Appendix

TABLE I: Code to generate the synthetic datasets with Tornado framework (Python) available on-line in https://github.com/alipsgh/tornado.

Datasets	Code to Generate
Circles	CIRCLES(concept_length=2000, noise_rate=0.1)
Sine1	SINE1(concept_length=2000, noise_rate=0.1)
Sine2	SINE2(concept_length=2000, noise_rate=0.1)
SEA	SEA(concept_length=2000, thresholds=[1, 9, 2, 6], noise_rate=0.1)
SEARec	SEA(concept_length=2000, thresholds=[1, 9, 2, 6, 1, 9, 2, 6], noise_rate=0.1)

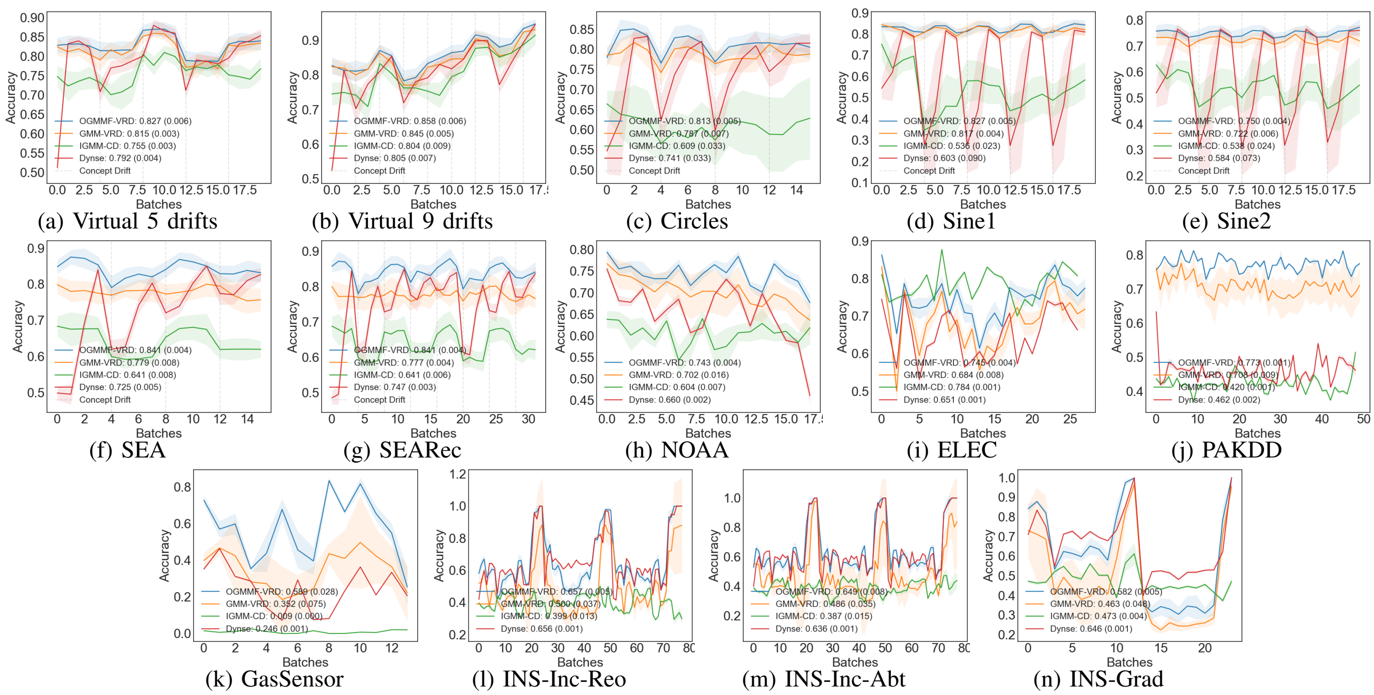


Fig. 1: Mean of accuracy over time for methods that handle virtual and real drifts on each dataset. The standard deviation is represented by shadow lines of the same color. Each point represents the accuracy for a batch observations, where 500 was used for synthetic datasets, and 1000 for real datasets.

TABLE II: Accuracy for approaches compared for all experimented datasets. The results highlighted with bold represent the best accuracy in comparison with the other approaches. Values in brackets are the standard deviations.

Dataset	**IGMM-CD**	**Dynse**	**GMM-VRD**	**OGMMF-VRD (Filter)**	**OGMMF-VRD (No Filter)**	**HAT-DDM**	**HAT-EDDM**	**HAT-ADWIN**	**AWE**	**LevBag**	**OzaAD**	**OzaAS**	**ARF**
Circles	0.609 (0.033)	0.741 (0.033)	0.787 (0.007)	0.813 (0.005)	0.804 (0.005)	0.6189 (0.005)	0.4926 (0.003)	0.5592 (0.013)	**0.8489 (0.001)**	0.8122 (0.001)	0.7373 (0.008)	0.7247 (0.001)	0.815 (0.003)
Sine1	0.536 (0.023)	0.603 (0.090)	0.817 (0.004)	0.827 (0.005)	0.824 (0.004)	0.5653 (0.025)	0.4975 (0.003)	0.5094 (0.005)	**0.8286 (0.002)**	0.8082 (0.001)	0.6584 (0.017)	0.5658 (0.002)	0.8137 (0.003)
Sine2	0.538 (0.024)	0.584 (0.073)	0.722 (0.006)	0.750 (0.004)	0.739 (0.004)	0.7044 (0.003)	0.4978 (0.004)	0.6585 (0.013)	0.7532 (0.001)	0.7319 (0.002)	0.5893 (0.016)	0.5525 (0.001)	**0.7886 (0.003)**
Virtual5	0.755 (0.003)	0.792 (0.004)	0.815 (0.003)	0.827 (0.006)	0.824 (0.003)	0.6941 (0.01)	0.3987 (0.002)	0.5127 (0.01)	**0.8504 (0.001)**	0.7987 (0.001)	0.7702 (0.005)	0.7368 (0.002)	0.838 (0.004)
Virtual9	0.804 (0.007)	0.805 (0.007)	0.845 (0.005)	0.858 (0.006)	0.854 (0.005)	0.7082 (0.011)	0.4104 (0.002)	0.492 (0.014)	**0.8697 (0.001)**	0.8104 (0.004)	0.7658 (0.014)	0.7267 (0.001)	0.8451 (0.003)
SEA	0.641 (0.008)	0.725 (0.004)	0.779 (0.008)	0.841 (0.004)	0.832 (0.007)	0.6975 (0.004)	0.5046 (0.003)	0.5233 (0.004)	**0.8534 (0.001)**	0.8295 (0.002)	0.8057 (0.003)	0.8049 (0.001)	0.8335 (0.004)
SEARec	0.641 (0.006)	0.747 (0.003)	0.777 (0.004)	0.841 (0.004)	0.833 (0.002)	0.7146 (0.025)	0.5014 (0.002)	0.5279 (0.015)	**0.8558 (0.001)**	0.8304 (0.001)	0.8106 (0.002)	0.8094 (0)	0.8291 (0.003)
NOAA	0.420 (0.001)	0.462 (0.002)	0.708 (0.009)	0.743 (0.004)	0.723 (0.006)	0.7072 (0.004)	0.6862 (0.001)	0.6989 (0.007)	0.7416 (0.002)	0.7098 (0.003)	0.6634 (0.011)	0.6869 (0.015)	**0.7656 (0.004)**
ELEC	0.783 (0.001)	0.651 (0.001)	0.685 (0.008)	0.745 (0.004)	0.755 (0.005)	0.6966 (0.013)	0.6752 (0.005)	0.6967 (0.006)	0.7112 (0.001)	0.7606 (0.003)	0.7059 (0.004)	0.6785 (0.001)	**0.7935 (0.003)**
PAKDD	0.604 (0.007)	0.660 (0.002)	0.702 (0.016)	0.773 (0.001)	0.785 (0.001)	0.8002 (0.001)	0.8024 (0)	0.8001 (0.001)	0.6205 (0.041)	0.7109 (0.005)	0.3951 (0.026)	0.5484 (0.037)	**0.7955 (0.001)**
GasSensor	0.009 (0)	0.246 (0.001)	0.3333 (0.079)	0.5785 (0.022)	0.589 (0.019)	0.3729 (0.008)	0.3608 (0.003)	0.3619 (0.001)	0.3326 (0.003)	**0.8464 (0.002)**	0.565 (0.003)	0.5552 (0.002)	0.8053 (0.007)
INSECT-Inc-Rec-Bal	0.3951 (0.014)	0.656 (0.001)	0.4941 (0.032)	0.6555 (0.004)	0.651 (0.004)	0.4636 (0.005)	0.4872 (0.001)	0.4694 (0)	0.5788 (0.005)	0.6789 (0.007)	0.5007 (0.007)	0.4851 (0.001)	**0.7228 (0.005)**
INSECT-Inc-Abt-Bal	0.3938 (0.013)	0.636 (0.001)	0.4861 (0.031)	0.6464 (0.005)	0.645 (0.006)	0.4843 (0.003)	0.508 (0)	0.4919 (0)	0.5613 (0.006)	0.6708 (0.005)	0.6011 (0.004)	0.5865 (0.001)	**0.7024 (0.004)**
INSECT-Grad-Bal	0.473 (0.003)	0.646 (0.001)	0.4876 (0.007)	0.5866 (0.005)	0.586 (0.010)	0.3484 (0.01)	0.3841 (0.001)	0.3631 (0.001)	0.6013 (0.006)	0.6921 (0.003)	0.6232 (0.032)	0.5441 (0.001)	**0.703 (0.017)**
Friedman Ranking	10.26 (2.93)	8.19 (2.92)	7.31 (2.19)	3.42 (1.59)	4.06 (1.09)	9.42 (2.77)	10.87 (3.28)	10.12 (2.72)	3.58 (2.87)	4.48 (1.85)	7.88 (2.25)	8.93 (1.65)	2.48 (1.60)

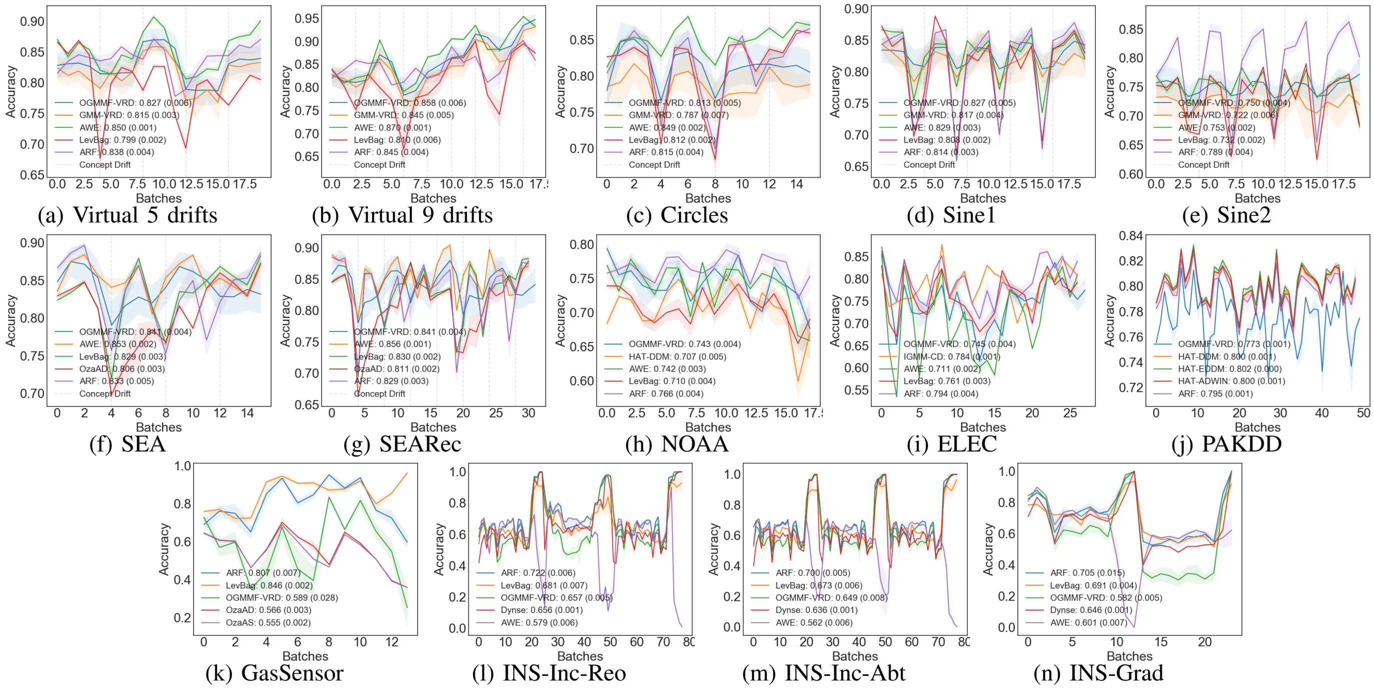


Fig. 2: Mean of accuracy over time for the five best methods in each dataset. The standard deviation is represented by shadow lines of the same color. Each point represents the accuracy for a batch observations, where 500 was used for synthetic datasets, and 1000 for real datasets.

TABLE III: G-mean for approaches compared for all experimented datasets. The results highlighted with bold represent the best accuracy in comparison with the other approaches. Values in brackets are the standard deviations.

Dataset	IGMM-CD	Dynse	GMM-VRD	OGMMF-VRD (Filter)	OGMMF-VRD (No Filter)	HAT-DDM	HAT-EDDM	HAT-ADWIN	AWE	LevBag	OzaAD	OzaAS	ARF
Circles	0.592 (0.041)	0.740 (0.033)	0.787 (0.007)	0.813 (0.005)	0.804 (0.005)	0.615 (0.008)	0.492 (0.004)	0.546 (0.019)	**0.848 (0.002)**	0.811 (0.002)	0.737 (0.009)	0.725 (0.002)	0.815 (0.004)
Sine1	0.521 (0.041)	0.603 (0.090)	0.817 (0.004)	0.827 (0.005)	0.824 (0.004)	0.562 (0.032)	0.496 (0.004)	0.498 (0.012)	**0.829 (0.003)**	0.808 (0.002)	0.658 (0.029)	0.561 (0.006)	0.814 (0.003)
Sine2	0.530 (0.028)	0.584 (0.073)	0.722 (0.006)	0.749 (0.004)	0.739 (0.004)	0.704 (0.004)	0.497 (0.004)	0.657 (0.017)	0.753 (0.002)	0.732 (0.002)	0.588 (0.020)	0.548 (0.003)	**0.789 (0.004)**
Virtual5	0.746 (0.004)	0.785 (0.005)	0.809 (0.004)	0.823 (0.006)	0.818 (0.004)	0.691 (0.013)	0.370 (0.005)	0.483 (0.017)	**0.844 (0.002)**	0.788 (0.002)	0.766 (0.006)	0.733 (0.002)	0.836 (0.004)
Virtual9	0.799 (0.010)	0.802 (0.007)	0.842 (0.006)	0.855 (0.006)	0.850 (0.005)	0.707 (0.012)	0.404 (0.003)	0.474 (0.024)	**0.866 (0.001)**	0.807 (0.006)	0.761 (0.018)	0.724 (0.001)	0.843 (0.004)
SEA	0.633 (0.008)	0.725 (0.005)	0.779 (0.008)	0.841 (0.004)	0.832 (0.007)	0.669 (0.009)	0.496 (0.006)	0.302 (0.090)	**0.853 (0.002)**	0.828 (0.003)	0.805 (0.003)	0.805 (0.001)	0.833 (0.005)
SEARec	0.632 (0.006)	0.747 (0.003)	0.777 (0.004)	0.841 (0.004)	0.833 (0.002)	0.712 (0.027)	0.501 (0.003)	0.489 (0.044)	**0.856 (0.001)**	0.830 (0.002)	0.811 (0.002)	0.809 (0.001)	0.829 (0.003)
NOAA	0.596 (0.005)	0.589 (0.003)	0.679 (0.015)	**0.697 (0.005)**	0.608 (0.010)	0.457 (0.053)	0.121 (0.028)	0.367 (0.070)	0.683 (0.006)	0.708 (0.003)	0.680 (0.005)	0.662 (0.020)	0.654 (0.009)
ELEC	0.785 (0.001)	0.618 (0.002)	0.670 (0.009)	0.729 (0.005)	0.744 (0.006)	0.644 (0.021)	0.608 (0.010)	0.642 (0.012)	0.686 (0.002)	0.740 (0.004)	0.674 (0.009)	0.569 (0.004)	**0.777 (0.004)**
PAKDD	0.475 (0.001)	0.518 (0.001)	0.419 (0.013)	0.240 (0.003)	0.183 (0.007)	0.070 (0.014)	0.014 (0.006)	0.071 (0.016)	0.551 (0.030)	0.449 (0.014)	0.482 (0.028)	0.557 (0.030)	0.189 (0.008)
GasSensor	0.008 (0.000)	0.242 (0.002)	0.330 (0.084)	0.585 (0.026)	0.587 (0.017)	0.328 (0.013)	0.318 (0.009)	0.315 (0.006)	0.292 (0.003)	**0.848 (0.002)**	0.557 (0.003)	0.547 (0.002)	0.796 (0.005)
INSECT-Inc-Rec-Bal	0.385 (0.014)	0.648 (0.001)	0.491 (0.038)	0.651 (0.005)	0.645 (0.004)	0.449 (0.008)	0.476 (0.001)	0.449 (0.002)	0.551 (0.013)	0.660 (0.007)	0.411 (0.011)	0.387 (0.001)	**0.716 (0.006)**
INSECT-Inc-Abt-Bal	0.375 (0.015)	0.618 (0.001)	0.462 (0.042)	0.633 (0.008)	0.629 (0.006)	0.453 (0.005)	0.485 (0.001)	0.464 (0.007)	0.512 (0.015)	0.633 (0.006)	0.525 (0.005)	0.510 (0.001)	**0.682 (0.006)**
INSECT-Grad-Bal	0.458 (0.003)	0.641 (0.001)	0.454 (0.059)	0.578 (0.007)	0.579 (0.010)	0.125 (0.062)	0.357 (0.003)	0.249 (0.033)	0.578 (0.007)	0.680 (0.005)	0.596 (0.035)	0.513 (0.002)	**0.684 (0.017)**
Friedman Ranking	9.32 (3.25)	7.28 (2.76)	6.79 (2.09)	3.44 (1.84)	4.63 (2.12)	10.39 (1.51)	11.82 (1.66)	11.20 (1.51)	3.14 (2.42)	4.16 (1.86)	6.99 (2.05)	8.47 (2.94)	3.36 (2.47)

TABLE XI: Part 1 of Recall for approaches compared for experimented datasets. The results highlighted with bold represent the best accuracy in comparison with the other approaches.

Dataset	Approaches	Class 0	Class 1	Class 2
Circles	HAT-DDM	0.580 (0.054)	0.657 (0.050)	-
	HAT-EDDM	0.482 (0.030)	0.503 (0.028)	-
	HAT-ADWIN	0.528 (0.104)	0.590 (0.128)	-
	AWE	**0.810 (0.003)**	**0.888 (0.002)**	-
	LevBag	0.771 (0.003)	0.853 (0.003)	-
	OzaAD	0.742 (0.008)	0.733 (0.012)	-
	OzaAS	0.731 (0.005)	0.718 (0.003)	-
	ARF	0.817 (0.004)	0.813 (0.005)	-
	OGMMF-VRD	0.806 (0.010)	0.820 (0.009)	-
	GMM-VRD	0.754 (0.021)	0.821 (0.012)	-
	Dynse	0.752 (0.015)	0.729 (0.055)	-
	IGMM-CD	0.659 (0.115)	0.558 (0.146)	-
	HAT-DDM	0.600 (0.067)	0.531 (0.063)	-
	HAT-EDDM	0.522 (0.023)	0.473 (0.023)	-
	HAT-ADWIN	0.597 (0.067)	0.422 (0.065)	-

Sine1

	AWE	0.835 (0.005)	0.822 (0.004)	-
	LevBag	0.809 (0.002)	0.808 (0.002)	-
	OzaAD	0.666 (0.031)	0.651 (0.032)	-
	OzaAS	0.638 (0.031)	0.494 (0.033)	-
	ARF	0.809 (0.004)	0.818 (0.004)	-
	OGMMF-VRD	0.826 (0.009)	**0.827 (0.007)**	-
	GMM-VRD	**0.815 (0.009)**	0.819 (0.003)	-
	Dynse	0.604 (0.093)	0.602 (0.088)	-
	IGMM-CD	0.534 (0.121)	0.538 (0.125)	-
Sine2	HAT-DDM	0.699 (0.015)	0.709 (0.016)	-
	HAT-EDDM	0.483 (0.016)	0.513 (0.016)	-
	HAT-ADWIN	0.631 (0.040)	0.686 (0.029)	-
	AWE	0.750 (0.002)	0.756 (0.003)	-
	LevBag	0.726 (0.003)	0.737 (0.002)	-
	OzaAD	0.554 (0.021)	0.624 (0.022)	-
	OzaAS	0.491 (0.015)	0.613 (0.013)	-
	ARF	**0.785 (0.005)**	**0.792 (0.005)**	-
	OGMMF-VRD	0.752 (0.008)	0.748 (0.008)	-
	GMM-VRD	0.721 (0.013)	0.724 (0.015)	-
	Dynse	0.582 (0.076)	0.586 (0.072)	-
	IGMM-CD	0.497 (0.081)	0.578 (0.077)	-
Virtual5	HAT-DDM	0.700 (0.043)	0.715 (0.041)	0.663 (0.043)
	HAT-EDDM	0.466 (0.016)	0.478 (0.017)	0.229 (0.014)
	HAT-ADWIN	0.532 (0.053)	0.642 (0.054)	0.338 (0.063)
	AWE	**0.819 (0.003)**	**0.937 (0.002)**	**0.784 (0.004)**
	LevBag	0.790 (0.004)	0.900 (0.002)	0.689 (0.003)
	OzaAD	0.709 (0.006)	0.852 (0.013)	0.743 (0.012)
	OzaAS	0.704 (0.003)	0.804 (0.003)	0.696 (0.008)
	ARF	0.803 (0.004)	0.882 (0.008)	0.827 (0.006)
	OGMMF-VRD	0.798 (0.010)	0.901 (0.009)	0.775 (0.013)
	GMM-VRD	0.796 (0.009)	0.901 (0.005)	0.738 (0.012)
	Dynse	0.778 (0.007)	0.875 (0.008)	0.710 (0.016)
	IGMM-CD	0.694 (0.007)	0.884 (0.004)	0.676 (0.011)
Virtual9	HAT-DDM	0.664 (0.023)	0.712 (0.050)	0.748 (0.027)
	HAT-EDDM	0.380 (0.016)	0.485 (0.017)	0.360 (0.015)
	HAT-ADWIN	0.363 (0.070)	0.610 (0.064)	0.493 (0.067)
	AWE	**0.833 (0.003)**	**0.942 (0.002)**	0.827 (0.003)
	LevBag	0.760 (0.013)	0.873 (0.010)	0.794 (0.006)
	OzaAD	0.733 (0.011)	0.848 (0.015)	0.710 (0.034)
	OzaAS	0.710 (0.004)	0.784 (0.003)	0.682 (0.004)
	ARF	0.806 (0.007)	0.889 (0.008)	**0.836 (0.005)**
	IGMM-CD	0.760 (0.017)	0.889 (0.008)	0.756 (0.011)
	OGMMF-VRD	0.814 (0.011)	0.922 (0.009)	0.834 (0.012)
	GMM-VRD	0.810 (0.013)	0.913 (0.004)	0.807 (0.010)
	Dynse	0.773 (0.014)	0.866 (0.006)	0.772 (0.010)
SEA	HAT-DDM	0.880 (0.019)	0.509 (0.011)	-
	HAT-EDDM	0.584 (0.025)	0.422 (0.026)	-
	HAT-ADWIN	**0.914 (0.092)**	0.118 (0.093)	-
	AWE	0.878 (0.002)	0.828 (0.003)	-
	LevBag	0.861 (0.003)	0.797 (0.005)	-
	OzaAD	0.815 (0.010)	0.796 (0.004)	-
	OzaAS	0.811 (0.002)	0.799 (0.002)	-
	ARF	0.838 (0.006)	**0.829 (0.010)**	-
	OGMMF-VRD	0.855 (0.007)	0.826 (0.008)	-
	GMM-VRD	0.797 (0.010)	0.761 (0.015)	-
	Dynse	0.701 (0.018)	0.750 (0.019)	-
	IGMM-CD	0.740 (0.011)	0.543 (0.015)	-

SEARec	HAT-DDM	0.735 (0.064)	0.694 (0.068)	-
	HAT-EDDM	0.519 (0.017)	0.484 (0.017)	-
	HAT-ADWIN	0.660 (0.133)	0.396 (0.153)	-
	AWE	**0.876 (0.002)**	**0.835 (0.002)**	-
	LevBag	0.868 (0.003)	0.793 (0.004)	-
	OzaAD	0.819 (0.004)	0.802 (0.004)	-
	OzaAS	0.821 (0.001)	0.798 (0.001)	-
	ARF	0.836 (0.006)	0.822 (0.009)	-
	OGMMF-VRD	0.853 (0.005)	0.828 (0.007)	-
	GMM-VRD	0.790 (0.013)	0.764 (0.010)	-
	Dynse	0.734 (0.007)	0.760 (0.008)	-
	IGMM-CD	0.744 (0.009)	0.538 (0.013)	-
NOAA	HAT-DDM	0.230 (0.053)	**0.925 (0.020)**	-
	HAT-EDDM	0.016 (0.006)	0.992 (0.003)	-
	HAT-ADWIN	0.148 (0.056)	0.950 (0.020)	-
	AWE	0.569 (0.015)	0.821 (0.010)	-
	LevBag	0.705 (0.013)	0.712 (0.010)	-
	OzaAD	**0.738 (0.036)**	0.630 (0.037)	-
	OzaAS	0.613 (0.066)	0.721 (0.056)	-
	ARF	0.478 (0.015)	0.897 (0.004)	-
	OGMMF-VRD	0.603 (0.009)	0.806 (0.006)	-
	GMM-VRD	0.628 (0.035)	0.735 (0.030)	-
	Dynse	0.462 (0.006)	0.750 (0.004)	-
	IGMM-CD	0.573 (0.007)	0.619 (0.010)	-
ELEC	HAT-DDM	0.494 (0.033)	0.841 (0.018)	-
	HAT-EDDM	0.439 (0.016)	0.843 (0.008)	-
	HAT-ADWIN	0.489 (0.023)	0.844 (0.014)	-
	AWE	0.589 (0.005)	0.798 (0.004)	-
	LevBag	0.656 (0.007)	0.835 (0.006)	-
	OzaAD	0.563 (0.025)	0.807 (0.021)	-
	OzaAS	0.357 (0.007)	**0.907 (0.004)**	-
	ARF	0.705 (0.007)	0.857 (0.006)	-
	OGMMF-VRD	0.659 (0.011)	0.807 (0.008)	-
	GMM-VRD	0.606 (0.020)	0.740 (0.017)	-
	Dynse	0.508 (0.004)	0.752 (0.002)	-
	IGMM-CD	**0.793 (0.002)**	0.777 (0.002)	-
PAKDD	HAT-DDM	0.996 (0.001)	0.005 (0.002)	-
	HAT-EDDM	**1.000 (0.000)**	0.000 (0.000)	-
	HAT-ADWIN	0.996 (0.002)	0.005 (0.002)	-
	AWE	0.656 (0.086)	0.476 (0.098)	-
	LevBag	0.826 (0.014)	0.245 (0.020)	-
	OzaAD	0.299 (0.048)	**0.788 (0.041)**	-
	OzaAS	0.537 (0.094)	0.594 (0.083)	-
	ARF	0.982 (0.001)	0.037 (0.003)	-
	OGMMF-VRD	0.948 (0.002)	0.061 (0.001)	-
	GMM-VRD	0.830 (0.015)	0.212 (0.017)	-
	Dynse	0.417 (0.002)	0.644 (0.002)	-
	IGMM-CD	0.376 (0.001)	0.601 (0.001)	-

TABLE XII: Part 2 of Recall for approaches compared for all experimented datasets. The results highlighted with bold represent the best accuracy in comparison with the other approaches.

Datasets	Algorithms	Class 0	Class 1	Class 2	Class 3	Class 4	Class 5
	IGMM-CD	0.011 (0.001)	0.009 (0.000)	0.010 (0.001)	0.018 (0.002)	0.009 (0.001)	0.002 (0.000)
	Dynse	0.181 (0.004)	0.284 (0.003)	0.248 (0.003)	0.251 (0.002)	0.272 (0.002)	0.234 (0.002)
	GMM-VRD	0.554 (0.110)	0.442 (0.104)	0.365 (0.114)	0.261 (0.099)	0.261 (0.082)	0.248 (0.098)

GasSensor

	OGMMF-VRD	0.673 (0.012)	0.662 (0.035)	0.582 (0.053)	0.558 (0.052)	0.522 (0.012)	0.539 (0.070)
	HAT-DDM	0.342 (0.017)	0.386 (0.032)	0.420 (0.018)	0.201 (0.048)	0.246 (0.039)	0.481 (0.037)
	HAT-EDDM	0.323 (0.024)	0.412 (0.047)	0.430 (0.022)	0.201 (0.042)	0.222 (0.058)	0.436 (0.062)
	HAT-ADWIN	0.303 (0.012)	0.396 (0.033)	0.437 (0.010)	0.165 (0.048)	0.265 (0.049)	0.456 (0.037)
	AWE	0.383 (0.005)	0.381 (0.010)	0.573 (0.004)	0.269 (0.017)	0.181 (0.003)	0.153 (0.002)
	LevBag	**0.904 (0.014)**	0.837 (0.010)	**0.865 (0.003)**	**0.844 (0.006)**	**0.822 (0.013)**	0.819 (0.004)
	OzaAD	0.793 (0.002)	0.623 (0.006)	0.595 (0.011)	0.459 (0.007)	0.471 (0.002)	0.468 (0.004)
	OzaAS	0.792 (0.002)	0.600 (0.005)	0.577 (0.002)	0.449 (0.005)	0.466 (0.002)	0.466 (0.003)
	ARF	0.815 (0.028)	**0.840 (0.025)**	0.829 (0.008)	0.748 (0.016)	0.707 (0.020)	**0.848 (0.018)**
INS-Inc-Rec	IGMM-CD	0.340 (0.008)	0.266 (0.008)	0.449 (0.011)	0.345 (0.028)	0.615 (0.010)	0.378 (0.015)
	Dynse	0.493 (0.002)	0.561 (0.002)	0.693 (0.002)	0.798 (0.001)	0.675 (0.001)	0.715 (0.002)
	GMM-VRD	0.417 (0.038)	0.432 (0.055)	0.465 (0.046)	0.672 (0.112)	0.489 (0.030)	0.522 (0.033)
	OGMMF-VRD	0.615 (0.016)	0.616 (0.013)	0.556 (0.012)	0.823 (0.006)	0.700 (0.009)	0.629 (0.011)
	HAT-DDM	0.591 (0.024)	0.449 (0.041)	0.377 (0.036)	0.587 (0.044)	0.463 (0.038)	0.310 (0.048)
	HAT-EDDM	0.552 (0.010)	0.471 (0.016)	0.407 (0.002)	0.665 (0.004)	0.499 (0.002)	0.330 (0.007)
	HAT-ADWIN	0.618 (0.003)	0.435 (0.020)	0.344 (0.001)	0.643 (0.001)	0.497 (0.003)	0.279 (0.021)
	AWE	0.502 (0.005)	0.597 (0.005)	0.451 (0.007)	0.330 (0.040)	0.750 (0.002)	0.845 (0.008)
	LevBag	0.388 (0.004)	0.585 (0.005)	**0.767 (0.015)**	**0.819 (0.021)**	0.742 (0.004)	0.781 (0.006)
	OzaAD	0.144 (0.012)	0.186 (0.009)	0.486 (0.020)	0.784 (0.005)	0.559 (0.008)	**0.847 (0.006)**
	OzaAS	0.123 (0.002)	0.171 (0.003)	0.442 (0.001)	0.783 (0.002)	0.549 (0.002)	0.838 (0.001)
	ARF	**0.649 (0.010)**	**0.682 (0.011)**	0.574 (0.007)	0.809 (0.003)	**0.803 (0.006)**	0.811 (0.017)
INS-Inc-Abt	IGMM-CD	0.322 (0.005)	0.257 (0.011)	0.425 (0.006)	0.375 (0.032)	0.578 (0.014)	0.363 (0.021)
	Dynse	0.410 (0.001)	0.528 (0.001)	0.630 (0.002)	0.873 (0.001)	0.671 (0.001)	0.699 (0.002)
	GMM-VRD	0.352 (0.066)	0.384 (0.045)	0.337 (0.056)	0.759 (0.104)	0.534 (0.072)	0.547 (0.067)
	OGMMF-VRD	0.547 (0.014)	0.542 (0.020)	0.458 (0.010)	**0.883 (0.007)**	0.747 (0.015)	0.717 (0.016)
	HAT-DDM	0.482 (0.008)	0.251 (0.026)	0.317 (0.020)	0.767 (0.003)	0.607 (0.024)	0.488 (0.031)
	HAT-EDDM	0.457 (0.009)	0.328 (0.005)	0.383 (0.000)	0.780 (0.002)	0.656 (0.002)	0.441 (0.005)
	HAT-ADWIN	0.475 (0.013)	0.298 (0.059)	0.340 (0.000)	0.755 (0.001)	0.638 (0.004)	0.443 (0.054)
	AWE	0.344 (0.004)	0.564 (0.004)	0.605 (0.010)	0.239 (0.042)	0.779 (0.003)	0.840 (0.003)
	LevBag	0.300 (0.005)	0.515 (0.006)	**0.757 (0.013)**	0.877 (0.021)	0.789 (0.001)	0.795 (0.006)
	OzaAD	0.171 (0.006)	0.372 (0.011)	0.609 (0.020)	0.815 (0.007)	0.780 (0.004)	0.850 (0.004)
	OzaAS	0.163 (0.001)	0.365 (0.004)	0.557 (0.001)	0.792 (0.001)	0.779 (0.002)	0.857 (0.001)
	ARF	**0.581 (0.009)**	**0.573 (0.005)**	0.496 (0.013)	0.866 (0.002)	**0.819 (0.010)**	**0.863 (0.006)**
Ins-Grad	IGMM-CD	0.464 (0.003)	0.305 (0.004)	0.542 (0.026)	0.372 (0.004)	0.676 (0.003)	0.478 (0.002)
	Dynse	0.604 (0.003)	0.532 (0.003)	0.745 (0.003)	0.593 (0.002)	0.682 (0.004)	0.720 (0.003)
	GMM-VRD	0.413 (0.087)	0.400 (0.075)	0.670 (0.028)	0.457 (0.089)	0.421 (0.070)	0.439 (0.068)
	OGMMF-VRD	0.488 (0.027)	0.501 (0.018)	0.714 (0.023)	0.553 (0.028)	0.622 (0.031)	0.626 (0.018)
	HAT-DDM	0.058 (0.020)	0.322 (0.010)	0.808 (0.074)	0.262 (0.070)	0.008 (0.013)	0.603 (0.057)
	HAT-EDDM	0.232 (0.014)	0.264 (0.020)	0.591 (0.012)	0.437 (0.002)	0.262 (0.029)	0.509 (0.022)
	HAT-ADWIN	0.074 (0.007)	0.318 (0.010)	0.713 (0.081)	0.373 (0.002)	0.083 (0.056)	0.608 (0.077)
	AWE	0.627 (0.004)	**0.579 (0.007)**	0.313 (0.002)	0.566 (0.042)	0.723 (0.006)	0.802 (0.006)
	LevBag	**0.619 (0.012)**	0.494 (0.010)	**0.848 (0.006)**	**0.722 (0.014)**	0.704 (0.002)	0.752 (0.009)
	OzaAD	0.565 (0.018)	0.322 (0.033)	0.716 (0.055)	0.649 (0.102)	0.666 (0.017)	0.805 (0.040)
	OzaAS	0.537 (0.004)	0.254 (0.009)	0.573 (0.004)	0.466 (0.007)	0.618 (0.002)	0.811 (0.003)
	ARF	0.529 (0.037)	0.482 (0.021)	0.819 (0.022)	0.710 (0.039)	**0.812 (0.021)**	**0.857 (0.020)**

TABLE IV: Time for approaches compared for all experimented datasets. The results highlighted with bold represent the best accuracy in comparison with the other approaches.

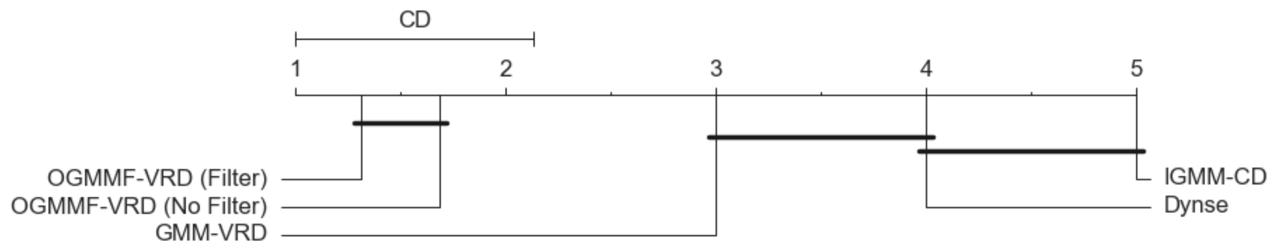
Datasets	**IGMM-CD**	**Dynse**	**GMM-VRD**	**OGMMF-VRD**	**HAT-DDM**	**HAT-EDDM**	**HAT-ADWIN**	**AWE**	**LevBag**	**OzaAD**	**OzaAS**	**ARF**
Circles	221.2 (90.9)	733.5 (56.8)	55.6 (14.6)	140.9 (44.6)	16.8 (0.1)	17.1 (0.1)	16.7 (0.1)	18.9 (0.7)	20.6 (0.1)	18.5 (0.1)	**16.1 (0.1)**	27.6 (0.2)
Sine1	249.3 (86.2)	1078.7 (33.7)	78.4 (24.6)	205.6 (68.6)	25.5 (0.1)	25.4 (0.1)	24.8 (0.1)	27.9 (0.1)	29.9 (0.1)	27.2 (0.1)	**24.3 (0.1)**	36.5 (0.2)
Sine2	258.4 (87.1)	1048.6 (38.2)	84.5 (25.5)	237.4 (85.2)	25.5119 (0.1)	25.4 (0.1)	25.4 (0.1)	27.9 (0.1)	29.8 (0.1)	27.3 (0.1)	**24.3 (0.1)**	36.6 (0.1)
Virtual5	648.3 (193.1)	881.2 (63.5)	102.4 (25.7)	346.6 (121.2)	25.0807 (0.2)	24.5 (0.1)	23.9 (0.1)	27.8 (0.1)	29.1 (0.1)	26.6 (0.1)	**23.3 (0.1)**	38.6 (0.5)
Virtual9	499.4 (162.6)	839.6 (61.1)	75.2 (20.5)	219.9 (62.4)	20.8 (0.1)	20.3 (0.1)	19.7 (0.1)	23.2 (0.1)	24.4 (0.1)	22.1 (0.1)	**19.2 (0.1)**	32.6 (0.6)
SEA	233.6 (88.3)	589.5 (50.1)	60.7 (19.8)	149.5 (61.4)	17.3 (0.1)	17.1 (0.1)	16.5 (0.1)	19.8 (0.1)	21.2 (0.1)	18.9 (0.1)	**16.3 (0.1)**	28.5 (0.3)
SEARec	549.7 (183.9)	1099.7 (81.7)	166.6 (55.3)	385.4 (117.3)	62.5 (0.5)	60.9 (0.3)	60.1 (0.4)	66.9 (0.2)	69.5 (0.2)	64.9 (0.2)	**59.6 (0.1)**	86.3 (1.3)
NOAA	1099.1 (367.8)	2495.7 (125.5)	367.1 (119.7)	987.3 (354.9)	76.8 (1.2)	76.4 (1.2)	75.8 (1.3)	88.5 (1.3)	90.4 (1.5)	81.9 (1.2)	**74.6 (1.1)**	120.5 (3.7)
ELEC	1202.8 (215.6)	3383.5 (43.6)	528.6 (67.9)	1122.2 (69.1)	165.6 (0.9)	165.4 (0.8)	**164.7 (0.8)**	178.5 (0.8)	183.8 (0.9)	174.6 (0.6)	165.1 (0.1)	212.1 (2.5)
PAKDD	2858.6 (1085.1)	7285.5 (61.1)	2498.1 (2244.3)	3997.9 (1476.1)	548.6 (16.9)	533.8 (12.1)	**549.7 (14.9)**	667.5 (16.8)	652.3 (16.8)	596.1 (15.9)	559.6 (16.1)	749.2 (35.2)
GasSensor	11504.4 (219.3)	1657.9 (19.4)	1646.8 (188.7)	3096.7 (234.6)	96.2 (10.2)	97.9 (11.1)	**84.1 (11.6)**	206.3 (22.9)	243.7 (27.4)	419.6 (30)	264.3 (28.7)	96.1 (11.3)
INSECT-Inc-Rec-Bal	24868.9 (1638.1)	8230.7 (685.4)	4690.9 (181.6)	6313.6 (49.1)	1294.3 (6.1)	1325.4 (1.9)	**1279.2 (1.9)**	1588.6 (4.5)	1686 (6.9)	1916.5 (5.8)	1639.2 (7.5)	1725.1 (65.5)
INSECT-Inc-Abt-Bal	24650.4 (1642.4)	8135.3 (130.6)	4739.3 (232.6)	6377.1 (48.9)	1372.3 (62.5)	1323.5 (1.2)	**1278.6 (1.9)**	1585.1 (4.5)	1685.6 (5.4)	1925.2 (5.7)	1647.3 (5.2)	1634.5 (8.3)
INSECT-Grad-Bal	5294.7 (931.7)	2189.8 (21.9)	867.7 (73.9)	1366.9 (77.7)	161.6 (13.9)	184.3 (16)	**166.2 (8)**	253.6 (25.9)	276.9 (31)	349.5 (38.8)	251.3 (25.8)	253.4 (22.7)
Friedman Ranking	11.25 (0.57)	11.58 (0.71)	9.38 (0.62)	9.79 (0.55)	3.12 (0.98)	3.02 (0.52)	1.91 (0.83)	5.60 (0.77)	6.87 (0.33)	5.92 (1.38)	2.53 (2.16)	7.03 (1.67)

TABLE V: Grid search for radius parameter of the OGMMF-VRD. The results highlighted with bold represent the best accuracy. According to the p-value 4.21E-01 obtained by the Friedman test. the H0 was not rejected. which means that this parameter did not have significant impact on the models' accuracy.

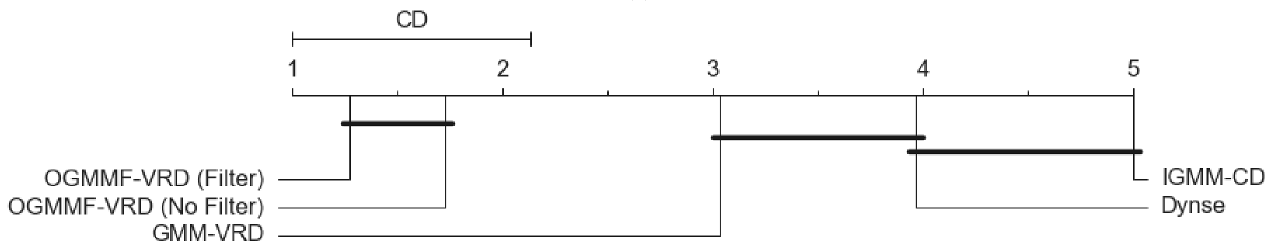
Datasets	**radius=10**	**radius=15**	**radius=20**	**radius=25**
Circles	0.8143 (0.003)	**0.8145 (0.003)**	0.813 (0.004)	0.8136 (0.003)
Sine1	0.8225 (0.003)	0.823 (0.004)	**0.8239 (0.003)**	0.8224 (0.003)
Sine2	0.7475 (0.003)	**0.7482 (0.004)**	0.7475 (0.003)	0.7481 (0.002)
Virtual5	**0.8299 (0.003)**	0.8295 (0.003)	0.8298 (0.003)	0.8292 (0.003)
Virtual9	0.8555 (0.003)	0.8543 (0.003)	**0.8569 (0.004)**	0.8558 (0.002)
SEA	0.8415 (0.003)	0.841 (0.005)	**0.8436 (0.004)**	0.8417 (0.003)

TABLE VI: Grid search for EDDM drift level threshold used in OGMMF-VRD. The results highlighted with bold represent the best accuracy. According to the p-value 8.29E-01 obtained by the Friedman test, the H0 was not rejected, which means that this parameter did not have significant impact on the models' accuracy.

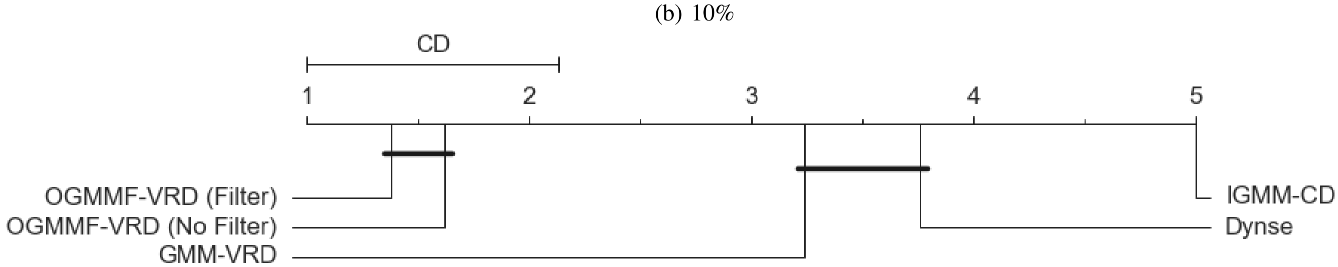
Datasets	**c=1**	**c=1.5**	**c=2**	**c=2.5**
Circles	**0.8138 (0.003)**	0.8133 (0.004)	0.813 (0.004)	0.8129 (0.004)
Sine1	0.8221 (0.003)	0.8219 (0.002)	**0.8227 (0.003)**	0.8212 (0.003)
Sine2	0.7478 (0.003)	0.7467 (0.003)	**0.7488 (0.003)**	0.7478 (0.003)
Virtual5	**0.8293 (0.004)**	0.8287 (0.003)	0.8288 (0.003)	0.8295 (0.003)
Virtual9	0.8563 (0.004)	**0.8573 (0.003)**	0.8564 (0.003)	0.8564 (0.004)
SEA	0.8416 (0.005)	**0.8416 (0.004)**	0.8408 (0.004)	**0.8416 (0.004)**



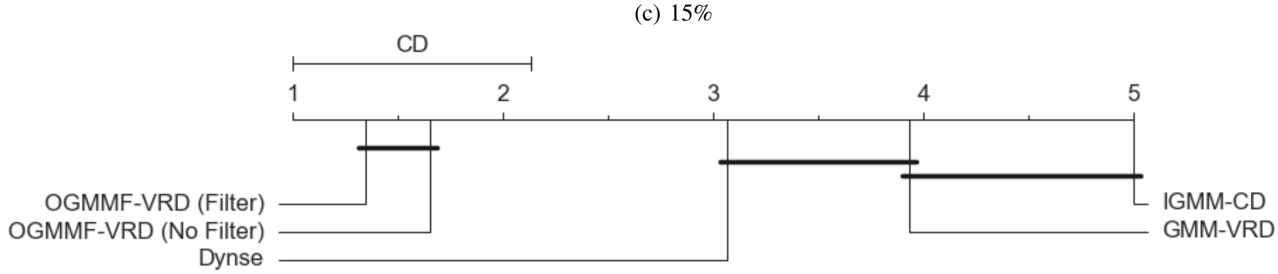
(a) 5%



(b) 10%

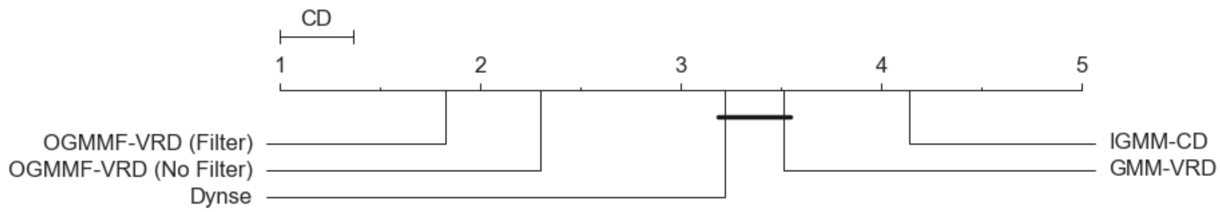


(c) 15%

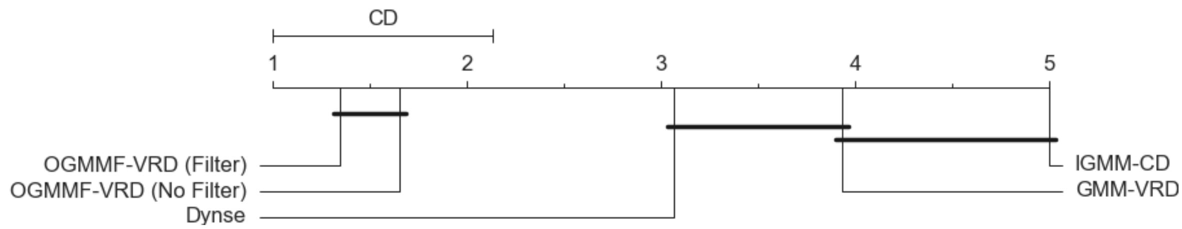


(d) 20%

Fig. 3: Friedman and Nemenyi tests for OGMMF-VRD with m=50 (chunk size) for average accuracy in synthetic datasets with different noise levels. Friedman's p-value were p=4.38E-23, p=5.44E-23, p=4.50E-22, p=1.04E-22 and its ranking is shown from left (best) to right (worst). Any pair of approaches whose distance between them is larger than CD is considered to be significantly different.

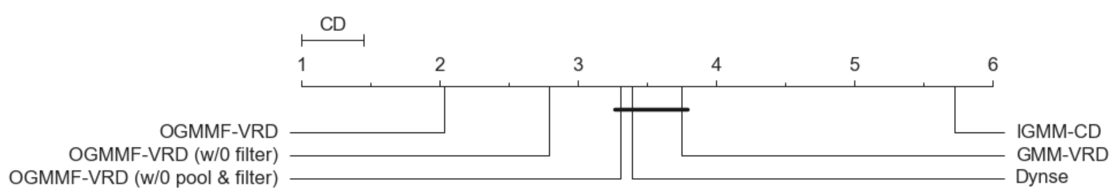


(a) G-mean

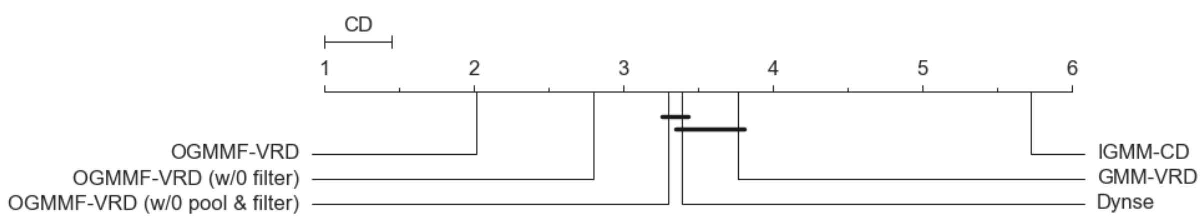


(b) Accuracy

Fig. 4: Friedman and Nemenyi tests for OGMMF-VRD with m=50 (chunk size) for average G-mean and Accuracy in all synthetic datasets with all different noise levels. Friedman's p-value were p=1.72E-83 and p=9.73E-25 and its ranking is shown from left (best) to right (worst). Any pair of approaches whose distance between them is larger than CD is considered to be significantly different.



(a) G-mean



(b) Accuracy

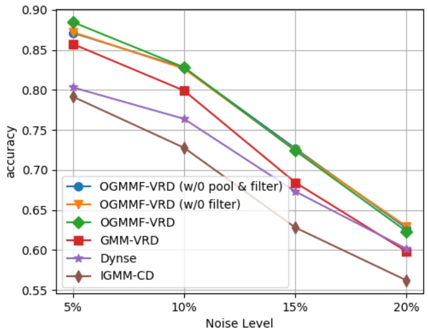
Fig. 5: Friedman and Nemenyi tests for OGMMF-VRD with m=200 (chunk size) for average G-mean and Accuracy in all synthetic datasets with all different noise levels. w/o means the system without the mechanism. Friedman's p-value were p=4.27E-133 and p=8.18E-132 and its ranking is shown from left (best) to right (worst). Any pair of approaches whose distance between them is larger than CD is considered to be significantly different.

TABLE VII: Average accuracy for synthetic datasets with different noise levels. w/o means the system without the mechanism. m is the chunk size used in the experiments. The results highlighted with bold represent the best accuracy in comparison with the other approaches.

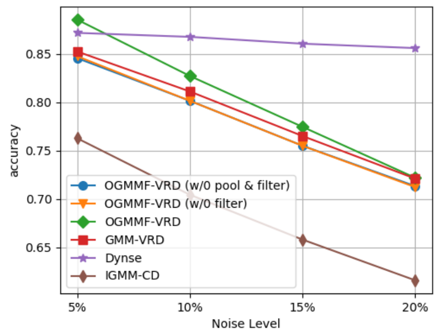
Datasets	OGMMF-VRD (w/o pool) m = 200	OGMMF-VRD (w/o filter and pool) m = 200	OGMMF-VRD m = 200	OGMMF-VRD (w/o filter) m = 50	OGMMF-VRD m = 50	GMM-VRD	Dynse	IGMM-CD
Circles 5%	0.871 (0.003)	0.872 (0.003)	**0.885 (0.002)**	0.8657 (0.004)	0.8652 (0.003)	0.8583 (0.004)	0.8227 (0.013)	0.7923 (0.003)
Circles 10%	0.828 (0.003)	0.826 (0.003)	**0.828 (0.005)**	0.814 (0.004)	0.8143 (0.003)	0.798 (0.004)	0.78 (0.011)	0.7291 (0.002)
Circles 15%	**0.727 (0.005)**	0.725 (0.003)	0.725 (0.004)	0.7043 (0.004)	0.703 (0.004)	0.6854 (0.004)	0.6944 (0.014)	0.6276 (0.003)
Circles 20%	0.628 (0.005)	**0.630 (0.003)**	0.624 (0.005)	0.611 (0.004)	0.6118 (0.003)	0.5991 (0.006)	0.6124 (0.009)	0.5619 (0.003)
Sine1 5%	0.846 (0.004)	0.848 (0.005)	0.885 (0.006)	**0.8902 (0.003)**	0.889 (0.005)	0.8519 (0.002)	0.7791 (0.001)	0.7628 (0.003)
Sine1 10%	0.802 (0.003)	0.802 (0.002)	0.827 (0.005)	0.8295 (0.004)	**0.8313 (0.004)**	0.8121 (0.003)	0.7445 (0.001)	0.7042 (0.001)
Sine1 15%	0.755 (0.003)	0.755 (0.003)	0.775 (0.006)	0.8295 (0.004)	**0.8313 (0.004)**	0.8121 (0.003)	0.7445 (0.001)	0.7042 (0.001)
Sine1 20%	0.713 (0.001)	0.712 (0.003)	**0.722 (0.004)**	0.715 (0.004)	0.7157 (0.003)	0.7207 (0.003)	0.6738 (0.001)	0.6156 (0.002)
Sine2 5%	0.766 (0.005)	0.765 (0.004)	**0.790 (0.008)**	0.7888 (0.003)	0.7888 (0.003)	0.7821 (0.003)	0.4781 (0.026)	0.7741 (0.002)
Sine2 10%	0.727 (0.005)	0.725 (0.005)	**0.749 (0.003)**	0.7476 (0.003)	0.7475 (0.003)	0.7349 (0.003)	0.4819 (0.024)	0.7133 (0.002)
Sine2 15%	0.658 (0.004)	0.659 (0.003)	**0.666 (0.004)**	0.6601 (0.004)	0.658 (0.004)	0.6482 (0.003)	0.5602 (0.093)	0.612 (0.002)
Sine2 20%	0.596 (0.002)	**0.599 (0.004)**	0.597 (0.007)	0.587 (0.002)	0.5856 (0.003)	0.5788 (0.004)	0.6024 (0.002)	0.5449 (0.003)
Virtual5 5%	0.799 (0.003)	**0.809 (0.001)**	0.809 (0.003)	0.8014 (0.003)	0.8018 (0.004)	0.8076 (0.002)	0.7575 (0.001)	0.7176 (0.001)
Virtual5 10%	0.725 (0.005)	**0.738 (0.002)**	0.738 (0.003)	0.724 (0.004)	0.7243 (0.003)	0.7309 (0.006)	0.6894 (0.001)	0.6236 (0.001)
Virtual5 15%	0.622 (0.004)	0.647 (0.003)	**0.648 (0.003)**	0.6257 (0.003)	0.6226 (0.003)	0.6349 (0.006)	0.5992 (0.001)	0.5228 (0.002)
Virtual5 20%	0.521 (0.004)	0.544 (0.001)	**0.545 (0.004)**	0.5167 (0.004)	0.5189 (0.004)	0.5196 (0.005)	0.4904 (0.001)	0.4357 (0.001)
Virtual9 5%	0.825 (0.004)	0.831 (0.003)	**0.831 (0.002)**	0.806 (0.004)	0.8042 (0.003)	0.7879 (0.006)	0.7641 (0.026)	0.7568 (0.002)
Virtual9 10%	0.739 (0.005)	**0.753 (0.001)**	0.753 (0.003)	0.7143 (0.003)	0.7153 (0.004)	0.6843 (0.007)	0.6849 (0.022)	0.6413 (0.002)
Virtual9 15%	0.739 (0.004)	0.752 (0.003)	**0.753 (0.003)**	0.7145 (0.004)	0.7177 (0.004)	0.6836 (0.008)	0.6958 (0.004)	0.6449 (0.002)
Virtual9 20%	0.599 (0.006)	0.619 (0.004)	**0.620 (0.004)**	0.572 (0.004)	0.5752 (0.003)	0.5141 (0.012)	0.5689 (0.002)	0.5108 (0.001)
SEA 5%	0.900 (0.004)	0.899 (0.004)	**0.913 (0.003)**	0.9118 (0.002)	0.9133 (0.002)	0.9052 (0.002)	0.8718 (0.001)	0.6476 (0.001)
SEA 10%	0.854 (0.004)	0.853 (0.003)	**0.856 (0.005)**	0.8576 (0.002)	0.8555 (0.002)	0.8487 (0.005)	0.8221 (0.001)	0.6103 (0.001)
SEA 15%	0.801 (0.003)	**0.804 (0.003)**	0.800 (0.004)	0.7992 (0.004)	0.798 (0.003)	0.7911 (0.003)	0.7717 (0.001)	0.5885 (0.001)
SEA 20%	0.750 (0.003)	**0.752 (0.003)**	0.747 (0.002)	0.7474 (0.002)	0.7458 (0.004)	0.7475 (0.007)	0.7275 (0.001)	0.5687 (0.001)
SEARec 5%	0.900 (0.002)	0.899 (0.002)	**0.912 (0.001)**	0.9128 (0.001)	0.9115 (0.002)	0.9022 (0.004)	0.8671 (0)	0.635 (0.001)
SEARec 10%	0.849 (0.002)	0.850 (0.002)	**0.854 (0.002)**	0.8541 (0.001)	0.8519 (0.002)	0.8307 (0.005)	0.8197 (0.001)	0.6066 (0.002)
SEARec 15%	**0.802 (0.002)**	0.800 (0.002)	0.795 (0.004)	0.7943 (0.002)	0.7924 (0.003)	0.7766 (0.004)	0.7733 (0.001)	0.5859 (0.001)
SEARec 20%	**0.749 (0.002)**	0.747 (0.003)	0.743 (0.002)	0.7399 (0.002)	0.7405 (0.002)	0.7224 (0.003)	0.7289 (0.001)	0.5611 (0.001)

TABLE VIII: Average G-mean for synthetic datasets with different noise levels. w/o means the system without the mechanism. m is the chunk size used in the experiments. The results highlighted with bold represent the best accuracy in comparison with the other approaches.

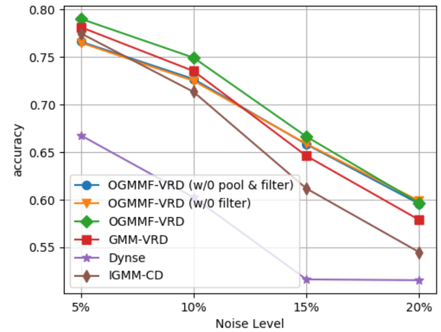
Datasets	OGMMF-VRD (w/o pool) m = 200	OGMMF-VRD (w/o filter and pool) m = 200	OGMMF-VRD m = 200	OGMMF-VRD (w/o filter) m = 50	OGMMF-VRD m = 50	GMM-VRD	Dynse	IGMM-CD
Circles 5%	0.871 (0.003)	0.872 (0.003)	**0.885 (0.002)**	0.866 (0.005)	0.868 (0.004)	0.857 (0.005)	0.803 (0.003)	0.792 (0.003)
Circles 10%	**0.828 (0.003)**	0.826 (0.003)	0.828 (0.005)	0.813 (0.005)	0.809 (0.006)	0.799 (0.005)	0.764 (0.003)	0.728 (0.004)
Circles 15%	0.727 (0.005)	**0.725 (0.003)**	0.724 (0.004)	0.703 (0.005)	0.703 (0.005)	0.684 (0.007)	0.673 (0.004)	0.628 (0.003)
Circles 20%	0.627 (0.005)	**0.629 (0.004)**	0.623 (0.005)	0.608 (0.004)	0.609 (0.005)	0.598 (0.006)	0.602 (0.007)	0.562 (0.004)
Sine1 5%	0.846 (0.004)	0.847 (0.005)	0.885 (0.006)	**0.890 (0.004)**	0.887 (0.007)	0.852 (0.004)	0.872 (0.002)	0.763 (0.004)
Sine1 10%	0.801 (0.003)	0.801 (0.003)	0.827 (0.005)	**0.829 (0.005)**	0.831 (0.005)	0.811 (0.005)	0.868 (0.002)	0.704 (0.002)
Sine1 15%	0.755 (0.003)	0.755 (0.003)	**0.775 (0.006)**	0.774 (0.007)	0.777 (0.007)	0.765 (0.004)	0.860 (0.002)	0.658 (0.004)
Sine1 20%	0.713 (0.001)	0.712 (0.003)	**0.722 (0.004)**	0.715 (0.005)	0.715 (0.004)	0.721 (0.004)	0.856 (0.002)	0.616 (0.003)
Sine2 5%	0.766 (0.005)	0.765 (0.004)	**0.790 (0.008)**	0.788 (0.006)	0.789 (0.004)	0.781 (0.004)	0.515 (0.003)	0.775 (0.003)
Sine2 10%	0.727 (0.005)	0.725 (0.005)	**0.749 (0.003)**	0.745 (0.004)	0.746 (0.004)	0.735 (0.003)	0.516 (0.003)	0.713 (0.002)
Sine2 15%	0.658 (0.004)	0.659 (0.003)	**0.666 (0.004)**	0.658 (0.003)	0.657 (0.004)	0.646 (0.003)	0.668 (0.002)	0.612 (0.004)
Sine2 20%	0.596 (0.002)	**0.599 (0.004)**	0.597 (0.007)	0.587 (0.004)	0.587 (0.003)	0.579 (0.005)	0.602 (0.002)	0.545 (0.004)
Virtual5 5%	0.793 (0.003)	**0.803 (0.001)**	0.803 (0.003)	0.797 (0.004)	0.798 (0.005)	0.803 (0.004)	0.798 (0.003)	0.711 (0.002)
Virtual5 10%	0.719 (0.005)	**0.732 (0.002)**	0.732 (0.003)	0.718 (0.006)	0.720 (0.005)	0.726 (0.009)	0.749 (0.001)	0.619 (0.002)
Virtual5 15%	0.616 (0.004)	0.639 (0.003)	**0.641 (0.003)**	0.620 (0.005)	0.617 (0.005)	0.628 (0.010)	0.686 (0.003)	0.686 (0.003)
Virtual5 20%	0.514 (0.004)	0.536 (0.001)	**0.537 (0.004)**	0.511 (0.007)	0.512 (0.006)	0.512 (0.008)	0.628 (0.002)	0.433 (0.002)
Virtual9 5%	0.821 (0.005)	0.827 (0.003)	**0.827 (0.002)**	0.799 (0.003)	0.800 (0.006)	0.786 (0.006)	0.725 (0.003)	0.752 (0.003)
Virtual9 10%	0.734 (0.005)	**0.749 (0.001)**	0.749 (0.003)	0.709 (0.006)	0.709 (0.006)	0.685 (0.010)	0.651 (0.003)	0.637 (0.004)
Virtual9 15%	0.595 (0.006)	0.615 (0.005)	**0.616 (0.004)**	0.714 (0.003)	0.715 (0.003)	0.681 (0.006)	0.687 (0.003)	0.642 (0.003)
Virtual9 20%	0.595 (0.006)	0.615 (0.005)	**0.616 (0.004)**	0.569 (0.004)	0.570 (0.004)	0.511 (0.015)	0.564 (0.003)	0.510 (0.002)
SEA 5%	0.900 (0.004)	0.899 (0.004)	**0.913 (0.003)**	0.912 (0.003)	0.913 (0.003)	0.906 (0.002)	0.863 (0.002)	0.640 (0.002)
SEA 10%	0.854 (0.005)	0.853 (0.003)	**0.855 (0.005)**	0.858 (0.003)	0.855 (0.003)	0.847 (0.007)	0.834 (0.003)	0.605 (0.001)
SEA 15%	0.801 (0.003)	**0.803 (0.003)**	0.800 (0.004)	0.798 (0.006)	0.799 (0.005)	0.790 (0.006)	0.799 (0.002)	0.585 (0.002)
SEA 20%	0.750 (0.003)	**0.752 (0.003)**	0.746 (0.003)	0.746 (0.004)	0.746 (0.003)	0.746 (0.008)	0.761 (0.003)	0.565 (0.002)
SEARec 5%	0.900 (0.002)	0.899 (0.002)	**0.912 (0.001)**	0.912 (0.003)	0.913 (0.002)	0.902 (0.007)	0.901 (0.001)	0.627 (0.002)
SEARec 10%	0.849 (0.002)	0.849 (0.002)	**0.854 (0.002)**	0.852 (0.003)	0.854 (0.002)	0.830 (0.007)	0.861 (0.001)	0.599 (0.002)
SEARec 15%	**0.801 (0.002)**	0.800 (0.002)	0.794 (0.004)	0.792 (0.004)	0.794 (0.003)	0.776 (0.005)	0.822 (0.001)	0.580 (0.002)
SEARec 20%	**0.748 (0.002)**	0.747 (0.003)	0.743 (0.003)	0.740 (0.004)	0.740 (0.003)	0.721 (0.005)	0.787 (0.002)	0.557 (0.002)



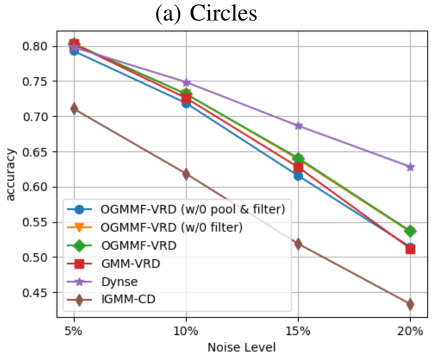
(a) Circles



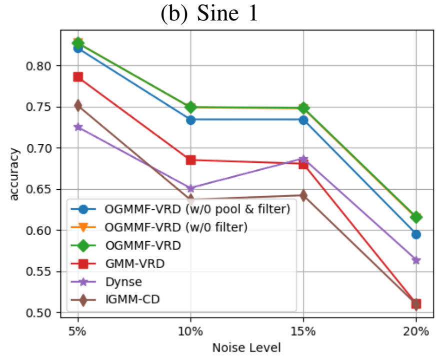
(b) Sine 1



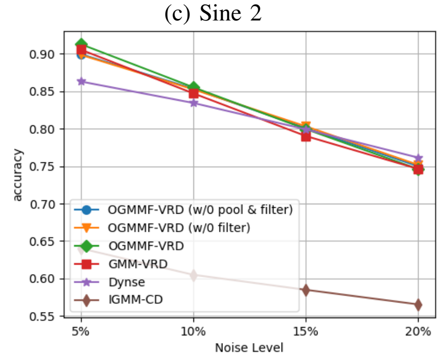
(c) Sine 2



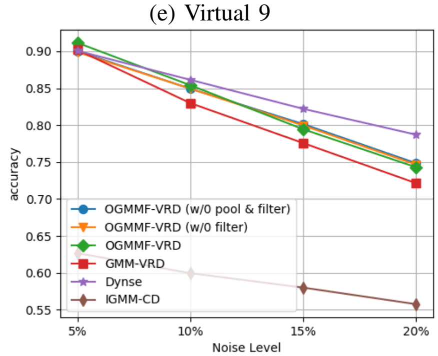
(d) Virtual 5



(e) Virtual 9



(f) SEA



(g) SEA

Fig. 6: Line graph with the accuracy of the models for synthetic datasets with different noise levels. w/o means the system without the mechanism.

TABLE IX: Accuracy improvements obtained by each of OGMMF-VRD's mechanisms. Each column represents OGMMF-VRD without a given mechanism (e.g. w/o non-severe drift adaptation). P-values representing statistically significant difference at the level of α = 0:05 are marked by *. The results highlighted with bold represent the best accuracy.

Datasets	W/0 Virtual + Ns Real	W/0 Severe Real	W/0 Pool	OGMMF-VRD
Circles	0.8313 (0.005)	0.5983 (0.012)*	0.8314 (0.003)	**0.8332 (0.004)**
Sine1	0.8341 (0.004)	0.567 (0.004)*	0.8098 (0.005)*	**0.8356 (0.005)**
Sine2	0.7533 (0.003)*	0.5519 (0.004)*	0.739 (0.004)*	**0.757 (0.004)**
Virtual5	0.841 (0.003)*	0.5762 (0.014)*	0.8408 (0.003)*	**0.8436 (0.003)**
Virtual9	0.8662 (0.004)*	0.4684 (0.022)*	0.8656 (0.004)*	**0.8721 (0.004)**
SEA	0.8606 (0.003)	0.7501 (0.025)*	0.8588 (0.003)*	**0.8625 (0.003)**
SEARec	0.86 (0.002)*	0.7499 (0.014)*	0.858 (0.002)*	**0.8611 (0.002)**

TABLE X: Time execution obtained by each of OGMMF-VRD's mechanisms. Each column represents OGMMF-VRD without a given mechanism (e.g. w/o non-severe drift adaptation). The results highlighted with bold represent the best time.

Datasets	**w/o Virtual + Ns. Real**	**w/o Real**	**w/o Pool**	**w/o Filter**	**Full**
Circles	35.4 (0.4)	**29.8 (1)**	39.4 (0.3)	45.8 (0.3)	46.1 (0.4)
Sine1	48.8 (0.5)	**43.8 (1.8)**	55.1 (0.2)	64.3 (0.3)	63.8 (0.5)
Sine2	52.6 (0.2)	**44.4 (1.1)**	57.3 (0.3)	67.9 (0.2)	67.8 (0.3)
Virtual5	52.1 (0.4)	**49 (1.3)**	56.4 (0.3)	68.1 (0.3)	68 (0.4)
Virtual9	40.5 (0.4)	**41.4 (2.2)**	47 (0.2)	55.4 (0.3)	55.5 (0.4)
SEA	35.2 (0.4)	**32.2 (0.5)**	40.1 (0.2)	47.4 (0.5)	47.5 (0.4)
SEARec	97.5 (0.3)	**86.1 (1)**	107.3 (0.3)	122.5 (0.3)	122.4 (0.6)

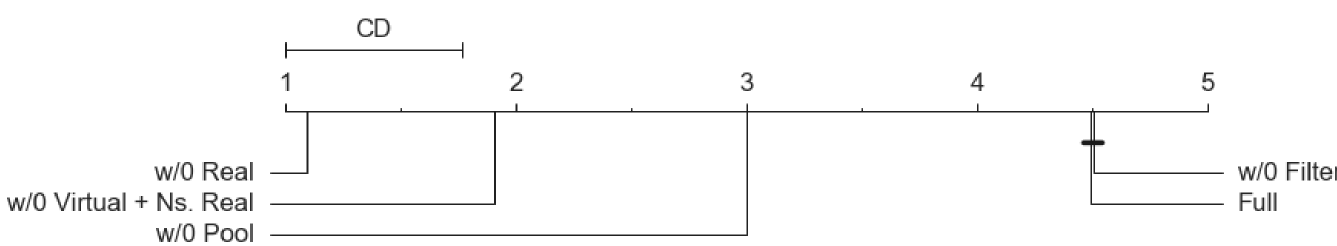


Fig. 7: Friedman and Nemenyi tests for average time execution for each OGMMF-VRD's mechanisms in all synthetic datasets. Friedman's p-value was p=1.07E-49. Each approach represents OGMMF-VRD without a given mechanism (e.g. w/o Virtual + Ns. Real adaptation). The last column (Full) represents the complete OGMMF-VRD. Any pair of approaches whose distance between them is larger than CD is considered to be significantly different.