Fast color quantization using weighted sort-means clustering

M. Emre Celebi

Department of Computer Science, Louisiana State University in Shreveport, Shreveport, Louisiana 71115, USA (ecelebi@lsus.edu)

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Color quantization is an important operation with numerous applications in graphics and image processing. Most quantization methods are essentially based on data clustering algorithms. However, despite its popularity as a general purpose clustering algorithm, K-means has not received much respect in the color quantization literature because of its high computational requirements and sensitivity to initialization. In this paper, a fast color quantization method based on K-means is presented. The method involves several modifications to the conventional (batch) K-means algorithm, including data reduction, sample weighting, and the use of the triangle inequality to speed up the nearest-neighbor search. Experiments on a diverse set of images demonstrate that, with the proposed modifications, K-means becomes very competitive with state-of-the-art color quantization methods in terms of both effectiveness and efficiency. © 2009 Optical Society of America OCIS codes: 100.2000, 100.5010.

1. INTRODUCTION

True-color images typically contain thousands of colors, which makes their display, storage, transmission, and processing problematic. For this reason, color quantization (reduction) is commonly used as a preprocessing step for various graphics and image processing tasks. In the past, color quantization was a necessity due to the limitations of the display hardware, which could not handle the 16 million possible colors in 24-bit images. Although 24bit display hardware has become more common, color quantization still maintains its practical value [1]. Modern applications of color quantization include (i) image compression [2], (ii) image segmentation [3], (iii) image analysis [4], (iv) image watermarking [5], and (v) contentbased image retrieval [6].

The process of color quantization is mainly composed of two phases: palette design (the selection of a small set of colors that represents the original image colors) and pixel mapping (the assignment of each input pixel to one of the palette colors). The primary objective is to reduce the number of unique colors, N', in an image to K ($K \ll N'$) with minimal distortion. In most applications, 24-bit pixels in the original image are reduced to 8 bits or fewer. Since natural images often contain a large number of colors, faithful representation of these images with a limited palette is a difficult problem.

Color quantization methods can be broadly classified into two categories [7]: image-independent methods that determine a universal (fixed) palette without regard to any specific image [8], and image-dependent methods that determine a custom (adaptive) palette based on the color distribution of the images. Despite being very fast, imageindependent methods usually give poor results since they do not take into account the image contents. Therefore, most of the studies in the literature consider only imagedependent methods, which strive to achieve a better balance between computational efficiency and visual quality of the quantization output.

Numerous image-dependent color quantization methods have been developed in the past three decades. These can be categorized into two families: preclustering methods and postclustering methods [1]. Preclustering methods are mostly based on the statistical analysis of the color distribution of the images. Divisive preclustering methods start with a single cluster that contains all N image pixels. This initial cluster is recursively subdivided until K clusters are obtained. Well-known divisive methods include median cut [9], octree [10], variance-based method [11], binary splitting [12], greedy orthogonal bipartitioning [13], center cut [14], and radius-weightedmean cut [15]. More recent methods can be found in [16–18]. On the other hand, agglomerative preclustering methods [19-23] start with N singleton clusters, each of which contains one image pixel. These clusters are repeatedly merged until K clusters remain. In contrast to preclustering methods that compute the palette only once, postclutering methods first determine an initial palette and then improve it iteratively. Essentially, any data clustering method can be used for this purpose. Since these methods involve iterative or stochastic optimization, they can obtain higher-quality results when compared with preclustering methods, at the expense of increased computational time. Clustering algorithms adapted to color quantization include K-means (KM) [24–27], minmax [28], competitive learning [29–31], fuzzy c-means [32,33], BIRCH [34], and self-organizing maps [35-37].

In this paper, a fast color quantization method based on the KM clustering algorithm [38] is presented. The method first reduces the amount of data to be clustered by sampling only the pixels with unique colors. In order to incorporate the color distribution of the pixels into the clustering procedure, each color sample is assigned a weight proportional to its frequency. These weighted samples are then clustered by using a fast and exact variant of the KM algorithm. The set of final cluster centers is taken as the quantization palette.

The rest of the paper is organized as follows. Section 2 describes the conventional KM clustering algorithm and the proposed modifications. Section 3 describes the experimental setup and presents the comparison of the proposed method with other color quantization methods. Finally, Section 4 gives the conclusions.

2. COLOR QUANTIZATION USING *K*-MEANS CLUSTERING ALGORITHM

The KM algorithm is inarguably one of the most widely used methods for data clustering [39]. Given a data set $X = \{\mathbf{x}_1, \ldots, \mathbf{x}_N\} \in \mathbb{R}^D$, the objective of KM is to partition X into K exhaustive and mutually exclusive clusters S $=\{S_1, \ldots, S_k\}, \cup_{k=1}^K S_k = X, S_i \cap S_j \equiv \emptyset$ for $i \neq j$ by minimizing the sum of squared error (SSE):

$$SSE = \sum_{k=1}^{K} \sum_{\mathbf{x}_i \in S_k} \|\mathbf{x}_i - \mathbf{c}_k\|_2^2, \tag{1}$$

where $\| \|_2$ denotes the Euclidean (L_2) norm and \mathbf{c}_k is the center of cluster S_k calculated as the mean of the points that belong to this cluster. This problem is known to be computationally intractable even for K=2 [40], but a heuristic method developed by Lloyd [41] offers a simple solution. Lloyd's algorithm starts with K arbitrary centers, typically chosen uniformly at random from the data points [42]. Each point is then assigned to the nearest center, and each center is recalculated as the mean of all points assigned to it. These two steps are repeated until a predefined termination criterion is met. The pseudocode for this procedure is given in Algorithm 1 (bold symbols denote vectors). Here, m[i] denotes the membership of point \mathbf{x}_i , i.e., index of the cluster center that is nearest to \mathbf{x}_i .

Algorithm 1. Conventional K-Means Algorithm

input : $X = {\mathbf{x}_1, \dots, \mathbf{x}_N} \in \mathbb{R}^D$ ($N \times D$ input data set) output: $C = \{ \mathbf{c}_1, \dots, \mathbf{c}_K \} \in \mathbb{R}^D$ (K cluster centers) Select a random subset C of X as the initial set of cluster centers; while termination criterion is not met do for $(i = 1; i \le N; i = i + 1)$ do Assign x_i to the nearest cluster; $m[i] = \operatorname{argmin} \|\mathbf{x}_i - \mathbf{c}_k\|^2;$ $k \in \{1, ..., K\}$ end Recalculate the cluster centers; for $(k = 1; k \le K; k = k + 1)$ do Cluster \overline{S}_k contains the set of points \mathbf{x}_i that are nearest to the center \mathbf{c}_k ; $S_k = \{\mathbf{x}_i | m[i] = k\};$ Calculate the new center \mathbf{c}_k as the mean of the points that belong to S_k ; $\mathbf{c}_k = \frac{1}{|S_k|} \sum_{\mathbf{x}_i \in S_k} \mathbf{x}_i;$ end end

When compared with the preclustering methods, there are two problems with using KM for color quantization. First, because of its iterative nature, the algorithm might require an excessive amount of time to obtain an acceptable output quality. Second, the output is quite sensitive to the initial choice of the cluster centers. In order to address these problems, we propose several modifications to the conventional KM algorithm:

• Data sampling. A straightforward way to speed up KM is to reduce the amount of data, which can be achieved by sampling the original image. Although random sampling can be used for this purpose, there are two problems with this approach. First, random sampling will further destabilize the clustering procedure in the sense that the output will be less predictable. Second, the sampling rate will be an additional parameter that will have a significant impact on the output. In order to avoid these drawbacks, we propose a deterministic sampling strategy in which only the pixels with unique colors are sampled. The unique colors in an image can be determined efficiently by using a hash table that uses chaining for collision resolution and a universal hash function of the form $h_a(\mathbf{x}) = (\sum_{i=1}^3 a_i x_i) \mod m$, where $\mathbf{x} = (x_1, x_2, x_3)$ denotes a pixel with red (x_1) , green (x_2) , and blue (x_3) components, m is a prime number, and the elements of sequence a $=(a_1,a_2,a_3)$ are chosen randomly from the set $\{0, 1, \ldots, m-1\}.$

• **Sample weighting.** An important disadvantage of the proposed sampling strategy is that it disregards the color distribution of the original image. In order to address this problem, each point is assigned a weight that is proportional to its frequency (note that the frequency information is collected during the data sampling stage). The weights are normalized by the number of pixels in the image to avoid numerical instabilities in the calculations. In addition, Algorithm 1 is modified to incorporate the weights into the clustering procedure.

• Sort-means (SM) algorithm. The assignment phase of KM involves many redundant distance calculations. In particular, for each point, the distances to each of the K cluster centers are calculated. Consider a point \mathbf{x}_i , two cluster centers \mathbf{c}_a and \mathbf{c}_b , and a distance metric d; using the triangle inequality, we have $d(\mathbf{c}_a, \mathbf{c}_b) \leq d(\mathbf{x}_i, \mathbf{c}_a)$ $+d(\mathbf{x}_i, \mathbf{c}_b)$. Therefore, if we know that $2d(\mathbf{x}_i, \mathbf{c}_a)$ $\leq d(\mathbf{c}_a, \mathbf{c}_b)$, we can conclude that $d(\mathbf{x}_i, \mathbf{c}_a) \leq d(\mathbf{x}_i, \mathbf{c}_b)$ without having to calculate $d(\mathbf{x}_i, \mathbf{c}_b)$. The compare-means algorithm [43] precalculates the pairwise distances between cluster centers at the beginning of each iteration. When searching for the nearest cluster center for each point, the algorithm often avoids a large number of distance calculations with the help of the triangle inequality test. The SM algorithm [43] further reduces the number of distance calculations by sorting the distance values associated with each cluster center in ascending order. At each iteration, point \mathbf{x}_i is compared against the cluster centers in increasing order of distance from the center \mathbf{c}_k that \mathbf{x}_i was assigned to in the previous iteration. If a center that is far enough from \mathbf{c}_k is reached, all of the remaining centers can be skipped, and the procedure continues with the next point. In this way, SM avoids the overhead of going through all the centers. It should be noted that more elaborate approaches to accelerate KM have been proposed in the literature. These include algorithms based on *Kd*-trees [44], core sets [45], and more sophisticated uses of the triangle inequality [46]. Some of these algorithms [45,46] are not suitable for low-dimensional data sets

such as color image data, since they incur significant overhead to create and update auxiliary data structures [46]. Others [44] provide computational gains comparable with SM at the expense of significant conceptual and implementation complexity. In contrast, SM is conceptually simple, easy to implement, and incurs very small overhead, which makes it an ideal candidate for color clustering.

We refer to the KM algorithm with the abovementioned modifications as the weighted SM (WSM) algorithm. The pseudocode for WSM is given in Algorithm 2.

Algorithm 2. Weighted Sort-Means Algorithm

```
\mathbf{input} \ : \ X = \{\mathbf{x}_1, \dots, \mathbf{x}_{N'}\} \in \mathbb{R}^D \ (N' \times D \ \mathrm{input} \ \mathrm{data} \ \mathrm{set})
W = \{w_1, \dots, w_{N'}\} \in [0, 1] \ (N' \text{ point weights})output: C = \{\mathbf{c}_1, \dots, \mathbf{c}_K\} \in \mathbb{R}^D \ (K \text{ cluster centers})
Select a random subset C of X as the initial set of cluster centers;
while termination criterion is not met do
     Calculate the pairwise distances between the cluster centers;
     for (i = 1; i \le K; i = i + 1) do
        for (j = i + 1; j \le K; j = j + 1) do

| d[i][j] = d[j][i] = ||\mathbf{c}_i - \mathbf{c}_j||^2;
        end
     \mathbf{end}
     Construct a K \times K matrix M in which row i is a permutation of
    1,\ldots K that represents the clusters in increasing order of
     distance of their centers from c_i;
     for (i = 1; i \le N'; i = i + 1) do
         Let S_p be the cluster that \mathbf{x}_i was assigned to in the previous
         iteration;
         p = m[i];
         min_dist = prev_dist = \|\mathbf{x}_i - \mathbf{c}_p\|^2;
         Update the nearest center if necessary;
         for (j = 2; j \le K; j = j + 1) do
              t = M[p][j];
             if d[p][t] \ge 4 \text{ prev.dist} then
| There can be no other closer center. Stop checking;
                  break;
              end
              dist = \|\mathbf{x}_i - \mathbf{c}_t\|^2;
             if dist \leq min_dist then
                  \mathbf{c}_t is closer to \mathbf{x}_i than \mathbf{c}_p;
                  \min_{dist} = dist;
                 m[i] = t;
             end
         end
    end
    Recalculate the cluster centers;
     for (k = 1; k \le K; k = k + 1) do
         Calculate the new center c_k as the weighted mean
         of points that are nearest to it;
                 \left(\sum_{m[i]=k} w_i \mathbf{x}_i\right)
                                    \sum_{m[i]=k} w_i;
    end
end
```

3. EXPERIMENTAL RESULTS AND DISCUSSION

A. Image Set and Performance Criteria

The proposed method was tested on some of the most commonly used test images in the quantization literature (see Fig. 1). The natural images in the set included Airplane (512 \times 512, 77,041 (29%) unique colors), Baboon (512 \times 512, 153,171 (58%) unique colors), Boats (787 \times 576, 140,971 (31%) unique colors), Lenna (512 \times 480, 56,164 (23%) unique colors), Parrots (1536 \times 1024, 200,611 (13%) unique colors), and Peppers (512 \times 512, 111,344 (42%) unique colors). The synthetic images included Fish (300 \times 200, 28,170 (47%) unique colors) and Poolballs (510 \times 383, 13,604 (7%) unique colors).

The effectiveness of a quantization method was quantified by the mean squared error (MSE) measure:

$$MSE(\mathbf{X}, \hat{\mathbf{X}}) = \frac{1}{HW} \sum_{h=1}^{H} \sum_{w=1}^{W} \|\mathbf{x}(h, w) - \hat{\mathbf{x}}(h, w)\|_{2}^{2}, \qquad (2)$$

where **X** and $\hat{\mathbf{X}}$ denote, respectively, the $H \times W$ original and quantized images in the RGB color space. MSE represents the average distortion with respect to the L_2^2 norm (1) and is the most commonly used evaluation measure in the quantization literature [1,7]. Note that the peak signal-to-noise ratio (PSNR) measure can be easily calculated from the MSE value:

$$PSNR = 20 \log_{10} \left(\frac{255}{\sqrt{MSE}} \right).$$
(3)

The efficiency of a quantization method was measured by CPU time in milliseconds. Note that only the palette generation phase was considered, since this is the most time-consuming part of the majority of quantization methods. All of the programs were implemented in the C language, compiled with the gcc v4.2.4 compiler, and executed on an Intel Core 2 Quad Q6700 2.66 GHz machine. The time figures were averaged over 100 runs.

B. Comparison of WSM against Other Quantization Methods

The WSM algorithm was compared with some of the wellknown quantization methods in the literature:

• Median-cut (MC) [9]. This method starts by building a $32 \times 32 \times 32$ color histogram that contains the original pixel values reduced to 5 bits per channel by uniform quantization. This histogram volume is then recursively split into smaller boxes until K boxes are obtained. At each step, the box that contains the largest number of pixels is split along the longest axis at the median point, so that the resulting subboxes each contain approximately the same number of pixels. The centroids of the final K boxes are taken as the color palette.

• Variance-based method (WAN) [11]. This method is similar to MC, with the exception that at each step the box with the largest weighted variance (squared error) is split along the major (principal) axis at the point that minimizes the marginal squared error.

• Greedy orthogonal bipartitioning (WU) [13]. This method is similar to WAN, with the exception that at each step the box with the largest weighted variance is split along the axis that minimizes the sum of the variances on both sides.

• Neu-quant (NEU) [35]. This method utilizes a onedimensional self-organizing map (Kohonen neural network) with 256 neurons. A random subset of N/f pixels is used in the training phase, and the final weights of the neurons are taken as the color palette. In the experiments, the highest-quality configuration, i.e., f=1, was used.

• Modified minmax (MMM) [28]. This method choses the first center \mathbf{c}_1 arbitrarily from the data set, and the *i*th center \mathbf{c}_i (i=2,...,K) is chosen to be the point that



Fig. 1. (Color online) Test images: a, Airplane; b, Baboon; c, Boats; d, Lenna; e, Parrots; f, Peppers; g, Fish; h, Poolballs.

has the largest minimum weighted L_2^2 distance (the weights for the red, green, and blue channels are taken as 0.5, 1.0, and 0.25, respectively) to the previously selected centers, i.e., $\mathbf{c}_1, \mathbf{c}_2, \ldots, \mathbf{c}_{i-1}$. Each of these initial centers is then recalculated as the mean of the points assigned to it.

• **Split and Merge (SAM)** [23]. This two-phase method first divides the color space uniformly into *B* partitions. This initial set of *B* clusters is represented as an adjacency graph. In the second phase, (B-K) merge operations are performed to obtain the final *K* clusters. At each step of the second phase, the pair of clusters with the minimum joint quantization error are merged. In the experiments, the initial number of clusters was set to *B* = 20*K*.

• **Fuzzy** *c*-means (**FCM**) [47]. FCM is a generalization of KM in which points can belong to more than one cluster. The algorithm involves the minimization of the functional $J_q(U, V) = \sum_{i=1}^N \sum_{k=1}^K u_{ik}^q \|\mathbf{x}_i - \mathbf{v}_k\|_2^2$ with respect to U (a fuzzy *K*-partition of the data set) and V (a set of prototypes—cluster centers). The parameter q controls the fuzziness of the resulting clusters. At each iteration, the membership matrix U is updated by $u_{ik} = (\sum_{j=1}^K (\|\mathbf{x}_i - \mathbf{v}_k\|_2)^{2/(q-1)})^{-1}$, which is followed by the update of the prototype matrix V by $\mathbf{v}_k = (\sum_{i=1}^N u_{ik}^q \mathbf{x}_i)/(\sum_{i=1}^N u_{ik}^q)$. A näive implementation of the FCM algorithm has a complexity that is quadratic in K. In the experiments, a linear complexity formulation described in [48] was used, and the fuzziness parameter was set to q = 2, as is commonly seen in the fuzzy clustering literature [39].

• Fuzzy *c*-means with partition index maximization (PIM) [32]. This method is an extension of FCM in which the functional to be minimized incorporates a cluster validity measure called the partition index. This index measures how well a point \mathbf{x}_i has been classified and is defined as $P_i = \sum_{k=1}^{K} u_{ik}^q$. The FCM functional can be modified to incorporate P_i as follows: $J_q^{\alpha}(U, V) = \sum_{i=1}^{N} \sum_{k=1}^{K} u_{ik}^q \|\mathbf{x}_i - \mathbf{v}_k\|_2^2 - \alpha \sum_{i=1}^{N} P_i$. The parameter α controls the weight of the second term. The procedure that minimizes $J_q^{\alpha}(U, V)$ is identical to the one used in FCM except for the membership matrix update equation: $u_{ik} = (\sum_{j=1}^{K} [(\|\mathbf{x}_i - \mathbf{v}_k\|_2 - \alpha)/(\|\mathbf{x}_i - \mathbf{v}_j\|_2 - \alpha)]^{2/(q-1)})^{-1}$. An adaptive method to determine the value of α is to set it to a fraction $0 \le \delta < 0.5$ of the distance between the nearest two centers, i.e., $\alpha = \delta \min_{i \ne j} \|\mathbf{v}_i - \mathbf{v}_j\|_2^2$. Following [32], the fraction value was set to $\delta = 0.4$.

• Finite-state KM (FKM) [25]. This method is a fast approximation for KM. The first iteration is the same as that of KM. In each of the subsequent iterations, the nearest center for a point \mathbf{x}_i is determined from among the K' ($K' \ll K$) nearest neighbors of the center that the point was assigned to in the previous iteration. When compared with KM, this technique leads to considerable computational savings, since the nearest center search is performed in a significantly smaller set of K' centers rather than the entire set of K centers. Following [25], the number of nearest neighbors was set to K' = 8.

• Stable-flags KM (SKM) [26]. This method is another fast approximation for KM. The first I' iterations are the same as those of KM. In the subsequent iterations, the clustering procedure is accelerated by using the concepts of center stability and point activity. More specifically, if a cluster center \mathbf{c}_k does not move by more than θ units (as measured by the L_2^2 distance) in two successive iterations, this center is classified as stable. Furthermore, points that were previously assigned to the stable centers are classified as inactive. At each iteration, only unstable centers and active points participate in the clustering procedure. Following [26], the algorithm parameters were set to I' = 10 and $\theta = 1.0$.

For each KM-based quantization method (except for SKM), two variants were implemented. In the first one, the number of iterations was limited to 10, which makes this variant suitable for time-critical applications. These *fixed-iteration* variants are denoted by the plain acronyms KM, FKM, and WSM. In the second variant, to obtain higher-quality results, the method was executed until it

	K —	30	K	64	K -	198	K -	256	K -	20	K -	64	K -	198	K -	256
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Method	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ
				Airpl	ane							Bab	oon			
MC	124	-	81	-	54	-	41	-	546	-	371	-	248	Ξ.	166	-
WAN	117	-	69	-	50	-	39	-	509	-	326	-	216	-	142	-
WU	75	-	47	-	30	-	21	_	422	-	248	-	155	-	99	-
NEU	101		17		24		15		363		216		128		84	
MMM	194	-	90	-	44	-	10	-	400	-	210	-	120	-	100	-
	134	-	82	-	44	-	28	-	489	-	270	-	189	-	120	-
SAM	120	-	65	-	43	-	31	-	396	-	245	-	153	-	99	-
FCM	74	9	44	4	29	2	21	1	415	15	265	10	174	6	119	4
PIM	73	9	45	4	29	2	21	1	413	18	261	13	172	7	117	4
KM	112	25	65	12	36	4	22	2	345	9	206	5	129	2	83	1
KM-C	59	2	35	1	25	ō	10	0	320	3	196	1	123	1	79	ō
EKM	119	10	64	0	20	4	20	1	246	0	206	1	120	2	02	1
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FKM-C	59	2	35	T	26	T	19	1	328	3	196	1	123	T	79	0
SKM	112	20	63	9	36	4	22	1	343	10	207	6	129	2	83	1
WSM	64	4	36	1	23	1	15	0	345	8	204	3	127	1	81	1
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MC	200	-	126	-	78	-	57	-	165	-	94		71	-	47	-
WAN	198	-	117	-	71	-	45	-	159	~	93	-	61	~	43	-
WU	154	-	87	-	50	-	32	-	130	-	76	-	46	-	29	-
NEU	147	-	79	-	41	-	26	-	119	-	68	(=)	36	-	23	-
MMM	203		114		60		41		130		86		50		34	
CAM	200		05	-	50	-	41	-	100	-	00	-	50	-	40	-
SAM	101	-	95	-	59	-	42	-	135	-	00	_	50	-	40	-
FCM	160	13	99	8	64	5	42	3	132	10	83	7	53	4	38	2
PIM	161	14	99	11	63	5	43	3	136	12	81	6	53	4	38	2
KM	135	11	78	5	47	3	30	1	106	5	61	2	38	1	24	0
KM-C	115	1	64	1	39	0	25	0	97	1	57	1	35	0	22	0
FKM	13/	10	77	5	47	3	20	1	107	8	61	2	38	1	24	õ
FUM	110	10	CF	1	20	0	29		107	1	57	1	30	1	24	0
FKM-C	116	1	65	1	39	0	25	0	97	1	57	1	35	0	22	0
SKM	137	13	77	4	47	2	30	1	107	6	62	2	38	1	24	1
WSM	125	$\overline{7}$	68	2	40	1	24	0	103	5	60	2	36	1	23	0
$WSM_{-}C$	115	1	63	0	97	0	20	0	07	0	56	1	24	0	00	0
	119	1	00	0	01	0	40	0	97	2	00	1	04	0	44	0
<i>WDM-0</i>	115	1	00	Parr	ots	0	23	0	97	2	50	Penr	04	0	44	0
MC	401	1	00	Parr	ots	0	23	0	97	2	012	Pepp	34 Ders	0	22	0
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MC WAN WU NEU MMM SAM ECM	401 365 291 306 332 276 207	- - - - - - -	258 225 171 153 200 160	Parr - - - - - -	ots 144 146 96 84 117 94		99 90 59 47 73 60 60		97 333 333 264 249 292 268 272	2	213 215 160 151 182 161	Pepp - - - - - - - 7	34 pers 147 142 101 83 113 100 120		98 93 63 55 76 64 84	
MC WAN WU NEU MMM SAM FCM	401 365 291 306 332 276 297	- - - - - 19	258 225 171 153 200 160 178	Parr - - - - 14	ots 144 146 96 84 117 94 107		99 90 59 47 73 60 69		97 333 333 264 249 292 268 272 268	2	213 215 160 151 182 161 179	1 Pepp - - - - 7	34 pers 147 142 101 83 113 100 120 110		$ \begin{array}{c} 98\\93\\63\\55\\76\\64\\84\\\end{array} $	
MC WAN WU NEU MMM SAM FCM PIM	401 365 291 306 332 276 297 295	- - - - - 19 21	258 225 171 153 200 160 178 175	Parr - - - - 14 12	ots 144 146 96 84 117 94 107 107	- - - 5 5	99 90 59 47 73 60 69	- - - - - 2 2	97 333 333 264 249 292 268 272 266	2 - - - - 15 14	$ \begin{array}{r} 213 \\ 215 \\ 160 \\ 151 \\ 182 \\ 161 \\ 179 \\ 176 \\ \end{array} $	1 Pepp - - - - 7 7	34 pers 147 142 101 83 113 100 120 119	- - - - - 4 5	$ \begin{array}{r} 98 \\ 93 \\ 63 \\ 55 \\ 76 \\ 64 \\ 84 \\ 84 \\ \end{array} $	- - - - - 3 3
MC WAN WU NEU MMM SAM FCM PIM KM	401 365 291 306 332 276 297 295 262	- - - 19 21 20	$\begin{array}{c} 258\\ 225\\ 171\\ 153\\ 200\\ 160\\ 178\\ 175\\ 149 \end{array}$	Parr - - - - 14 12 9	ots 144 146 96 84 117 94 107 107 85	- - - - 5 5 4	99 90 59 47 73 60 69 51	- - - - 2 2 2 2	97 333 333 264 249 292 268 272 266 232	2 - - - 15 14 7	213 215 160 151 182 161 179 176 141	Pepp - - - - 7 7 4	34 pers 147 142 101 83 113 100 120 119 87	- - - - 4 5 2	$\begin{array}{c} 22\\ 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 54\\ \end{array}$	0 - - - - 3 3 1
MC WAN WU NEU MMM SAM FCM FCM PIM KM KM-C	401 365 291 306 332 276 297 295 262 237	- - - 19 21 20 7	258 225 171 153 200 160 178 175 149 131	Parr - - - 14 12 9 3	$\begin{array}{c} 37 \\ \text{ots} \\ 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \end{array}$	- - - - 5 5 4 1	$\begin{array}{c} 99\\ 99\\ 90\\ 59\\ 47\\ 73\\ 60\\ 69\\ 69\\ 51\\ 46\end{array}$	- - - 2 2 2 1	97 333 333 264 249 292 268 272 266 232 220	2 - - 15 14 7 2	213 215 160 151 182 161 179 176 141 132	Pepp - - - 7 7 4 1	34 bers 147 142 101 83 113 100 120 119 87 80	- - - 4 5 2 0	$\begin{array}{c} 22 \\ \hline 98 \\ 93 \\ 63 \\ 55 \\ 76 \\ 64 \\ 84 \\ 84 \\ 84 \\ 54 \\ 51 \end{array}$	0 - - - - 3 3 1 0
MC WAN WU NEU MMM SAM FCM PIM KM KM-C FKM	401 365 291 306 332 276 297 295 262 237 264	- - - 19 21 20 7 21	258 225 171 153 200 160 178 175 149 131 150	Parr - - - 14 12 9 3 10	$\begin{array}{c} 37 \\ \text{ots} \\ \hline 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \end{array}$	- - - 5 5 4 1 4	$\begin{array}{c} 99\\ 99\\ 90\\ 59\\ 47\\ 73\\ 60\\ 69\\ 69\\ 51\\ 46\\ 51 \end{array}$	- - - - 2 2 2 2 1 2	97 333 333 264 249 292 268 272 266 232 220 231	2 - - 15 14 7 2 6	213 215 160 151 182 161 179 176 141 132 142	1 Pepp - - - 7 7 4 1 4	34 bers 147 142 101 83 113 100 120 119 87 80 86	- - - - 4 5 2 0 2	$\begin{array}{c} 22 \\ \hline 98 \\ 93 \\ 63 \\ 55 \\ 76 \\ 64 \\ 84 \\ 84 \\ 84 \\ 54 \\ 51 \\ 55 \end{array}$	0 - - - - 3 3 1 0 1
MC WAN WU NEU MMM SAM FCM PIM KM KM KM-C FKM FKM-C	401 365 291 306 332 276 297 295 262 237 264 237	- - - 19 21 20 7 21 7	258 225 171 153 200 160 178 175 149 131 150 132	Parr - - - - 14 12 9 3 10 3	37 ots 144 146 96 84 117 94 107 107 85 76 87 77	- - - - 5 5 4 1 4 2	$\begin{array}{c} 99\\ 99\\ 90\\ 59\\ 47\\ 73\\ 60\\ 69\\ 69\\ 51\\ 46\\ 51\\ 47\end{array}$	-	97 333 333 264 249 292 268 272 266 232 220 231 220	$ \frac{2}{2} $	213 215 160 151 182 161 179 176 141 132 142 132	1 Pepp - - - 7 7 4 1 4 2	34 bers 147 142 101 83 113 100 120 119 87 80 86 81	-	$\begin{array}{c} 22\\ 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 54\\ 51\\ 55\\ 51\\ \end{array}$	0 - - - - - - - - - - - - - - - - - - -
MC WAN WU NEU MMM SAM FCM PIM KM FCM FKM-C FKM-C SKM	401 365 291 306 332 276 297 295 262 237 264 237 250	1 - - - 19 21 20 7 21 7	$\begin{array}{c} 258\\ 225\\ 171\\ 153\\ 200\\ 160\\ 178\\ 175\\ 149\\ 131\\ 150\\ 132\\ 152\end{array}$	Parr - - - 14 12 9 3 10 3	37 ots 144 146 96 84 117 94 107 107 85 76 87 77 86	-	$\begin{array}{c} 99\\ 99\\ 90\\ 59\\ 47\\ 73\\ 60\\ 69\\ 69\\ 51\\ 46\\ 51\\ 47\\ 51\end{array}$		97 333 333 264 249 292 268 272 266 232 220 231 220 231 223	$ \frac{2}{2} $	213 215 160 151 182 161 179 176 141 132 142 132	1 Pepp - - - 7 7 4 1 4 2 4	34 bers 147 142 101 83 113 100 120 119 87 80 81 87	- - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 22\\ 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 54\\ 51\\ 55\\ 51\\ 55\\ 51\\ 55\end{array}$	0 - - - - - - - - - - - - - - - - - - -
MC WAN WU NEU MMM SAM FCM PIM KM FCM FKM FKM-C FKM FKM-C SKM	401 365 291 306 332 276 297 295 262 237 264 237 264 237 259 264	- - - 19 21 20 7 21 7 16	258 225 171 153 200 160 178 175 149 131 150 132 152	Parr - - - - 14 12 9 3 10 3 11	ots 144 146 96 84 117 94 107 107 85 76 87 77 86 87 77 86 87 77 86 87 77 86 87 77 86 87 77 86 87 87 87 87 87 87 87 87 87 87	-	$\begin{array}{c} 99\\ 90\\ 59\\ 47\\ 73\\ 60\\ 69\\ 69\\ 51\\ 46\\ 51\\ 47\\ 51\\ 47\\ 51\\ 46\end{array}$	- - - - 2 2 2 2 2 1 2 1 2 1 2 1 2 2	97 333 333 264 249 292 268 272 266 232 220 231 220 233	$ \frac{2}{2} $	213 215 160 151 182 161 179 176 141 132 142 132 142 132	Pepp - - - 7 7 4 1 4 2 4	34 bers 147 142 101 83 113 100 120 119 87 80 86 81 87 80 86 81 87	- - - 4 5 2 0 2 1 2	$\begin{array}{c} 22\\ 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 54\\ 51\\ 55\\ 51\\ 55\\ 51\\ 55\\ 52\\ \end{array}$	0 - - - - - - - - - - - - - - - - - - -
MC WAN WU NEU MMM SAM FCM PIM KM FCM PIM KM-C FKM FKM-C SKM WSM	$\begin{array}{c} 401\\ 365\\ 291\\ 306\\ 332\\ 276\\ 297\\ 295\\ 262\\ 237\\ 264\\ 237\\ 259\\ 249\\ \end{array}$	- - - - 19 21 20 7 21 7 16 13	$\begin{array}{c} 258\\ 225\\ 171\\ 153\\ 200\\ 160\\ 178\\ 175\\ 149\\ 131\\ 150\\ 132\\ 152\\ 136\end{array}$	Parr - - - 14 12 9 3 10 3 11 5	37 ots 144 146 96 84 117 94 107 85 76 87 77 86 79	- - - - 5 5 4 1 4 2 4 2	$\begin{array}{c} 23 \\ 99 \\ 90 \\ 59 \\ 47 \\ 73 \\ 60 \\ 69 \\ 69 \\ 51 \\ 46 \\ 51 \\ 47 \\ 51 \\ 46 \\ 69 \\ 51 \\ 47 \\ 51 \\ 46 \\ 69 \\ 69 \\ 51 \\ 46 \\ 69 \\ 69 \\ 69 \\ 51 \\ 69 \\ 69 \\ 69 \\ 69 \\ 51 \\ 69 \\ 69 \\ 69 \\ 69 \\ 51 \\ 69 \\ 69 \\ 69 \\ 69 \\ 69 \\ 69 \\ 69 \\ 6$	- - - 2 2 2 2 1 2 1 2 1 2 1 2 1 2	97 333 333 264 249 268 272 266 232 220 231 220 233 232	2 - - - 15 14 7 2 6 2 7 7	213 215 160 151 182 161 179 176 141 132 142 132 142 139	Pepp - - - 7 7 4 1 4 2 4 3	34 ports 147 142 101 83 113 100 120 119 87 80 86 81 87 85	- - - 4 5 2 0 2 1 2 1	$\begin{array}{c} 22\\ 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 54\\ 51\\ 55\\ 51\\ 55\\ 51\\ 55\\ 53\\ 31\\ 55\\ 53\\ 31\\ 55\\ 53\\ 53\\ 53\\ 53\\ 53\\ 53\\ 53\\ 53\\ 53$	0 - - - - - - - - - - - - - - - - - - -
MC WAN WU NEU MMM SAM FCM FCM FIM KM-C FKM FKM-C SKM WSM-C	401 365 291 306 332 276 297 262 237 264 237 259 249 232		258 225 171 153 200 160 178 175 149 131 150 132 152 136 128	Parr - - - 14 12 9 3 10 3 11 5 2	ots 144 146 96 84 117 94 107 107 85 76 87 77 86 79 74	- - - - 5 5 4 1 4 2 4 2 1	99 90 59 47 73 60 69 69 51 46 51 47 51 46 43 3	- - - - 2 2 2 2 2 1 2 1 2 1 2 1 0	97 333 333 264 249 268 272 266 232 220 231 220 233 232 233 232 219		213 215 160 151 182 161 179 176 141 132 142 132 142 139 131	Pepp - - - - 7 7 4 1 4 2 4 3 1	34 ports 147 142 101 83 113 100 120 119 87 80 81 87 85 80		22 98 93 63 55 76 64 84 54 51 55 51 55 53 50	- - - - - - - - - - - - - - - - - - -
MC WAN WU NEU MMM SAM FCM FCM FIM KM-C FKM-C FKM-C SKM WSM-C	401 365 291 306 332 276 297 295 262 237 262 237 262 237 269 249 232		258 225 171 153 200 160 178 175 149 131 150 132 152 136 128	Parr - - - - 14 12 9 3 10 3 11 5 2 Fis	$\begin{array}{c} 37 \\ \text{ots} \\ \hline 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ \mathbf{h} \end{array}$		99 90 59 47 73 60 69 51 46 51 46 43		97 333 333 264 249 292 268 272 266 232 220 231 220 233 232 233 232 219	$ \frac{2}{2} $	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131	1 Pepp - - - - 7 7 4 1 4 2 4 3 1 Poolt	34 porrs 147 142 101 83 113 100 120 119 87 80 86 81 87 85 80 palls		$\begin{array}{c} 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 51\\ 55\\ 51\\ 55\\ 53\\ {\bf 50} \end{array}$	0 - - - - - - - - - - - - - - - - - - -
MC WAN WU NEU MMM SAM FCM PIM KM FCM FKM FKM-C FKM FKM-C SKM WSM-C WSM-C	401 365 291 306 332 276 297 295 262 237 264 237 249 249 232		258 225 171 153 200 160 178 175 149 131 150 132 152 136 128	Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ \text{ots} \\ 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ \mathbf{h} \\ 107 \end{array}$		$\begin{array}{c} 23 \\ 99 \\ 90 \\ 59 \\ 47 \\ 73 \\ 60 \\ 69 \\ 69 \\ 51 \\ 46 \\ 51 \\ 47 \\ 51 \\ 46 \\ 43 \\ \end{array}$	-	97 333 343 249 292 268 272 266 232 220 231 220 233 232 219 136	$ \frac{2}{2} $	213 215 160 151 182 161 179 176 141 132 142 132 142 132 142 131	1 Pepp - - - - 7 7 4 1 4 2 4 3 1 Pooll	34 ports 147 142 101 83 113 100 120 119 87 80 86 81 87 85 80 palls 38	- - - - - - - - - - - - - - - - - - -	98 93 63 55 76 64 84 54 51 55 51 55 53 50	0 - - - - - - - - - - - - - - - - - - -
MC WAN WU NEU MMM SAM FCM PIM KM FCM FKM FKM-C FKM FKM-C SKM WSM-C WAN	401 365 291 306 332 276 297 295 262 237 264 237 249 232 276 311	1 - - - - - - - - - - - - - - - - - - -	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128 169 208	Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ \text{ots} \\ \hline 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ \mathbf{h} \\ \hline 107 \\ 124 \end{array}$		$\begin{array}{c} 99\\ 99\\ 59\\ 47\\ 73\\ 60\\ 69\\ 69\\ 51\\ 46\\ 51\\ 47\\ 51\\ 46\\ 43\\ \end{array}$	- - - - 2 2 2 2 2 1 2 1 2 1 2 1 0	97 333 333 264 249 292 268 272 266 232 220 231 220 233 232 219 136 112	2 - - - - - - - - - - - - - - - - - - -	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131 64 59	1 Pepp - - - 7 7 4 1 4 2 4 3 1 Pooll	34 ports 147 142 101 83 113 100 120 119 87 80 86 81 87 85 80 palls 38 45	0 - - - - - - - - - - - - - - - - - - -	22 98 93 55 76 64 84 54 51 55 53 50 27 38	0 - - - - - - - - - - - - - - - - - - -
MC WAN WU NEU MMM SAM FCM PIM KM FCM FKM FKM-C FKM FKM-C SKM WSM-C WSM-C MC WAN WAN	401 365 291 306 332 276 297 295 262 237 264 237 249 232 276 311 117	- - - - - - - - - - - - - - - - - - -	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128 169 208	Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ \text{ots} \\ \hline 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ \mathbf{h} \\ \hline 107 \\ 124 \\ 60 \\ \end{array}$	-	99 90 59 47 73 60 69 51 46 51 47 51 46 43 68 74	- - - - 2 2 2 2 2 1 2 1 2 1 2 1 2 1 0	97 333 333 264 249 292 268 272 266 232 220 231 220 233 232 219 136 112 68	2 - - - - - - - - - - - - - - - - - - -	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131 64 59 21	Pepp - - - - 7 7 4 1 4 2 4 3 1 Poolt	34 porrs 147 142 101 83 113 100 120 119 87 80 86 81 87 85 80 palls 38 45 17	0 - - - - - - - - - - - - - - - - - - -	22 98 93 63 55 76 64 84 54 51 55 53 50 27 38 11	
MC WAN WU NEU MMM SAM FCM PIM KM FCM FKM-C FKM FKM-C SKM WSM-C WSM-C WSM-C	401 365 291 306 332 276 297 295 262 237 264 237 265 237 264 237 263 237 263 237 269 237 269 237 269 311 187	1 - - - - - - - - - - - - - - - - - - -	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128 169 208 111	Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37\\ \text{ots}\\ 144\\ 146\\ 96\\ 84\\ 117\\ 94\\ 107\\ 107\\ 85\\ 76\\ 87\\ 77\\ 86\\ 79\\ \textbf{74}\\ \textbf{h}\\ \hline 107\\ 124\\ 69\\ -9\\ \hline \end{array}$	-	23 99 90 59 47 73 60 69 51 46 43 68 77 44	- - - - 2 2 2 2 1 2 2 1 2 2 1 2 2 1 2 2 1 2 2 1 2 2 1 2 2 2 2 2 1 2 2 2 2 2 1 2 2 2 2 2 1 - - - -	97 333 333 264 249 292 268 272 266 232 220 231 220 231 220 231 220 231 202 136 112 68	2 - - - - - - - - - - - - - - - - - - -	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131 64 59 31	Pepp - - - - - - - - - - - 7 4 1 4 2 4 3 1 Pooll	34 porrs 147 142 101 83 113 100 120 119 87 80 86 81 87 85 80 palls 38 45 17	- - - - 4 5 2 0 2 1 1 2 1 1 1	$\begin{array}{c} 22\\ 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 54\\ 55\\ 51\\ 55\\ 53\\ 50\\ \hline \end{array}$	
MC WAN WU NEU MMM SAM FCM PIM KM FCM FKM-C FKM-C FKM-C SKM WSM-C WSM-C WSM-C WSM-C WSM-C WAN WU NEU	401 365 291 306 332 276 297 262 237 264 237 264 237 264 237 264 237 264 137 249 232 276 311 187 173	- - - - - - - - - - - - - - - - - - -	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128 169 208 111 107	Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ \mathbf{ots} \\ 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ \mathbf{h} \\ \hline 107 \\ 124 \\ 69 \\ 57 \end{array}$	-	99 90 59 47 73 60 69 51 46 51 47 51 46 51 47 51 46 51 47 51 46 51 43 68 77 44 42 68	- - - - 2 2 2 2 1 2 1 2 1 2 1 2 1 0	97 333 333 264 249 268 272 266 232 220 231 220 231 220 231 220 231 220 231 220 231 220 231 232 219 1366 112 68 104	2 - - - - - - - - - - - - - - - - - - -	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131 64 59 31 44	Pepp - - - - 7 7 4 1 4 2 4 3 1 Poolt	34 porrs 147 142 101 83 113 100 120 119 87 80 86 81 87 85 80 palls 38 45 17 18		22 98 93 63 55 76 64 84 54 51 55 51 55 53 50 27 38 11 9	
MC WAN WU NEU MMM SAM FCM PIM KM FCM FKM KM-C FKM FKM-C SKM WSM-C WSM-C WSM-C WAN WU NEU NEU MMM	$\begin{array}{c} 401\\ 365\\ 291\\ 306\\ 332\\ 276\\ 297\\ 295\\ 262\\ 237\\ 264\\ 237\\ 259\\ 249\\ \textbf{232}\\ \textbf{232}\\ \textbf{232}\\ \textbf{2332}\\ \textbf{2332}\\ \textbf{2333}\\ \textbf{2335}\\ \textbf$	1 - - - - - - - - - - - - - - - - - - -	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128	Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ \hline \text{ots} \\ \hline 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ \mathbf{h} \\ \hline 107 \\ 124 \\ 69 \\ 57 \\ 81 \\ \end{array}$		99 90 59 47 73 60 69 51 46 51 47 51 46 51 47 51 46 3 68 77 44 42 53	- - - - 2 2 2 2 2 1 2 2 1 2 1 2 1 2 1 2	97 333 333 264 249 292 268 272 266 232 220 231 220 233 232 219 136 112 68 104 166	2 - - - - - - - - - - - - - - - - - - -	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131 64 59 31 44 91	1 Pepp - - - - 7 7 4 1 4 2 4 3 1 Poolh - - - - - - - - - - - - - - - - - - -	34 porrs 147 142 101 83 113 100 120 119 87 80 86 81 87 85 80 palls 38 45 17 18 42	- - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 22\\ \hline 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 51\\ 55\\ 51\\ 55\\ 53\\ \textbf{50}\\ \hline 27\\ 38\\ 11\\ 9\\ 20\\ \end{array}$	
MC WAN WU NEU MMM SAM FCM PIM KM FCM FKM FKM-C FKM FKM-C SKM WSM-C WSM-C WSM-C WAN WU NEU MMM SAM	401 365 291 306 332 276 297 295 262 237 264 237 264 237 264 237 264 237 264 237 264 237 264 311 187 173 235 198	1 - - - - - - - - - - - - - - - - - - -	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128 169 208 111 107 136 120	Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ \hline \text{ots} \\ \hline 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ \textbf{74} \\ \hline 74 \\ \hline 107 \\ 124 \\ 69 \\ 57 \\ 81 \\ 74 \\ \end{array}$		99 90 59 47 73 60 69 51 46 51 47 51 46 43 68 77 44 42 53 49	0 - - - - - - - - - - - - - - - - - - -	97 333 333 264 249 292 268 272 266 232 220 231 220 233 232 219 136 112 68 104 166 91	2 - - - - - - - - - - - - - - - - - - -	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131 64 59 31 44 91 54	1 Pepp - - - - 7 7 4 1 4 2 4 3 1 Pooll - - - - - -	34 pers 147 142 101 83 113 100 120 119 87 80 86 81 87 80 ast balls 38 45 17 18 42 37	0 - - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 22\\ 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 54\\ 51\\ 55\\ 51\\ 55\\ 53\\ \textbf{50}\\ \hline \end{array}$	0 - - - - - - - - - - - - - - - - - - -
MC WAN WU NEU MMM SAM FCM PIM KM FCM FKM FKM-C FKM FKM-C SKM WSM-C WSM-C WSM-C WSM-C WSM WSM-C	$\begin{array}{c} 113\\ 401\\ 365\\ 291\\ 306\\ 332\\ 276\\ 297\\ 295\\ 262\\ 237\\ 262\\ 237\\ 262\\ 237\\ 259\\ 249\\ \textbf{232}\\ \hline \\ 237\\ 259\\ 249\\ \textbf{232}\\ \hline \\ 187\\ 173\\ 235\\ 198\\ 169\\ \hline \end{array}$	1 - - - - - - - - - - - - - - - - - - -	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128 169 208 111 107 136 120 110	Parr Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ \mathbf{ots} \\ 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ \mathbf{h} \\ \hline \\ 107 \\ 124 \\ 69 \\ 57 \\ 81 \\ 74 \\ 79 \\ \end{array}$		23 99 90 59 47 73 60 69 51 46 43 68 77 44 42 53 49 60		97 333 333 264 249 268 272 266 232 220 231 220 233 232 219 1366 112 68 104 166 91 153	2 - - - - - - - - - - - - - - - - - - -	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131 64 59 31 44 91 54 61	Pepp - - - - - - - - - - - - -	34 pers 147 142 101 83 113 100 120 119 87 80 86 81 87 86 81 87 80 palls 38 45 17 18 42 37 25		$\begin{array}{c} 22\\ 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 54\\ 55\\ 51\\ 55\\ 53\\ {\color{black}{55}}\\ 55\\ 53\\ {\color{black}{50}}\\ 27\\ 38\\ 11\\ 9\\ 20\\ 20\\ 14\\ \end{array}$	0 - - - - - - - - - - - - - - - - - - -
MC WAN WU NEU MMM SAM FCM PIM KM FKM-C FKM FKM-C SKM WSM-C FKM FKM FKM FKM FKM FKM FKM FKM FKM FKM	$\begin{array}{c} 113\\ 401\\ 365\\ 291\\ 306\\ 332\\ 276\\ 297\\ 295\\ 262\\ 237\\ 262\\ 237\\ 262\\ 237\\ 259\\ 249\\ 232\\ \hline \\ 232\\ \hline \\ 276\\ 311\\ 187\\ 173\\ 235\\ 198\\ 169\\ 168\\ \hline \end{array}$	1 - - - - - - - - - - - - - - - - - - -	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128 169 208 111 107 136 120 110 111	Parr Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{r} 37 \\ \mathbf{ots} \\ 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ \mathbf{h} \\ \hline 107 \\ 124 \\ 69 \\ 57 \\ 81 \\ 74 \\ 79 \\ 79 \\ 70 \end{array}$		23 99 90 59 47 73 60 69 51 46 51 46 51 46 51 46 43 68 77 44 42 53 49 60		97 333 333 364 249 268 272 266 232 220 231 220 233 232 219 136 112 68 104 166 91 153 140	$\frac{2}{2}$	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131 64 59 31 44 91 54 61 57	Pepp - - - - - - - - - - - - -	34 bers 147 142 101 83 113 100 120 119 87 80 86 81 87 80 38 45 17 18 42 37 25 25		22 98 93 63 55 76 64 84 84 51 55 51 55 53 50 27 38 11 9 20 14	$ \begin{array}{c} 0 \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ -$
MC WAN WU NEU MMM SAM FCM PIM KM-C FKM-C FKM-C SKM WSM-C FKM FCM FKM FKM FKM FKM FKM FKM FKM FKM FKM FK	$\begin{array}{c} 401\\ 365\\ 291\\ 306\\ 332\\ 276\\ 297\\ 295\\ 262\\ 237\\ 264\\ 237\\ 259\\ 249\\ 232\\ \hline \\ 232\\ \hline \\ 232\\ 169\\ 169\\ 169\\ 169\\ 164\\ 174\\ \hline \end{array}$	1 - - - - - - - - - - - - - - - - - - -	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128 169 208 111 107 136 120 110 111	Parr Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{r} 37 \\ \mathbf{ots} \\ 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ \mathbf{h} \\ \hline 107 \\ 124 \\ 69 \\ 57 \\ 81 \\ 74 \\ 79 \\ 79 \\ 79 \\ 64 \\ \end{array}$		99 90 59 47 73 60 69 51 46 51 47 51 46 51 47 53 43 43	- - - - 2 2 2 2 1 2 1 2 1 2 1 2 1 2 1 2	97 333 333 264 249 268 272 266 232 220 231 220 233 232 219 136 112 68 104 166 91 153 149	2 - - - - - - - - - - - - - - - - - - -	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131 64 59 31 44 91 54 61 57	1 Pepp - - - - - 7 7 4 1 4 2 4 3 1 Poolt - - - - - - - - - - - - 7 7 7 4 1 4 2 4 3 1 Poolt - - - - - - - - - - - - - - - - - - -	34 pers 147 142 101 83 113 100 120 119 87 80 86 81 87 85 80 palls 38 45 17 18 42 37 25 25 25 25	0 - - - - - - - - - - - - - - - - - - -	22 98 93 63 55 76 64 84 54 51 55 51 55 53 50 27 38 11 9 20 14 32	$ \begin{array}{c} 0 \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ -$
MC WAN WU NEU MMM SAM FCM PIM KM FKM-C FKM FKM-C SKM WSM-C WSM-C WSM-C WSM-C WSM-C WAN WU NEU MMM SAM FCM PIM KM	$\begin{array}{c} 401\\ 365\\ 291\\ 306\\ 332\\ 276\\ 297\\ 295\\ 262\\ 237\\ 264\\ 237\\ 259\\ 249\\ \textbf{232}\\ \hline \\ \textbf{236}\\ 111\\ 187\\ 173\\ 235\\ 198\\ 169\\ 168\\ 174\\ \end{array}$	1 - - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 258\\ 225\\ 171\\ 153\\ 200\\ 160\\ 178\\ 175\\ 149\\ 131\\ 150\\ 132\\ 152\\ 136\\ 128\\ \end{array}$	Parr Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ \hline \text{ots} \\ \hline 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ \mathbf{h} \\ \hline \\ \hline \\ 107 \\ 124 \\ 69 \\ 57 \\ 81 \\ 74 \\ 79 \\ 79 \\ 64 \\ \hline \end{array}$	$\begin{array}{c} & & \\$	$\begin{array}{c} 23 \\ 99 \\ 99 \\ 90 \\ 59 \\ 47 \\ 73 \\ 60 \\ 69 \\ 69 \\ 51 \\ 46 \\ 51 \\ 46 \\ 51 \\ 46 \\ 51 \\ 46 \\ 43 \\ 68 \\ 77 \\ 44 \\ 42 \\ 53 \\ 49 \\ 60 \\ 60 \\ 60 \\ 40 \\ 40 \\ \end{array}$		97 333 333 264 249 292 268 272 266 232 220 231 220 233 232 219 136 112 68 104 166 91 153 149 226	$\frac{2}{2}$	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131 64 59 31 44 91 54 61 57 129	1 Pepp - - - - 7 7 4 1 4 2 4 3 1 Poolh - - - - - - - - - - - - - - 7 7 4 1 4 2 4 3 1 - - - - - - - - - - - - - - - - - -	34 pers 147 142 101 83 113 100 120 119 87 80 86 81 87 85 80 balls 38 45 17 18 42 37 25 25 75		$\begin{array}{c} 22\\ \hline 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 51\\ 55\\ 51\\ 55\\ 53\\ 50\\ \hline 27\\ 38\\ 11\\ 9\\ 20\\ 20\\ 14\\ 14\\ 39\\ 20\\ 20\\ 14\\ 14\\ 39\\ 55\\ 53\\ 50\\ \hline 27\\ 38\\ 11\\ 9\\ 20\\ 20\\ 14\\ 14\\ 39\\ 55\\ 51\\ 51\\ 53\\ 50\\ \hline 27\\ 53\\ 50\\ 50\\ 50\\ 50\\ 50\\ 50\\ 50\\ 50\\ 50\\ 50$	$\begin{array}{c} 0 \\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$
MC WAN WU NEU MMM SAM FCM PIM KM-C FKM FKM-C SKM WSM-C WSM-C WAN WU NEU MMM SAM FCM PIM KM KM-C	$\begin{array}{c} 401\\ 365\\ 291\\ 306\\ 332\\ 276\\ 297\\ 295\\ 262\\ 237\\ 264\\ 237\\ 259\\ 249\\ \textbf{232}\\ \hline \\ \textbf{232}\\ \hline \\ \textbf{235}\\ 111\\ 187\\ 173\\ 235\\ 198\\ 169\\ 168\\ 174\\ 145\\ \end{array}$	1 - - - - - - - - - - - - - - - - - - -	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128 169 208 111 107 136 120 110 111 105 90	Parr Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ 0 \\ \mathbf$	$\begin{array}{c} & & \\$	$\begin{array}{c} 23\\ 99\\ 90\\ 59\\ 47\\ 73\\ 60\\ 69\\ 69\\ 51\\ 46\\ 51\\ 46\\ 51\\ 47\\ 51\\ 46\\ 43\\ \hline \\ 43\\ 42\\ 53\\ 44\\ 42\\ 53\\ 49\\ 60\\ 60\\ 40\\ 37\\ \hline \end{array}$		97 333 333 264 249 292 268 272 266 232 220 231 220 233 232 219 136 112 68 104 166 91 153 149 226 94	2 - - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 213\\ 215\\ 160\\ 151\\ 182\\ 161\\ 179\\ 176\\ 141\\ 132\\ 142\\ 132\\ 142\\ 139\\ \textbf{131}\\ \hline \\ \textbf{64}\\ 59\\ \textbf{31}\\ 44\\ 91\\ 54\\ 61\\ 57\\ 129\\ 51\\ \end{array}$	1 Pepp - - - - 7 7 4 1 4 2 4 3 1 Pooll - - - - - - 30 26 31 5	34 bers 147 142 101 83 113 100 120 119 87 80 86 81 87 80 balls 38 45 17 18 42 37 25 25 75 44		$\begin{array}{c} 22\\ 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 54\\ 51\\ 55\\ 51\\ 55\\ 53\\ \textbf{50}\\ \hline \end{array}$	$\begin{array}{c} 0 \\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$
MC WAN WU NEU MMM SAM FCM PIM KM FKM-C FKM FKM-C SKM WSM-C WAN WU NEU MMM SAM FCM PIM FCM PIM KM KM-C FKM	$\begin{array}{c} 113\\ 401\\ 365\\ 291\\ 306\\ 332\\ 276\\ 297\\ 295\\ 262\\ 237\\ 262\\ 237\\ 264\\ 237\\ 259\\ 249\\ 232\\ \hline \\ 232\\ 232\\ \hline \\ 276\\ 311\\ 187\\ 173\\ 235\\ 198\\ 168\\ 174\\ 145\\ 173\\ \end{array}$	$ \begin{array}{c} 1 \\ - \\ - \\ - \\ - \\ - \\ - \\ 19 \\ 21 \\ 20 \\ 7 \\ 21 \\ 7 \\ 16 \\ 13 \\ 6 \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ 11 \\ 9 \\ 24 \\ 3 \\ 17 \\ \end{array} $	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128 169 208 111 107 136 120 110 111 105 90 105	Parr Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ \mathbf{ots} \\ 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ 74 \\ 69 \\ 57 \\ 81 \\ 74 \\ 79 \\ 79 \\ 64 \\ 58 \\ 65 \\ \end{array}$	$\begin{array}{c} & & \\$	$\begin{array}{c} 23\\ 99\\ 99\\ 90\\ 55\\ 47\\ 73\\ 60\\ 69\\ 69\\ 51\\ 46\\ 51\\ 47\\ 51\\ 46\\ 43\\ 68\\ 77\\ 44\\ 42\\ 53\\ 49\\ 60\\ 60\\ 40\\ 37\\ 40\\ \end{array}$		97 333 333 264 249 268 272 266 232 220 231 220 231 220 231 220 231 202 231 202 231 202 231 202 219 136 112 68 104 166 91 153 149 226 94 229	$\frac{2}{2}$ $ -$	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131 64 59 31 44 91 54 61 57 129 51 130	Pepp - - - - - - - - - 7 4 1 4 2 4 3 1 Pooll - - - - - - - - - - - - -	34 bers 147 142 101 83 113 100 120 119 87 80 86 81 87 85 80 balls 38 45 17 18 42 37 25 75 44 78		$\begin{array}{c} 22\\ 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 51\\ 55\\ 51\\ 55\\ 53\\ 50\\ \hline \\ 27\\ 38\\ 11\\ 9\\ 20\\ 14\\ 14\\ 39\\ 29\\ 37\\ \hline \end{array}$	$\begin{array}{c} 0 \\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$
MC WAN WU NEU MMM SAM FCM PIM KM FKM-C FKM-C SKM WSM-C WSM-C WSM-C WSM-C WSM-C WSM-C WSM-C FKM FCM PIM KM KM-C FKM FKM-C	$\begin{array}{c} 113\\ \hline \\ 401\\ 365\\ 291\\ 306\\ 332\\ 276\\ 297\\ 295\\ 262\\ 237\\ 264\\ 237\\ 259\\ 249\\ 232\\ \hline \\ 237\\ 249\\ 232\\ \hline \\ 276\\ 311\\ 187\\ 173\\ 235\\ 198\\ 169\\ 168\\ 174\\ 145\\ 173\\ 144\\ \hline \end{array}$	$ \begin{array}{c} 1 \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ -$	$\begin{array}{c} 258\\ 225\\ 171\\ 153\\ 200\\ 160\\ 178\\ 175\\ 149\\ 131\\ 150\\ 132\\ 152\\ 136\\ 128\\ \hline 169\\ 208\\ 111\\ 107\\ 136\\ 120\\ 110\\ 111\\ 105\\ 90\\ 105\\ 90\\ \hline 90\\ \end{array}$	Parr Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{r} 37 \\ \mathbf{ots} \\ \hline 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ 74 \\ 79 \\ 79 \\ 64 \\ 58 \\ 65 \\ 59 \end{array}$	$\begin{array}{c} 0 \\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	23 99 90 59 47 73 60 69 51 46 51 47 51 46 51 47 51 46 51 43 43 68 77 44 42 53 49 60 60 40 37 40 38		97 333 333 264 249 268 272 266 232 220 231 220 231 220 231 220 231 220 231 220 231 220 231 220 231 220 231 220 231 220 232 219 5	2 - - - - - - - -	$\begin{array}{c} 213\\ 215\\ 160\\ 151\\ 182\\ 161\\ 179\\ 176\\ 141\\ 132\\ 142\\ 132\\ 142\\ 132\\ 142\\ 139\\ 131\\ \hline \\ 131\\ 142\\ 139\\ 131\\ 142\\ 139\\ 131\\ 131\\ 157\\ 129\\ 51\\ 130\\ 55\\ \end{array}$	Pepp - - - - - - - - - 7 7 4 1 4 2 4 3 1 Poolt - - - - - - - - - - - - -	34 bers 147 142 101 83 113 100 120 119 87 80 86 81 87 85 80 balls 38 45 17 18 42 37 25 75 44 78 45		$\begin{array}{c} 22\\ 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 51\\ 55\\ 51\\ 55\\ 53\\ \textbf{50}\\ \hline \\ 27\\ 38\\ 11\\ 9\\ 20\\ 20\\ 14\\ 14\\ 39\\ 29\\ 37\\ 27\\ \end{array}$	$\begin{array}{c} 0 \\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$
MC WAN WU NEU MMM SAM FCM PIM KM FKM-C FKM FKM-C SKM WSM-C WAN WU NEU MMM SAM FCM PIM KM KM-C FKM FCM FKM-C FKM-C SKM	$\begin{array}{c} 113\\ 401\\ 365\\ 291\\ 306\\ 332\\ 276\\ 297\\ 295\\ 262\\ 237\\ 264\\ 237\\ 259\\ 249\\ \textbf{232}\\ \textbf{232}\\ \textbf{232}\\ \textbf{232}\\ \textbf{235}\\ 187\\ 173\\ 235\\ 198\\ 169\\ 168\\ 174\\ 145\\ 173\\ 144\\ 177\\ \textbf{177}\\ 177$	1 - - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 258\\ 225\\ 171\\ 153\\ 200\\ 160\\ 178\\ 175\\ 149\\ 131\\ 150\\ 132\\ 152\\ 136\\ 128\\ 169\\ 208\\ 111\\ 107\\ 136\\ 120\\ 110\\ 111\\ 105\\ 90\\ 105\\ 90\\ 105\\ \end{array}$	Parr Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ \mathbf{ots} \\ 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ \mathbf{h} \\ \hline \\ 107 \\ 124 \\ 69 \\ 57 \\ 81 \\ 74 \\ 79 \\ 79 \\ 64 \\ 58 \\ 65 \\ 59 \\ 65 \\ \end{array}$	$\begin{array}{c} 0 \\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	$\begin{array}{c} \textbf{23} \\ \textbf{99} \\ \textbf{99} \\ \textbf{90} \\ \textbf{59} \\ \textbf{47} \\ \textbf{73} \\ \textbf{60} \\ \textbf{69} \\ \textbf{69} \\ \textbf{51} \\ \textbf{46} \\ \textbf{51} \\ \textbf{46} \\ \textbf{51} \\ \textbf{47} \\ \textbf{51} \\ \textbf{46} \\ \textbf{43} \\ \textbf{42} \\ \textbf{53} \\ \textbf{49} \\ \textbf{60} \\ \textbf{60} \\ \textbf{40} \\ \textbf{37} \\ \textbf{40} \\ \textbf{38} \\ \textbf{40} \end{array}$		97 333 333 264 249 292 268 272 266 232 220 231 220 233 232 219 136 112 68 104 166 91 153 149 226 94 229 95 167	2 - - - - - - - -	$\begin{array}{c} 213\\ 215\\ 160\\ 151\\ 182\\ 161\\ 179\\ 176\\ 141\\ 132\\ 142\\ 132\\ 142\\ 132\\ 142\\ 139\\ \textbf{131}\\ \textbf{1}\\ \textbf{31}\\ \textbf{1}\\ \textbf{51}\\ \textbf{64}\\ 59\\ 31\\ 44\\ 91\\ 54\\ 61\\ 57\\ 129\\ 51\\ 130\\ 55\\ 120\\ \end{array}$	1 Pepr - - - - 7 7 4 1 4 2 4 3 1 Pooll - - - - - - - - - - - - - - - 7 7 4 1 4 2 4 3 1 - - - - - - - - - - - - - - - - - -	34 pers 147 142 101 83 113 100 120 119 87 80 86 81 87 85 80 palls 38 45 17 18 42 37 25 25 75 44 78 45 71		$\begin{array}{c} 22\\ 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 51\\ 55\\ 51\\ 55\\ 53\\ 50\\ \hline \\ 27\\ 38\\ 11\\ 9\\ 20\\ 20\\ 14\\ 14\\ 39\\ 29\\ 37\\ 27\\ 37\\ \hline \end{array}$	$\begin{array}{c} 0 \\ \hline \\ 0 \\ \hline \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ -$
MC WAN WU NEU MMM SAM FCM PIM KM FKM-C FKM FKM-C SKM WSM-C WAN WU NEU MMM SAM FCM PIM KM FCM PIM KM FCM FKM-C FKM FKM-C FKM	$\begin{array}{c} 113\\ 401\\ 365\\ 291\\ 306\\ 332\\ 276\\ 297\\ 295\\ 262\\ 237\\ 264\\ 237\\ 259\\ 249\\ \textbf{232}\\ \textbf{232}\\ \textbf{232}\\ \textbf{235}\\ 187\\ 173\\ 235\\ 198\\ 169\\ 168\\ 174\\ 145\\ 173\\ 144\\ 177\\ 148\\ \textbf{145}\\ 174\\ 148\\ \textbf{145}\\ 173\\ 144\\ \textbf{177}\\ 148\\ \textbf{148}\\ \textbf{145}\\ \textbf{174}\\ \textbf{148}\\ \textbf{148}\\$	$ \begin{array}{c} 1 \\ - \\ $	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128 169 208 111 107 136 120 110 111 105 90 105 90 105	Parr Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ \mathbf{ots} \\ 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ \mathbf{h} \\ \hline \\ 107 \\ 124 \\ 69 \\ 57 \\ 81 \\ 74 \\ 79 \\ 79 \\ 64 \\ 58 \\ 65 \\ 59 \\ 65$	$\begin{array}{c} & & \\$	$\begin{array}{c} 23\\ 99\\ 90\\ 59\\ 47\\ 73\\ 60\\ 69\\ 69\\ 51\\ 46\\ 51\\ 47\\ 51\\ 46\\ 51\\ 47\\ 51\\ 46\\ 43\\ 40\\ 37\\ 44\\ 42\\ 53\\ 49\\ 60\\ 60\\ 40\\ 37\\ 40\\ 38\\ 40\\ 38\\ 40\\ 37\\ 22\\ 32\\ 32\\ 32\\ 32\\ 32\\ 32\\ 32\\ 32\\ 32$		97 333 333 249 292 268 272 266 232 220 231 220 233 232 219 136 112 68 104 166 91 153 149 226 94 229 95 167 60	2 - - - - - - - -	$\begin{array}{c} 213\\ 215\\ 160\\ 151\\ 182\\ 161\\ 179\\ 176\\ 141\\ 132\\ 142\\ 132\\ 142\\ 139\\ 131\\ \hline \\ 64\\ 59\\ 31\\ 44\\ 91\\ 54\\ 61\\ 57\\ 129\\ 51\\ 130\\ 55\\ 120\\ 51\\ 130\\ 55\\ 120\\ 21\\ \hline \end{array}$	1 Pepp - - - - - 7 7 4 1 4 2 4 3 1 - - - - - - - - - - - - - - - - - -	34 pers 147 142 101 83 113 100 120 119 87 80 86 81 87 80 aalls 38 45 17 18 42 37 25 75 44 78 45 11 14		$\begin{array}{c} 22\\ \hline 98\\ 93\\ 63\\ 55\\ 76\\ 64\\ 84\\ 84\\ 51\\ 55\\ 51\\ 55\\ 53\\ \textbf{50}\\ \hline 27\\ 38\\ 11\\ 9\\ 20\\ 20\\ 14\\ 14\\ 39\\ 29\\ 37\\ 27\\ 37\\ 7\\ \hline 37\\ 7\\ \hline \end{array}$	$\begin{array}{c} 0 \\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$
MC WAN WU NEU MMM SAM FCM PIM KM FKM-C FKM FKM-C SKM WSM-C WAN WU NEU MMM SAM FCM PIM KM KM-C FKM FKM-C SKM FKM-C SKM	$\begin{array}{c} 113\\ 401\\ 365\\ 291\\ 306\\ 332\\ 276\\ 297\\ 295\\ 262\\ 237\\ 262\\ 237\\ 262\\ 237\\ 259\\ 249\\ 232\\ \hline \\ 237\\ 259\\ 249\\ 232\\ \hline \\ 235\\ 198\\ 169\\ 168\\ 174\\ 145\\ 173\\ 144\\ 177\\ 148\\ 145\\ 173\\ 144\\ 177\\ 148\\ 177\\ 188\\ 178\\ 178\\ 178\\ 178\\ 178\\ 17$	$ \begin{array}{c} 1 \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ -$	258 225 171 153 200 160 178 175 149 131 150 132 152 136 128 169 208 111 107 136 128 110 110 110 110 105 90 105 90 105 91	Parr Parr - - - - - - - - - - - - - - - - - -	$\begin{array}{c} 37 \\ \mathbf{ots} \\ 144 \\ 146 \\ 96 \\ 84 \\ 117 \\ 94 \\ 107 \\ 107 \\ 85 \\ 76 \\ 87 \\ 77 \\ 86 \\ 79 \\ 74 \\ 69 \\ 74 \\ 69 \\ 57 \\ 81 \\ 74 \\ 79 \\ 79 \\ 64 \\ 58 \\ 65 \\ 59 \\ 65 \\ 55 \\ 59 \\ 65 \\ 55 \\ 57 \\ 65 \\ 57 \\ 57 \\ 65 \\ 57 \\ 57 \\ 65 \\ 57 \\ 57 \\ 65 \\ 57 \\ 57 \\ 65 \\ 57 \\ \mathbf$	$\begin{array}{c} 0 \\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	23 99 90 59 47 73 60 69 51 46 51 47 73 60 69 51 46 43 49 60 60 40 37 40 38 40 33		97 333 333 364 249 292 268 272 266 232 220 231 220 231 220 233 232 219 136 112 68 104 166 91 153 149 226 94 229 95 167 69 220	2 $ -$	213 215 160 151 182 161 179 176 141 132 142 132 142 139 131 64 59 31 44 91 54 61 57 129 51 130 55 120 31	Pepp - - - - - - - - - - - - -	34 bers 147 142 101 83 113 100 120 119 87 80 81 87 80 81 87 80 balls 38 45 17 18 42 37 25 75 44 78 45 71 142		22 98 93 63 55 76 64 84 54 55 51 55 53 50 27 38 11 9 20 20 20 20 20 14 39 27 37 7	$\begin{array}{c} 0 \\ \hline \\ 0 \\ \hline \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ -$

Table 1.	MSE	Comparison	of the	Quantization	Methods
Table 1.		Comparison	or the	quantization	Methous

Method	K = 32	K = 64	K = 128	K = 256	K = 32	K = 64	K = 128	K = 256
		Air	plane		Baboon			
MC	10	10	11	12	10	10	11	13
WAN	13	14	15	18	14	15	16	20
WU	16	16	16	16	16	15	16	17
NEU	70	142	265	514	67	134	254	485
MMM	123	206	367	696	126	207	375	702
SAM	7	8	13	25	9	20	56	112
FCM	2739	5285	10612	21079	2737	5285	10612	21081
PIM	2410	5038	10402	20913	2488	5091	10407	20846
$\mathbf{K}\mathbf{M}$	584	1005	1791	3314	592	1012	1800	3317
KM-C	17688	43850	74814	71908	3136	7070	13164	25657
$\mathbf{F}\mathbf{K}\mathbf{M}$	189	222	299	505	189	223	299	508
FKM-C	4111	6144	6057	5376	746	934	1171	1959
SKM	530	903	1593	2952	547	927	1610	2961
WSM	68	92	145	301	147	188	270	477
WSM-C	257	359	522	1180	401	565	814	1580
		В	oats			Le	enna	
MC	19	18	19	21	9	8	10	10
WAN	24	24	26	29	12	15	15	17
WU	28	26	28	28	15	15	14	15
NEU	122	232	453	853	61	123	244	465
MMM	219	367	656	1237	116	193	346	654
SAM	17	19	21	32	8	7	9	13
FCM	4695	9141	18350	36471	2545	4954	9953	19770
PIM	4075	8555	17784	36071	2348	4820	9832	19681
$\mathbf{K}\mathbf{M}$	986	1727	3087	5729	536	939	1673	3101
KM-C	9853	22622	53858	111047	3457	6698	11927	23762
FKM	326	385	509	804	170	205	281	478
FKM-C	2393	3158	4007	6056	788	878	1167	1886
SKM	908	1551	2756	5105	485	837	1493	2778
WSM	136	174	255	464	52	68	110	244
WSM-C	486	614	853	1647	149	212	329	883
		Pa	rrots			Per	opers	
MC	57	58	59	61	10	10	11	12
WAN	81	82	83	86	13	14	16	18
WU	86	87	86	87	16	17	17	17
NEU	476	849	1571	2914	70	135	262	493
MMM	758	1265	2282	4286	125	206	371	700
SAM	74	77	103	150	8	11	29	53
FCM	16096	31734	63871	126554	2739	5288	10624	21107
PIM	14620	30159	61891	124794	2499	5107	10425	20883
KM	3309	5918	10657	19828	564	996	1785	3309
KM-C	23949	61168	119907	242439	3387	7761	14839	31893
FKM	1100	1302	1698	2510	1000	1101	11000	01000
FKM-C	1100	1004		7.01.9	181	219	295	500
SKM	5464	8557	9529	10482	181 869	$\begin{array}{c} 219 \\ 1017 \end{array}$	$295 \\ 1262$	$500 \\ 2233$
DILIVI	$5464 \\ 3072$	$8557 \\ 5429$	9529 9506	10482 17599	$ 181 \\ 869 \\ 523 $	$219 \\ 1017 \\ 905$	$295 \\ 1262 \\ 1605$	$500 \\ 2233 \\ 2971$
WSM	$5464 \\ 3072 \\ 250$	$8557 \\ 5429 \\ 298$	9529 9506 399	$ \begin{array}{r} 2319 \\ 10482 \\ 17599 \\ 639 \\ 639 \end{array} $	$ 181 \\ 869 \\ 523 \\ 107 $	$219 \\ 1017 \\ 905 \\ 138$	$295 \\ 1262 \\ 1605 \\ 201$	500 2233 2971 373
WSM WSM-C	$5464 \\ 3072 \\ 250 \\ 634$	$8557 \\ 5429 \\ 298 \\ 820$	9529 9506 399 1261	$ \begin{array}{r} 2319 \\ 10482 \\ 17599 \\ 639 \\ 2149 \end{array} $	$ 181 \\ 869 \\ 523 \\ 107 \\ 327 $	$219 \\1017 \\905 \\138 \\466$	$295 \\ 1262 \\ 1605 \\ 201 \\ 648$	500 2233 2971 373 1387
WSM WSM-C	$5464 \\ 3072 \\ 250 \\ 634$	8557 5429 298 820	9529 9506 399 1261	$ \begin{array}{r} 2319 \\ 10482 \\ 17599 \\ 639 \\ 2149 \\ \end{array} $	181 869 523 107 327	219 1017 905 138 466	295 1262 1605 201 648	500 2233 2971 373 1387
WSM WSM-C	5464 3072 250 634	8557 5429 298 820 F	9529 9506 399 1261 Tish	2319 10482 17599 639 2149	181 869 523 107 327	219 1017 905 138 466 Poo	295 1262 1605 201 648 olballs	500 2233 2971 373 1387
WSM WSM-C MC WAN	$ \begin{array}{r} 5464 \\ 3072 \\ 250 \\ 634 \\ \hline 6 \\ 5 \end{array} $	8557 5429 298 820 F 5 6	9529 9506 399 1261 Vish 7 8	2319 10482 17599 639 2149 6 12	181 869 523 107 327 9 10	219 1017 905 138 466 Poo 9 10	295 1262 1605 201 648 olballs 9 12	500 2233 2971 373 1387 11 14
WSM WSM-C MC WAN WIT	5464 3072 250 634 6 5 8	8557 5429 298 820 F 5 6 9	9529 9506 399 1261 ⁷ ish 7 8 8	2319 10482 17599 639 2149 6 12 9	181 869 523 107 327 9 10 12	219 1017 905 138 466 Poo 9 10 13	295 1262 1605 201 648 olballs 9 12 12	500 2233 2971 373 1387 11 14 13
WSM WSM-C MC WAN WU NEU	$ \begin{array}{r} 5464 \\ 3072 \\ 250 \\ 634 \\ \hline 6 \\ 5 \\ 8 \\ 12 \\ \end{array} $	8557 5429 298 820 F 5 6 9 27	9529 9506 399 1261 Vish 7 8 8 8	2319 10482 17599 639 2149 6 12 9 110	181 869 523 107 327 9 10 12 51	219 1017 905 138 466 Poc 9 10 13 103	295 1262 1605 201 648 olballs 9 12 12 12	500 2233 2971 373 1387 11 14 13 253
WSM WSM-C MC WAN WU NEU MMM	$ \begin{array}{r} 5464 \\ 3072 \\ 250 \\ 634 \\ \hline 6 \\ 5 \\ 8 \\ 12 \\ 23 \\ \end{array} $	8557 5429 298 820 F 5 6 9 277 34	9529 9506 399 1261 Vish 7 8 8 8 58 50	2319 10482 17599 639 2149 6 12 9 110 112	181 869 523 107 327 9 10 12 51 87	219 1017 905 138 466 9 10 13 103 145	295 1262 1605 201 648 olballs 9 12 12 12 192 263	500 2233 2971 373 1387 11 14 13 353 408
WSM WSM-C MC WAN WU NEU MMM SAM	5464 3072 250 634 6 5 8 12 23 4	8557 5429 298 820 F 5 6 9 27 34 6	9509 9506 399 1261 Čish 7 8 8 8 58 59 9 9	2319 10482 17599 639 2149 6 12 9 110 112 17	181 869 523 107 327 9 10 12 51 87 9	219 1017 905 138 466 9 10 13 103 145 10	295 1262 1605 201 648 olballs 9 12 12 12 192 263 16	500 2233 2971 373 1387 11 14 13 353 498 23
WSM WSM-C MC WAN WU NEU MMM SAM FCM	$ \begin{array}{r} 5464\\ 3072\\ 250\\ 634\\ \hline \\ \hline 6\\ 5\\ 8\\ 12\\ 23\\ 4\\ 610\\ \end{array} $	8557 5429 298 820 F 5 6 9 27 34 6 1209	9529 9506 399 1261 Vish 7 8 8 8 58 59 9 2428	2319 10482 17599 639 2149 6 12 9 110 112 17 4832	181 869 523 107 327 9 10 12 51 87 9 1900	219 1017 905 138 466 9 10 13 103 145 10 3940	295 1262 1605 201 648 olballs 9 12 12 12 192 263 16 7913	500 2233 2971 373 1387 11 14 13 353 498 23 15719
WSM WSM-C MC WAN WU NEU MMM SAM FCM PIM	$ \begin{array}{r} 5464\\3072\\250\\634\\\hline \\ \hline \\ 6\\5\\8\\12\\23\\4\\610\\560\\\end{array} $	8557 5429 298 820 F 5 6 9 27 34 6 1209 1171	9529 9506 399 1261 Vish 7 8 8 8 58 59 9 2428 2401	2319 10482 17599 639 2149 6 12 9 110 112 17 4832 4806	181 869 523 107 327 9 10 12 51 87 9 1999 1586	219 1017 905 138 466 9 10 13 103 145 10 3940 3406	295 1262 1605 201 648 olballs 9 12 12 12 192 263 16 7913 6817	500 2233 2971 373 1387 11 14 13 353 498 23 15719 13257
WSM WSM-C MC WAN WU NEU MMM SAM FCM PIM KM	$ \begin{array}{r} 5464\\ 3072\\ 250\\ 634\\ \hline 6\\ 5\\ 8\\ 12\\ 23\\ 4\\ 610\\ 560\\ 122\\ \end{array} $	8557 5429 298 820 F 5 6 9 27 34 6 1209 1171 220	9529 9506 399 1261 Vish 7 8 8 8 58 59 9 2428 2401 404	2319 10482 17599 639 2149 6 12 9 110 112 17 4832 4806 757	181 869 523 107 327 9 10 12 51 87 9 1999 1586 306	219 1017 905 138 466 9 10 13 103 145 10 3940 3406 702	295 1262 1605 201 648 olballs 9 12 12 12 192 263 16 7913 6817 1281	500 2233 2971 373 1387 11 14 13 353 498 23 15719 13257 2400
WSM WSM-C MC WAN WU NEU MMM SAM FCM PIM KM KM	54643072250634	8557 5429 298 820 F 5 6 9 27 34 6 1209 1171 229 2777	9529 9506 399 1261 Vish 7 8 8 8 58 59 9 2428 2401 404 4395	2319 10482 17599 639 2149 6 12 9 110 112 17 4832 4806 757 5223	181 869 523 107 327 9 10 12 51 87 9 1999 1586 396 3320	219 1017 905 138 466 9 10 13 103 145 10 3940 3406 703 13204	295 1262 1605 201 648 olballs 9 12 192 263 16 7913 6817 1281 14012	$500 \\ 2233 \\ 2971 \\ 373 \\ 1387 \\ 11 \\ 14 \\ 13 \\ 353 \\ 498 \\ 23 \\ 15719 \\ 13257 \\ 2400 \\ 22627 \\ $
WSM WSM-C MC WAN WU NEU MMM SAM FCM PIM KM KM-C FKM	54643072250634	8557 5429 298 820 F 5 6 9 27 34 6 1209 1171 229 2777 40	$\begin{array}{r} 1000\\ 9529\\ 9506\\ 399\\ 1261\\ \hline \\ \hline \\ \hline \\ \hline \\ \hline \\ \\ \hline \\ \\ \hline \\ \\ \hline \\$	2319 10482 17599 639 2149 6 12 9 110 112 17 4832 4806 757 5233 187	181 869 523 107 327 9 10 12 51 87 9 1999 1586 396 3339 122	219 1017 905 138 466 9 10 13 103 145 10 3940 3406 703 13294 158	295 1262 1605 201 648 blballs 9 12 12 12 192 263 16 7913 6817 1281 14912 212	$500 \\ 2233 \\ 2971 \\ 373 \\ 1387 \\ 11 \\ 14 \\ 13 \\ 353 \\ 498 \\ 23 \\ 15719 \\ 13257 \\ 2400 \\ 22637 \\ 360 \\ 1571 \\ 360 \\ 260 \\ 100$
WSM WSM-C MC WAN WU NEU MMM SAM FCM FCM PIM KM KM-C FKM	5464 3072 250 634 6 5 8 12 23 4 610 560 128 1147 39 267	8557 5429 298 820 F 5 6 9 27 34 6 1209 1171 229 2777 49 246	9529 9506 399 1261 Vish 7 8 8 8 58 59 9 2428 2401 404 4395 78 420	2319 10482 17599 639 2149 6 12 9 110 112 17 4832 4806 757 5233 187 802	181 869 523 107 327 9 10 12 51 87 9 1999 1586 396 3339 133 012	219 1017 905 138 466 9 10 13 103 145 10 3940 3406 703 13294 158	295 1262 1605 201 648 blballs 9 12 12 12 192 263 16 7913 6817 1281 14912 213 1285	$500 \\ 2233 \\ 2971 \\ 373 \\ 1387 \\ 11 \\ 14 \\ 13 \\ 353 \\ 498 \\ 23 \\ 15719 \\ 13257 \\ 2400 \\ 22637 \\ 369 \\ 2026 \\ 202$
WSM WSM-C MC WAN WU NEU MMM SAM FCM FCM FIM KM-C FKM FKM-C SKM	54643072250634	8557 5429 298 820 F 5 6 9 27 34 6 1209 1171 229 2777 49 346 207	9529 9506 399 1261 Vish 7 8 8 8 58 59 9 2428 2401 404 4395 78 420 261	2319 10482 17599 639 2149 6 12 9 110 112 17 4832 4806 757 5233 187 893 672	181 869 523 107 327 9 10 12 51 87 9 1999 1586 336 3339 133 913 280	$\begin{array}{c} 219\\ 1017\\ 905\\ 138\\ 466\\ \hline Poc\\ \textbf{9}\\ 10\\ 13\\ 103\\ 145\\ 10\\ 3940\\ 3406\\ 703\\ 13294\\ 158\\ 1565\\ 652\\ \end{array}$	$\begin{array}{c} 295\\ 1262\\ 1605\\ 201\\ 648\\ \hline \\ \hline \\ 9\\ 12\\ 12\\ 12\\ 192\\ 263\\ 16\\ 7913\\ 6817\\ 1281\\ 14912\\ 213\\ 1285\\ 1172\\ \end{array}$	$500 \\ 2233 \\ 2971 \\ 373 \\ 1387 \\ \hline 11 \\ 14 \\ 13 \\ 353 \\ 498 \\ 23 \\ 15719 \\ 13257 \\ 2400 \\ 22637 \\ 369 \\ 2036 \\ 2174 \\ \hline $
WSM WSM-C MC WAN WU NEU MMM SAM FCM FCM FIM KM-C FKM FKM-C SKM FKM-C SKM	5464 3072 250 634 6 5 8 12 23 4 610 560 128 1147 39 267 121 25	8557 5429 298 820 F 5 6 9 27 34 6 1209 1171 229 2777 49 346 207 32	9529 9506 399 1261 Vish 7 8 8 8 58 59 9 2428 2401 404 4395 78 420 361 57	$\begin{array}{c} 2319\\ 10482\\ 17599\\ 639\\ 2149\\ \hline \\ 6\\ 12\\ 9\\ 110\\ 112\\ 17\\ 4832\\ 4806\\ 757\\ 5233\\ 187\\ 893\\ 672\\ 172\\ \end{array}$	181 869 523 107 327 9 10 12 51 87 9 1999 1586 396 3339 133 913 380 9	$\begin{array}{c} 219\\ 1017\\ 905\\ 138\\ 466\\ \hline Poc\\ \hline 9\\ 10\\ 13\\ 103\\ 145\\ 10\\ 3940\\ 3406\\ 703\\ 13294\\ 158\\ 1565\\ 653\\ 15\\ \end{array}$	$\begin{array}{r} 295\\ 1262\\ 1605\\ 201\\ 648\\ \hline \\ 9\\ 12\\ 12\\ 192\\ 263\\ 16\\ 7913\\ 6817\\ 1281\\ 14912\\ 213\\ 1285\\ 1173\\ 34\\ \end{array}$	500 2233 2971 373 1387 11 14 13 353 498 23 15719 13257 2400 22637 369 2036 2174 196
WSM WSM-C MC WAN WU NEU MMM SAM FCM PIM KM FCM PIM KM-C FKM FKM-C SKM WSM WSM	$\begin{array}{c} 5464\\ 3072\\ 250\\ 634\\ \hline \\ \\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$	8557 5429 298 820 F 5 6 9 27 34 6 1209 1171 229 2777 49 346 207 32 100	9529 9506 399 1261 Vish 7 8 8 8 58 59 9 2428 2401 404 4395 78 420 361 57 182	$\begin{array}{c} 2319\\ 10482\\ 17599\\ 639\\ 2149\\ \hline \\ 6\\ 12\\ 9\\ 110\\ 112\\ 17\\ 4832\\ 4806\\ 757\\ 5233\\ 187\\ 893\\ 672\\ 173\\ 572\\ \end{array}$	181 869 523 107 327 9 10 12 51 87 9 1999 1586 396 3339 133 913 380 9 24	$\begin{array}{c} 219\\ 1017\\ 905\\ 138\\ 466\\ \hline Poc\\ \hline 9\\ 10\\ 13\\ 103\\ 145\\ 10\\ 3940\\ 3406\\ 703\\ 13294\\ 158\\ 1565\\ 653\\ 15\\ 84\\ \end{array}$	$\begin{array}{c} 295\\ 1262\\ 1605\\ 201\\ 648\\ \hline \\ 9\\ 12\\ 12\\ 192\\ 263\\ 16\\ 7913\\ 6817\\ 1281\\ 14912\\ 213\\ 1285\\ 1173\\ 34\\ 94\\ \end{array}$	$500 \\ 2233 \\ 2971 \\ 373 \\ 1387 \\ \hline 11 \\ 14 \\ 13 \\ 353 \\ 498 \\ 23 \\ 15719 \\ 13257 \\ 2400 \\ 22637 \\ 369 \\ 2036 \\ 2174 \\ 136 \\ 356 \\ 356 \\ \hline 136 \\ 356 \\ 136 \\ 356 \\ 137 \\ 136 \\ 356 \\ 137 \\ 136 \\ 356 \\ 137 \\ 136 \\ 356 \\ 137 \\ 136 \\ 356 \\ 137 \\ 136 \\ 356 \\ 137 \\ 136 \\ 356 \\ 137 $

Table 2. CPU Time Comparison of the Quantization Methods

 Table 3. Performance Rank Comparison of the Quantization Methods

Method	MSE Rank	Time Rank	Mean Rank
MC	13.97	1.38	7.67
WAN	13.66	2.84	8.25
WU	8.47	3.31	5.89
NEU	6.31	6.00	6.16
MMM	12.31	7.63	9.97
SAM	10.09	2.53	6.31
FCM	10.31	13.94	12.13
PIM	9.81	12.94	11.38
$\mathbf{K}\mathbf{M}$	7.56	11.34	9.45
KM-C	3.03	15.00	9.02
FKM	7.91	7.75	7.83
FKM-C	3.88	11.53	7.70
SKM	8.06	10.25	9.16
WSM	3.56	5.28	4.42
WSM-C	1.06	8.25	4.66

 Table 4. Stability Rank Comparison of the Quantization Methods

Method	MSE Rank
FCM	9.36
PIM	9.56
KM	8.31
KM-C	2.84
FKM	8.10
FKM-C	3.41
SKM	7.11
WSM	3.92
WSM-C	2.02

converged. Convergence was determined by the following commonly used criterion [38]: $(SSE_{i-1}-SSE_i)/SSE_i \leq \epsilon$, where SSE_i denotes the SSE [Eq. (1)] value at the end of the *i*th iteration. Following [25,26], the convergence threshold was set to $\epsilon = 0.0001$. The *convergent* variants of KM, FKM, and WSM are denoted KM-C, FKM-C, and WSM-C, respectively. Note that since SKM involves at least I' = 10 iterations, only the convergent variant was implemented for this method. As for the fuzzy quantization methods, i.e., FCM and PIM, because of their excessive computational requirements, the number of iterations for these methods was limited to 10.

Tables 1 and 2 compare the performance of the methods at quantization levels K={32,64,128,256} on the test images. Note that, for computational simplicity, random initialization was used in the implementations of FCM, PIM, KM, KM-C, FKM, FKM-C, SKM, WSM, and WSM-C. Therefore, in Table 1, the quantization errors for these methods are specified in the form of mean (μ) and standard deviation (σ) over 100 runs. The best (lowest) error values are shown in bold. In addition, with respect to each performance criterion, the methods are ranked based on their mean values over the test images. Table 3 gives the mean ranks of the methods. The last column gives the overall mean ranks with the assumption that each criterion has equal importance. Note that the best possible rank is 1. The following observations are in order:

• In general, the postclustering methods are more effective but less efficient than the preclustering methods.

• With respect to distortion minimization, WSM-C outperforms the other methods by a large margin. This method obtains an MSE rank of 1.06, which means that it almost always obtains the lowest distortion.

• WSM obtains a significantly better MSE rank than its fixed-iteration rivals.

• Overall, WSM and WSM-C are the best methods.



Fig. 2. (Color online) Sample quantization results for the Airplane image (K=32): a, MMM output; b, MMM error; c, NEU output; d, NEU error; e, WSM output; f, WSM error; g, WSM-C output; h, WSM-C error.



Fig. 3. (Color online) Sample quantization results for the Parrots image (K=64): a, MC output; b, MC error; c, FKM output; d, FKM error; e, WSM output; f, WSM error; g, WSM-C output; h, WSM-C error.

• In general, the fastest method is MC, which is followed by SAM, WAN, and WU. The slowest methods are KM-C, FCM, PIM, FKM-C, KM, and SKM.

• WSM-C is significantly faster than its convergent rivals. In particular, it provides up to 392 times speedup over KM-C with an average of 62.

• WSM is the fastest postclustering method. It provides up to 46 times speedup over KM with an average of 14.

• KM-C, FKM-C, and WSM-C are significantly more stable (particularly when K is small) than their fixed-

iteration counterparts as evidenced by their low standard deviation values in Table 1. This was expected, since these methods were allowed to run longer, which helped them overcome potentially adverse initial conditions.

Table 4 gives the mean stability ranks of the methods that involve random initialization. Given a test image and K value combination, the stability of a method is calculated based on the coefficient of variation (σ/μ) as $100(1 - \sigma/\mu)$, where μ and σ denote the mean and the standard deviation over 100 runs, respectively. Note that the μ and σ



Fig. 4. (Color online) CPU time for WSM for $K = \{2, \dots, 256\}$.

values are given in Table 1. Clearly, the higher the stability of a method, the better. For example, when K=32, WSM-C obtains a mean MSE of 57.461492 with a standard deviation of 0.861126 on the Airplane image. Therefore, the stability of WSM-C in this case is calculated as 100(1 - 0.861126/57.461492) = 98.50%. It can be seen that WSM-C is the most stable method, whereas WSM is the most stable fixed-iteration method.

Figures 2 and 3 show sample quantization results and the corresponding error images [49]. The error image for a particular quantization method was obtained by taking the pixelwise absolute difference between the original and quantized images. In order to obtain a better visualization, pixel values of the error images were multiplied by 4 and then negated. It can be seen that WSM-C and WSM obtain visually pleasing results with less prominent contouring. Furthermore, they achieve the highest color fidelity, which is evident by the clean error images that they produce.

Figure 4 illustrates the scaling behavior of WSM with respect to K. It can be seen that the complexity of WSM is sublinear in K, which is due to the intelligent use of the triangle inequality that avoids many distance computations once the cluster centers stabilize after a few iterations. For example, on the Parrots image, increasing K from 2 to 256 results in an only about 3.67-fold increase in the computational time (172 versus 630 ms).

We should also mention two other KM-based quantization methods [24,27]. As in the case of FKM and SKM, these methods aim to accelerate KM without degrading its effectiveness. However, they do not address the stability problems of KM and thus provide almost the same results in terms of quality. In contrast, WSM (WSM-C) not only provides a considerable speedup over KM (KM-C), but also gives significantly better results, especially at lower quantization levels.

4. CONCLUSIONS

In this paper, a fast and effective color quantization method called WSM (weighted sort-means) was introduced. The method involves several modifications to the conventional K-means (KM) algorithm, including data reduction, sample weighting, and the use of the triangle inequality to speed up the nearest-neighbor search. Two variants of WSM were implemented. Although both have very reasonable computational requirements, the fixediteration variant is more appropriate for time-critical applications, while the convergent variant should be preferred in applications where obtaining the highest output quality is of prime importance, or the number of quantization levels or the number of unique colors in the original image is small. Experiments on a diverse set of images demonstrated that the two variants of WSM outperform state-of-the-art quantization methods with respect to distortion minimization. Future work will be directed toward the development of a more effective initialization method for WSM.

The implementation of WSM will be made publicly available as part of the Fourier image processing and analysis library, which can be downloaded from http:// sourceforge.net/projects/fourier-ipal.

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