Coding of 3D Videos based on Visual Discomfort

Can Temel and Ghassan AlRegib
School of Electrical and Computer Engineering
Georgia Tech, Atlanta, GA

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A 3D Video Quality Measure (3VQM)

Stereoscopic 3D
A 3D Video Quality Measure (3VQM)

\[ \Delta Z = |Z_{\text{ideal}} - Z| \]

**Spatial Outliers (SO)**

\[ STD(\Delta Z) \]

Standard deviation of depth map errors

**Temporal Outliers (TO)**

\[ STD(\Delta Z_K - \Delta Z_{K-1}) \]

Standard deviation of two depth map errors in time domain

**Temporal Inconsistencies (TI)**

\[ STD(Z_K - Z_{K-1}) \]

Standard deviation of two depth values in two time instances
### A 3D Video Quality Measure (3VQM)

**RMSE:** Root Mean Squared Error  
**CC:** Pearson Linear Correlation Coefficient  
**ROCC:** Spearman Rank Order Correlation Coefficient  
**MAE:** Mean Absolute Error  

|                   | RMSE | CC  | ROCC | MAE  |
|-------------------|------|-----|------|------|
| Average PSNR      | 0.95 | 0.73| 0.72 | 0.82 |
| Weighted Average PSNR | 0.94 | 0.76| 0.78 | 0.79 |
| Average SSIM      | 0.81 | 0.60| 0.54 | 0.62 |
| 3VQM              | 0.62 | 0.89| 0.79 | 0.52 |

Low **RMSE**: Accuracy  
High **CC**: Coherency  
High **ROCC**: Coherency  
Low **MAE**: Accuracy
A 3D Video Quality Measure (3VQM)

| Measure             | OR |
|---------------------|----|
| Average PSNR        | 0.19 |
| Weighted Average PSNR | 0.19 |
| Average SSIM        | 0.13 |
| 3VQM                | 0.00 |
### 3VQM versus VDM

|                      | 3VQM                                    | VDM                                    |
|----------------------|-----------------------------------------|-----------------------------------------|
| **Error**            | $\Delta Z = |Z_{ideal} - Z_{GT}|$            | $\Delta \hat{Z} = |Z_{GT} - Z_{processed}|$ |
| **Spatial Outliers** | STD($\Delta Z$)                          | STD($\Delta \hat{Z}$)                  |
| **Temporal Outliers**| STD($\Delta Z_{t+1} - \Delta Z_{t}$)   | STD($\Delta \hat{Z}_{t+1} - \Delta \hat{Z}_{t}$) |
| **Temporal Inconsistencies** | STD($Z_{t+1} - Z_{t}$)   | STD($\hat{Z}_{t+1} - \hat{Z}_{t}$)   |
| **Fusing method**    | $K(1 - SO(SO \cap TO))^a(1 - TO)^b(1 - TI)^c$ | $K(1 - SO)^a(1 - TO)^b(1 - TI)^c$ |
| **K**                | 5.0                                     | 1.0                                     |
| **a**                | 8                                        | $^{3}\sqrt{\text{Spatial Information Index}}$ |
| **b**                | 8                                        | $^{3}\sqrt{\text{Temporal Information Index}}$ |
| **c**                | 6                                        | 0                                       |
3VQM versus VDM

\[ S_{Inf} = 3 \sqrt{\text{max}_{t} \{ \text{std}_{space}[\text{Sobel}(F_n)] \} } \]

\[ M_n(i, j) = F_n(i, j) - F_{n-1}(i, j) \]

\[ T_{Inf} = 3 \sqrt{\text{max}_{t} \{ \text{std}_{space}[M_n(i, j)] \} } \]
VDM versus SSIM and PSNR

Balloons

Quality vs QP Factor

QP=30  QP=35

QP=40  QP=45

QP=49
VDM versus SSIM and PSNR
Champagne Tower

QP=30
QP=35
QP=40
QP=45
QP=49

Quality vs QP Factor

VDM
SSIM
PSNRnorm
VDM versus SSIM and PSNR

Kendo

[Graph showing quality versus QP factor for VDM, SSIM, and PSNR norm]
VDM versus SSIM and PSNR

Lovebirds

QP=30

QP=35

QP=40

QP=45

QP=49

Quality

0.7  0.75  0.8  0.85  0.9  0.95

30  35  40  45  50

QP Factor

VDM
SSIM
PSNRnorm
Can Temel
Encoding Mode Selection

Uncompressed Depth Video → Estimation → Transform → Quantization → Entropy Coding → Bit stream

H.264/AVC

Compressed Depth Video

Loop filter → Inverse Transform → Inverse Quantization

VDM

SO → Combination → TO

Spatial Information

Temporal Information
Rate Distortion Analysis
Balloons

WRDO: Synthesized Video without Rate Distortion Optimization
SRDO: Synthesized Video with Standard Rate Distortion Optimization
VDM: Synthesized Video with VDM-based Rate Distortion Optimization

| BALLOONS | Without RDO | Standard RDO | VDM based RDO |
|----------|-------------|--------------|---------------|
| Bitrate  | 93.58       | 48.79        | 42.53         |
| PSNR     | 36.08       | 33.51        | 32.49         |
| SSIM     | 0.96        | 0.94         | 0.93          |
## Rate Distortion Analysis

### Champagne Tower

| CHAMPAGNE TOWER | Without RDO | Standard RDO | VDM based RDO |
|-----------------|-------------|--------------|---------------|
| Bitrate         | 56.58       | 50.45        | 26.45         |
| PSNR            | 39.73       | 38.78        | 35.45         |
| SSIM            | 0.98        | 0.98         | 0.95          |
## Rate Distortion Analysis

### Kendo

|   | WRDO | SRDO | VDM |
|---|------|------|-----|
|   | ![Kendo Without RDO](image1) | ![Kendo Standard RDO](image2) | ![Kendo VDM based RDO](image3) |

### Comparison Table

|   | Without RDO | Standard RDO | VDM based RDO |
|---|-------------|--------------|---------------|
| Bitrate | 153.84      | 57.83        | 67.76         |
| PSNR    | 35.11       | 30.63        | 30.96         |
| SSIM    | 0.95        | 0.89         | 0.90          |
Rate Distortion Analysis
Lovebirds

| LOVEBIRDS | Without RDO | Standard RDO | VDM based RDO |
|-----------|-------------|--------------|---------------|
| Bitrate   | 37.66       | 49.55        | 19.47         |
| PSNR      | 39.56       | 41.40        | 34.92         |
| SSIM      | 0.90        | 0.97         | 0.81          |
# Rate Distortion Analysis

**Pantomime**

| PANTOMIME | Without RDO | Standard RDO | VDM based RDO |
|-----------|-------------|--------------|---------------|
| Bitrate   | 71.81       | 48.86        | 38.75         |
| PSNR      | 39.37       | 36.70        | 35.90         |
| SSIM      | 0.97        | 0.95         | 0.95          |
## Conclusion

### Bit rate (kbits/sec)

| Depth Sequences | WRDO  | SRDO  | VDM  |
|-----------------|-------|-------|------|
| Balloons        | 93.58 | 48.79 | 42.53|
| Champagne       | 56.58 | 50.45 | 26.45|
| Kendo           | 153.84| 57.83 | 67.76|
| Lovebird        | 37.66 | 49.55 | 19.47|
| Pantomime       | 71.81 | 48.86 | 38.75|
| AVERAGE         | 82.69 | 54.10 | 38.99|

### PSNR (dB)

| Depth Sequences | WRDO  | SRDO  | VDM  |
|-----------------|-------|-------|------|
| Balloons        | 36.08 | 33.51 | 32.49|
| Champagne       | 39.73 | 38.78 | 35.45|
| Kendo           | 35.11 | 30.63 | 30.96|
| Lovebird        | 39.56 | 41.40 | 34.92|
| Pantomime       | 39.37 | 36.70 | 35.90|
| AVERAGE         | 37.97 | 36.20 | 33.94|

### SSIM

| Depth Sequences | WRDO  | SRDO  | VDM  |
|-----------------|-------|-------|------|
| Balloons        | 0.96  | 0.94  | 0.93 |
| Champagne       | 0.98  | 0.98  | 0.95 |
| Kendo           | 0.95  | 0.89  | 0.90 |
| Lovebird        | 0.90  | 0.97  | 0.81 |
| Pantomime       | 0.97  | 0.95  | 0.95 |
| AVERAGE         | 0.95  | 0.95  | 0.91 |
Questions

For more information and related work:
http://www.ece.gatech.edu/research/labs/msl/