcirc 0 \ \le \ d_{vc}(igcap_{k=1}^K \mathcal{H}_k) \ \le \ \max\{d_{vc}(\mathcal{H}_k)\}_{k=1}^K$	
$\bigcap \min\{d_{vc}(\mathcal{H}_k)\}_{k=1}^K \leq d_{vc}(igcap_{k=1}^K \mathcal{H}_k) \leq \max\{d_{vc}(\mathcal{H}_k)\}_{k=1}^K$	
$\bigcirc \min\{d_{ve}(\mathcal{H}_k)\}_{k=1}^K \leq d_{ve}(\bigcap_{k=1}^K \mathcal{H}_k) \leq \sum_{k=1}^K d_{ve}(\mathcal{H}_k)$	
15. For hypothesis sets $\mathcal{H}_1, \mathcal{H}_2,, \mathcal{H}_K$ with finite, positive VC-dimensions $d_{vc}(\mathcal{H}_k)$, some of the following bounds are correct and some are not.	
Which among the correct ones is the tightest bound on $d_{vv}(\bigcup_{k=1}^K \mathcal{H}_k)$, the VC-dimension of the \mathbf{union} of the sets?	
\bigcirc 0 $\le d_{vv}(\bigcup_{k=1}^K \mathcal{H}_k) \le K - 1 + \sum_{k=1}^K d_{vv}(\mathcal{H}_k)$	
$\bigcirc \min\{d_{vc}(\mathcal{H}_k)\}_{k=1}^{k} \leq d_{vc}(\bigcup_{k=1}^{k} \mathcal{H}_k) \leq \sum_{k=1}^{k} d_{vc}(\mathcal{H}_k)$	
$\bigcirc \max\{d_{ve}(\mathcal{H}_k)\}_{k=1}^K \leq d_{ve}(\bigcup_{k=1}^K \mathcal{H}_k) \leq \sum_{k=1}^K d_{ve}(\mathcal{H}_k)$	
$lack \max\{d_{vc}(\mathcal{H}_k)\}_{k=1}^K \leq d_{vc}(igcup_{k=1}^K \mathcal{H}_k) \leq K-1+\sum_{k=1}^K d_{vc}(\mathcal{H}_k)$	
$igcirc$ 0 \leq $d_{vc}(igcup_{k=1}^K \mathcal{H}_k)$ \leq $\sum_{k=1}^K d_{vc}(\mathcal{H}_k)$	
16. For Questions 16-20, you will play with the decision stump algorithm.	
In class, we taught about the learning model of "positive and negative rays" (which is simply one-dimensional perceptron) for one-dimensional data. The model contains hypotheses of the form:	
$h_{s, heta}(x) = s \cdot ext{sign}(x- heta).$	
The model is frequently named the "decision stump" model and is one of the simplest learning models. As shown in class, for one-dimensional data, the VC dimension of the decision stump model is 2.	
In fact, the decision stump model is one of the few models that we could easily minimize E_{in} efficiently by enumerating all possible thresholds. In particular, for N examples, there are at most $2N$ dichotomies (see page 22 of lecture 5 slides), and thus at most $2N$ different E_{in} values. We can then easily choose the dichotomy that leads to the lowest E_{in} , where ties can be broken by randomly choosing among the lowest E_{in} , ones. The chosen dichotomy stands for a combination of	
some "spot" (range of θ) and s , and commonly the median of the range is chosen as the θ that realizes the dichotomy.	
In this problem, you are asked to implement such and algorithm and run your program on an artificial data set. First of all, start by generating a one-dimensional data by the procedure below:	
(a) Generate x by a uniform distribution in $\left[-1,1\right]$.	
(b) Generate y by $f(x)= ilde s(x)$ + noise where $ ilde s(x)= ext{sign}(x)$ and the noise flips the result with 20% probability.	
For any decision stump $h_{s, \theta}$ with $\theta \in [-1, 1]$, express $E_{out}(h_{s, \theta})$ as a function of θ and s .	
$\bigcirc 0.3 + 0.5s(\theta - 1)$	
$0.3 + 0.5s(1 - \theta)$ $0.5 + 0.3s(\theta - 1)$	
$0.5 + 0.3s(1 - \theta)$	
none of the other choices	
17. Generate a data set of size 20 by the procedure above and run the one-dimensional decision stump algorithm on the data of points set. Record E_{in} and compute E_{out} with the formula above. Repeat the experiment (including data generation, running the decision stump algorithm, and computing E_{in} and E_{out}) 5, 000 times. What is the average E_{in} ? Please choose the closest option.	
O.05	
0.15	
O 0.25	
○ 0.35	
0.45	
18. Continuing from the previous question, what is the average E_{out} ? Please choose the closest option.	
○ 0.05	
O.15	
0.35	
0.45	
19. Decision stumps can also work for multi-dimensional data. In particular, each decision stump now deals with a specific dimension i, as shown below.	
$h_{s,i, heta}(\mathbf{x}) = s \cdot ext{sign}(x_i - heta).$	
Implement the following decision stump algorithm for multi-dimensional data:	
a) for each dimension $i=1,2,\cdots,d$, find the best decision stump $h_{s,i,\theta}$ using the one-dimensional decision stump algorithm that you have just implemented.	
b) return the "best of best" decision stump in terms of E_{in} . If there is a tie , please randomly choose among the lowest- E_{in} ones	
The training data \mathcal{D}_{train} is available at:	
https://www.csie.ntu.edu.tw/~htlin/mooc/datasets/mlfound_math/hw2_train.dat	
The testing data \mathcal{D}_{test} is available at:	
https://www.csie.ntu.edu.tw/~htlin/mooc/datasets/mlfound_math/hw2_test.dat	
Run the algorithm on the \mathcal{D}_{train} . Report the $E_{ ext{in}}$ of the optimal decision stump returned by your program. Choose the	

(The VC-dimension of an empty set or a singleton set is taken as zero.)

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C	0.45		
0	0.35		
C	0.25		
C	0.15		
C	0.05		
	se the returned decision stump to predict the label of each example within \mathcal{D}_{test} . Report an estimate case choose the closest option.	of $E_{ m out}$ by $E_{ m test}$.	10 points
С	0.45		
C	0.35		
0	0.25		
C	0.15		
C	0.05		