Mitigating Scale Imbalance and Conflicting Gradients in Deep Multi-Task Learning

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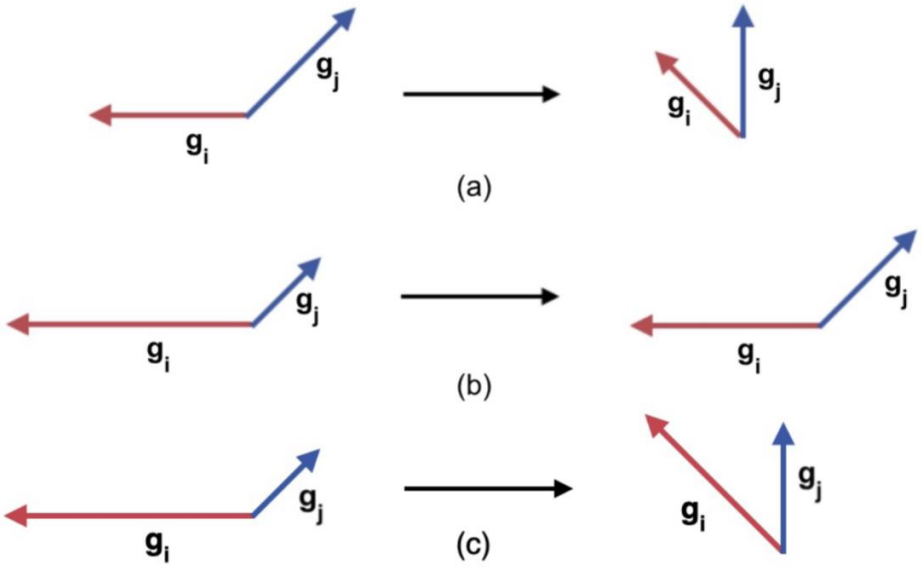
Problems & Ideas

- Problems of conventional multi-task learning approaches:
  - Conflicting gradients between tasks can degrade optimization.
  - Scale imbalance in gradient norms causes one task to dominate, hindering effective learning of all tasks.
- Ideas: POMSI combines PCGrad to resolve gradient conflicts and MSI to rescale gradients, improving optimization and task balance in multi-task learning. It's model-agnostic and end-to-end trainable.



Illustrations of the actions performed by the PCGrad, MSI, and POMSI methods. (a) The PCGrad method projects the gradient of task i onto the normal vector of that of task j, and vice versa. (b) The MSI method adaptively rescales the norms of gradient of task i and that of task j according to the magnitude similarity between them. (c) Combining MSI and PCGrad, the POMSI method projects them onto the respective normal vector of each other and then rescales the norms of gradient of task i and that of task j.

Main Contributions

- Contributions:
  - We design the MSI algorithm to ameliorate the issue of scale imbalance in MTL optimization by adaptively rescaling the gradients of each individual task according to magnitude similarities between them.
  - Built on the MSI method, the POMSI algorithm improves MTL optimization from two complementary aspects: altering the direction of gradients to avoid conflicting gradients and rescaling gradients to reduce the scale imbalance.
  - Extensive experimental results show that POMSI method outperforms state-of-the-art MTL methods with different MTL architectures.

Methods	T_1: Semantic Seg.		T_2: Depth Estimation		T_3: Surface Normal Pre.					
	mIoU↑	Pixel Acc↑	Abs Err↓	Rel Err↓	Mean↓	Median↓	11.25° ↑	22.5° ↑	30° ↑	$\triangle_T$ ↑
Equal Weighting	0.2151	0.5574	0.6214	0.2712	31.2850	26.9054	0.1962	0.4250	0.5543	0
GradNorm	0.2163	**0.5678**	0.6002	0.2541	30.0195	24.3635	0.2304	0.4702	0.5941	+3.5
PCGrad	0.2217	0.5635	0.6059	0.2509	31.5018	27.5378	0.1874	0.4133	0.5443	+2.0
Gradvac	0.2186	0.5666	0.5930	0.2471	30.8114	26.6739	0.2028	0.4287	0.5576	+3.0
POMSI-static	0.2126	0.5677	0.5929	0.2482	29.5834	24.5212	0.2304	0.4665	0.5933	+6.9
MSI	0.2158	0.5645	0.5982	0.2558	29.6020	23.9908	0.2417	0.4772	0.6012	+7.9
POMSI	**0.2229**	0.5672	**0.5830**	**0.2376**	**29.1819**	**23.7475**	**0.2456**	0.4812	0.6046	**+9.9**