Video Flashing Reduction

Author : Apple Inc.

Version : 1.0

Introduction

This notebook implements the Video Flashing Reduction algorithm. It reads a video file and exports a mitigated video file. It also returns an association that contains intermediate products of the algorithm. The main function is VideoFlashingReduction. Brief documentation is provided for that and the other functions. An example of usage is given below.

Initialization

3/10/23 12:10:56 In[1]:=

```
SetDirectory[NotebookDirectory[]]
```

Functions

VideoFlashingReduction

3/10/23 12:10:56 In[2]:=

```
VideoFlashingReduction::usage =
  "VideoFlashingReduction[file_,options___Rule] Apply the Video Flashing
    Reduction algorithm to a short video clip. The function returns
    an Association with a number of intermediate calculations.
    The mitigated video is exported as a file mitigated.mp4.
Options:
\"Nits\"->500 Peak luminance of the display
\"Area\"->(45^2/1.6) Area of the display (degrees^2)
\"FilterGain\"->1 Global filter gain
\"EnergyPoolGammaScale\"->0.15
    Scale parameter of the energy kernel (seconds)
\"EnergyPoolGammaShape\"->2 Shape parameter of the energy kernel
\"EnergyPoolExponent\"->2 Exponent for calculation of energy
\"RiskMapShape\"->3 Shape parameter of the risk mapping function
\"RiskMapScale\"->200 Scale parameter of the risk mapping function
\"RiskMapOffset\"->33 Offset parameter of the risk mapping function
\"MitigationWeights\"->{1,0}
    Luminance and contrast mitigation weights, each 0-1
\"MitigationGain\"-> 1 Overall gain of mitigation, 0-1
\"RiskThreshold\"->1.8 Threshold for step masking
\"TauMitigation\"->2 Time constant for mitigation fading (seconds)
\"TauAdapt\"->1 Time constant for light adaptation (seconds)
\"OutputFileName\"->\"mitigated.mp4\" filename
    of the exported mitigated video, False for no export.

 ";
```

3/10/23 12:10:56 In[3]:=

```
Options[VideoFlashingReduction] =
  {"Nits" → 500, "Area" → (45^2 / 1.6), "Verbose" → False, "FilterGain" → 1,
   "Kernels" :→ UFMKernels03, "EnergyPoolGammaScale" → 0.15,
   "EnergyPoolGammaShape" → 2, "EnergyPoolExponent" → 2,
   "RiskMapShape" → 3, "RiskMapScale" → 200, "RiskMapOffset" → 33
   , "MitigationWeights" → {1, 0}, "MitigationGain" → 1, "RiskThreshold" → 1.8,
   "TauMitigation" → 2, "TauAdapt" → 1, "OutputFileName" → "mitigated.mp4"};
```

3/2/23 14:19:05 In[ ]:=

```
Clear[VideoFlashingReduction]
```

3/10/23 12:10:56 In[4]:=

```
VideoFlashingReduction[file_, options___Rule] := Block[{
```

```
 muAdapt, tauAdapt, numFrames, vidFrameRate, kernels, nits, area,
 verbose, gain, frames, standardSizes, standardNits, logStandardNits,
 standardFrameRates, kernelSize, equivalentSize, kernelFrameRate,
 contrastKernels, contrastKernelLengths, luminance, adaptationLevel,
 energyExponent, energyGammaScale, energygammashape , energyKernel ,
 responseAdjust, response, responses, energy, contrast, cA, riskmapshape,
 riskmapscale, riskmapoffset, risk, mitigationGain , mitigationWeights,
 contrastFactor, luminanceFactor, contrastKernelEnergies, mitigated, energies,
 mitigationStrength, mitigationStrengthOld, MuMitigation, riskThreshold,
 tauMitigation, contrastEnergies, correlations, iota, normalizedCorrelations,
 correlationEnergies, correlationEnergy, tmp, outputFileName},

(* Set options *)
{kernels, nits, area, gain, energyExponent, energyGammaScale, energygammashape,
  riskmapshape, riskmapscale, riskmapoffset, mitigationGain,
  mitigationWeights, riskThreshold, tauMitigation, tauAdapt, outputFileName} =
 {"Kernels", "Nits", "Area", "FilterGain", "EnergyPoolExponent",
    "EnergyPoolGammaScale", "EnergyPoolGammaShape", "RiskMapShape",
    "RiskMapScale", "RiskMapOffset", "MitigationGain", "MitigationWeights",
    "RiskThreshold", "TauMitigation", "TauAdapt", "OutputFileName"} /.
   {options} /. Options[VideoFlashingReduction];

(* Read video *)
frames = VideoFrameList[Video[file], All];
vidFrameRate = QuantityMagnitude[Import[file, "FrameRate"]];
numFrames = QuantityMagnitude[Import[file, "FrameCount"]];

 (* Define standard sizes, nits, rates *)
standardSizes = {6, 20, 45};
standardNits = {0.2, 1, 10, 150, 500};
logStandardNits = Log10[standardNits] // N;
standardFrameRates = {24, 25, 30, 50, 60, 90, 120};

(* Select kernels *)
equivalentSize = Sqrt[area 1.6];
kernelSize = Nearest[standardSizes, equivalentSize, 1][[1]];
kernelFrameRate = Nearest[standardFrameRates, vidFrameRate, 1][[1]];
contrastKernels = kernels[[IndexOf[standardSizes, kernelSize],
  All, IndexOf[standardFrameRates, kernelFrameRate]]];
contrastKernelLengths = Length /@ contrastKernels;
contrastKernelEnergies = Total /@ (contrastKernels^energyExponent);
energyKernel =
 Rest@GammaKernel[vidFrameRate, energygammashape, energyGammaScale, 0.991];
```

```
(* Constants and derived quantities *)
cA = 0.263; (* Area scale for PoV *)
muAdapt = 1. - Exp[-1 / (tauAdapt vidFrameRate)];
MuMitigation = 1. - Exp[-1 / (tauMitigation vidFrameRate)];
responseAdjust = ((equivalentSize / kernelSize) ^ (2 cA))
  (gain / vidFrameRate ^ (1 / energyExponent));

(* Analyze frames *)
luminance = nits (MeanNormalizedLuminance /@ frames);
adaptationLevel = ExponentialMovingAverage[luminance, muAdapt];
contrast = (luminance / adaptationLevel) - 1;
responses = ListConvolve[#, contrast, 1, 0] & /@ contrastKernels;
energies =
 (ListConvolve[energyKernel, #, 1, 0] & /@ (responses ^ energyExponent)) ^
  (1 / energyExponent);
energy = MapThread[InterpolateEnergy[#1, logStandardNits, #2] & ,
  {Log10[adaptationLevel], Transpose[energies]}];
energy *= responseAdjust;
risk = RiskMap[#, riskmapshape, riskmapscale, riskmapoffset] & /@ energy;

(* Step masking *)
contrastEnergies =
 (# MovingAverage[PadLeft[contrast ^ 2, numFrames + # - 1, 0], #]) & /@
  contrastKernelLengths;
correlations = ListCorrelate[#, contrast, -1, 0] & /@ contrastKernels;
iota = .000001;
normalizedCorrelations = correlations /
  ((iota + contrastEnergies contrastKernelEnergies) ^ (1 / energyExponent));
correlationEnergies = (ListConvolve[energyKernel, #, 1, 0] & /@
    (normalizedCorrelations ^ energyExponent)) ^ (1 / energyExponent);
correlationEnergy = MapThread[InterpolateEnergy[#1, logStandardNits, #2] & ,
  {Log10[adaptationLevel], Transpose[correlationEnergies]}];
risk = MapThread[If[#1 < riskThreshold, 0, #2 ] & , { correlationEnergy, risk}];

(* Mitigation *)
mitigationStrength = mitigationGain Log10[Clip[risk, {1, 100}]] / 2.;
mitigationStrengthOld = 0;
mitigationStrength = If[ # < mitigationStrengthOld,
    (tmp = # MuMitigation + mitigationStrengthOld (1 - MuMitigation);
     If[tmp < .01, tmp = 0];
     mitigationStrengthOld = tmp;
     tmp), (mitigationStrengthOld = #; #)] & /@ mitigationStrength;
{contrastFactor, luminanceFactor} =
 1 - ((# mitigationStrength ) & /@ mitigationWeights);
```

```
  mitigated = MapThread[Mitigate,
    {frames, contrastFactor, luminanceFactor, adaptationLevel / nits}];

  (* Export mitigated video *)
  If[StringQ[outputFileName],
   Export[outputFileName, mitigated, FrameRate → vidFrameRate]];

  (* Return interesting quantities *)
  AssociationThread[{"vidFrameRate", "kernelFrameRate",
    "luminance", "adaptationLevel", "contrast", "energy", "risk",
    "correlationEnergy", "energies", "responses", "energyKernel",
    "mitigationStrength", "contrastKernels", "normalizedCorrelations"},
   {vidFrameRate, kernelFrameRate, luminance, adaptationLevel, contrast,
    energy, risk, correlationEnergy, energies, responses, energyKernel,
    mitigationStrength, contrastKernels, normalizedCorrelations}]
 ]
```

MeanNormalizedLuminance

3/10/23 12:10:56 In[5]:=

```
MeanNormalizedLuminance::usage =
  "MeanNormalizedLuminance[image_] Compute the mean
    normalized luminance from a color image.";
```

3/10/23 12:10:56 In[6]:=

```
MeanNormalizedLuminance[image_] :=
 Mean[ColorSeparate[ColorConvert[
     If[ImageChannels[image] == 4, RemoveAlphaChannel[image], image], "XYZ"]][[2]]]
```

InterpolateEnergy

3/10/23 12:10:56 In[7]:=

```
InterpolateEnergy::usage =
  "InterpolateEnergy[logNits_,logStandardNits_,energies_] Interpolate a
    single energy value from the five energies, based on the current
    adaptation level and the five standard log luminances of the kernels.";
```

3/10/23 12:10:56 In[8]:=

```
InterpolateEnergy[logNits_, logStandardNits_, energies_] := Piecewise[{
    {energies[[1]], logNits < logStandardNits[[1]]}
    , {energies[[1]] + (logNits - logStandardNits[[1]]) (energies[[2]] - energies[[1]]) /
        (logStandardNits[[2]] - logStandardNits[[1]]), logNits < logStandardNits[[2]]}
    , {energies[[2]] + (logNits - logStandardNits[[2]]) (energies[[3]] - energies[[2]]) /
        (logStandardNits[[3]] - logStandardNits[[2]]), logNits < logStandardNits[[3]]}
    , {energies[[3]] + (logNits - logStandardNits[[3]]) (energies[[4]] - energies[[3]]) /
        (logStandardNits[[4]] - logStandardNits[[3]]), logNits < logStandardNits[[4]]}
    , {energies[[4]] + (logNits - logStandardNits[[4]]) (energies[[5]] - energies[[4]]) /
        (logStandardNits[[5]] - logStandardNits[[4]]), logNits < logStandardNits[[5]]}
  }, energies[[5]]]
```

RiskMap

3/10/23 12:10:56 In[9]:=

```
RiskMap::usage =
  "RiskMap[energy_,shape_,scale_,offset_] Map the energy into a risk.
    The parameters are shape, scale and offset.";
```

3/10/23 12:10:56 In[10]:=

```
RiskMap[energy_, shape_, scale_, offset_] :=
 If[energy < offset, 0, 100 (1 - ℯ^-((energy-offset)/scale)^shape)]
```

Mitigate

3/10/23 12:10:56 In[11]:=

```
Mitigate::usage =
  "Mitigate[input_,contrastfactor_,lumfactor_,arlum_] Reduce the
    contrast and/or luminance of an image by factors (0-1) where
    1 means no change. The result is lumfactor (arlum-arlum
    contrastfactor+contrastfactor input). The result is clipped to
    {0,1}. The input can be an image, a relative luminance, or a
    list of relative luminances. arlum is either a single adapting
    relative luminance, or a list of length equal to the input.";
```

```
Mitigate[image_Image, contrastfactor_, lumfactor_, arlum_] :=
 Block[{gamma = 2.2, rlum, gain, offset},
  rlum = ImageData[image]^gamma;
  gain = contrastfactor lumfactor;
  offset = (1 - contrastfactor) lumfactor arlum;
  Image[Clip[gain rlum + offset, {0, 1}]^(1 / gamma), Options[image]]
 ]
```

GammaKernel

3/10/23 12:10:56 In[13]:=

```
GammaKernel::usage =
  "GammaKernel[w_,shape_,scale_,quantile_:0.99]. Compute a kernel
    that is sampled at rate w (Hz) from a Gamma PDF with
    paramaters shape and scale. The argument quantile specifies
    what quantile of the distribution should be included. ";
```

3/10/23 12:10:56 In[14]:=

```
GammaKernel[w_, shape_, scale_, quantile_ : 0.99] := Block[{dist, argmax, tmax},
  dist = GammaDistribution[shape, scale];
  tmax = Quantile[dist, quantile];
  PDF[dist, Range[0, tmax + 1 / w, 1 / w]]
 ]
```

IndexOf

3/10/23 12:10:56 In[15]:=

```
IndexOf::usage =
  "IndexOf[list_,item_] Return the index of the item in the list.";
```

3/10/23 12:10:56 In[16]:=

```
IndexOf[list_, item_] := Position[list, item][[1, 1]]
```

Kernels

3/10/23 12:10:56 In[17]:=

```
UFMKernels03::usage =
  "An array of filter kernels based on the Universal Flicker Metric.
    The dimensions of the array are {3, 5, 7}, corresponding to the
    standard sizes, standard luminances, and standard frame rates.";
```

3/10/23 12:10:56 In[18]:=

```
UFMKernels03 = {{{{16.71817198509924, 37.7068247160281,
```

```
  -33.40149682031351, -24.632145197796774, -0.38647089073704033},
 {46.90648095320929, -0.2783003114525284, -31.359460240507502,
  -11.151360698143074, -0.4410315788229566},
 {4.874872123894335, 39.68876196405938, 4.601124602820024,
  -29.597722947856745, -17.0841714460608, -3.986193783586406,
  -0.4994842991751935, -0.03975104977147303}, {0.3827336658504792,
  11.600592592584302, 25.926341747138856, 16.171444743032666,
  -4.071929807082321, -15.789140152149065, -15.459850353221718,
  -9.715645424431317, -4.578716201487029, -1.7376284698711058,
  -0.5549903887091708, -0.15387419364826427, -0.037895753778999834},
 {0, 0.4802136705750231, 6.921584852329777, 19.05440083711387,
  20.097901494730333, 8.063161384574201, -5.654891847393663,
  -13.177975787169684, -13.542034950335001, -9.90883878417787,
  -5.753277628650484, -2.789896929356679, -1.167391486077913,
  -0.43162765539701115, -0.14362424574074667, -0.043643447843307634,
  -0.012255914614523545}, {0, 0, 0.02542307453074896, 0.5148531514769089,
  3.0587391267160515, 8.361132695855487, 13.333054824532386,
  14.125431697636476, 10.316963858522698, 4.169591743341239,
  -1.9595046088224652, -6.610801790734411, -9.12081474097618,
  -9.497661239536212, -8.300467620008149, -6.339777008663937,
  -4.327111321072084, -2.679655089689874, -1.5232995603283963,
  -0.8024947180607245, -0.394919931337837, -0.18278386460087911,
  -0.08003421925639816, -0.03332257902010153, -0.013251567033012333},
 {-0.033983459186743295, -0.018342069019434287, 0,
  0.04142073998615343, 0.3812605526743317, 1.582273272508688,
  4.044248079246128, 7.264314062038102, 9.934484165247886,
  10.858633310633376, 9.678127344686978, 6.859568912853607,
  3.2425268301249663, -0.37349999157438135, -3.4182661903066256,
  -5.578013053407784, -6.761704544125862, -7.051814021835941,
  -6.645934326935291, -5.792363015204131, -4.7312225035033215,
  -3.6537633966395155, -2.685178882846643, -1.887521932205223,
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{{100.23732878107762, -0.8570770621676594, -63.966083344356505,
  -19.96448955893178, -0.6662960967103904},
 {96.98800634197241, 4.48142963749884, -63.553532418891805,
  -24.106361420485932, -1.8545472064088004, -0.049874055047917386},
 {9.559429399551036, 83.99168532406833, 17.931446405015162,
  -55.198745060844026, -36.01713423527094, -9.161688185521802,
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  9.408633265982841, 47.18905525185455, 43.213403403649, 3.8203808625875912,
  -27.065115212313817, -35.95078519716568, -27.301732131650674,
  -14.56983458885805, -5.9570753466386455, -1.9727942061582635,
  -0.5508216238175149, -0.1336329675269811, -0.028832803241512238},
```

```
 {0, 0.35056623364369577, 11.367555467652776, 39.30977665891702,
  39.391051894517034, 14.283919647694407, -10.213467933842914,
  -27.07740903710374, -31.17629727706288, -23.745862165842333,
  -13.214956404895691, -5.698052675391537, -1.9869209533340542,
  -0.5791412416883598, -0.14484038748972178, -0.03174165323791112},
 {0.0671107933368082, 3.1780473089217196, 15.065898482772218,
  27.822113436515913, 30.502333707859297, 23.335404002420365,
  11.921736354572463, 0.30551546830675763, -9.434449753336299,
  -15.927694076468262, -18.496507745162365, -17.557643661606836,
  -14.403386064022621, -10.506042483639735, -6.9411176043102305,
  -4.210728754716575, -2.370657739888276, -1.2495029563618223,
  -0.6210010293149386, -0.2927982337995886, -0.13164618919793797,
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  1.3716196759056354, 5.409177046774954, 12.478369967165058,
  19.44354822414024, 22.405208190214157, 20.176733397272475,
  14.40610260124229, 7.415374271082862, 0.6815097034988756,
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  -15.089984608538398, -15.197098830187125, -13.943021945590088,
  -11.80914175627919, -9.320077825179304, -6.905326149317534,
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  -0.22163655302055482, -0.11706454578813164}},
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  -14.744360139875422, -0.10665301834013836},
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  -4.531681193356933, -1.9717357566023892, -0.7997599931230713,
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  -0.012987670706400542}, {0, 0, 0.5029144163784453, 7.04812004848818,
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```

```
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      -7.35762909875796, -4.167461369641288, -2.224969834267148,
      -1.1283418242528866, -0.5470343540953257, -0.2549158140104673,
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    {{185.32913232993704, -177.09768649459116, -6.2786815090039045},
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      -0.10508232206586049}, {209.64448415679615,
      -179.6795253880063, -32.63119585345887, -0.02232788643589523},
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      -5.9656033496269085, -2.0063483493418612, -0.6130730215760712,
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    {{182.9483808988363, -180.3786089579802, -0.06878884917076183},
     {186.90203924486994, -184.33980892694987, -0.9848136528324837},
     {209.76510531040086, -190.96890502546427, -20.240707410446102,
      -0.042649912774731166}, {241.949053024825, -122.45068692357249,
      -117.36048567572868, -3.978487046861391, -0.013750321246549846},
     {4.809153804421468, 230.0117296209766, -65.42212473242911,
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     {156.49180061305, 99.79367901735378, -84.01408984301648,
      -102.86949956965529, -49.51805587201578, -12.87659731855713,
      -2.2578008119455086, -0.30327906629478457, -0.0336759928234398},
     {2.5008251651544264, 78.26396401215943, 133.197214617558, 36.84509493562824,
      -64.17665432761805, -87.46980522600316, -58.5915254449765,
      -26.439276052574684, -8.975370190317246, -2.443814447812751,
      -0.5575044906651122, -0.10999800245012448, -0.019226373909840683}}},
   {{{7.378500774172188, 70.14320036876754, -42.62937195462202,
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Example

3/10/23 12:11:09 In[19]:=

```
vfmtest = VideoFlashingReduction["Resources/movie.mp4"];
```

3/10/23 12:11:43 In[20]:=

```
Keys[vfmtest]
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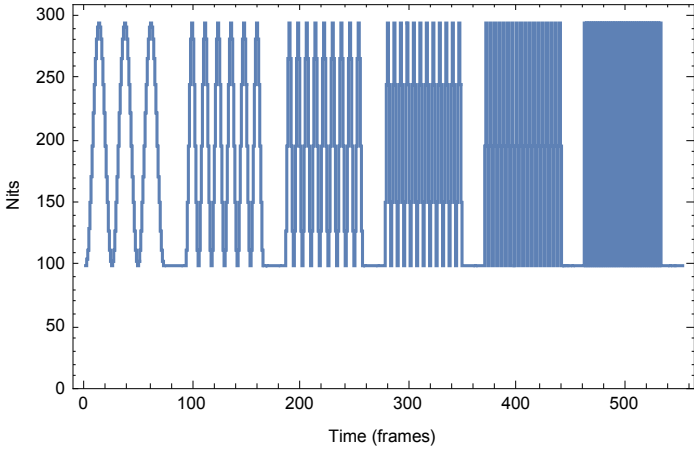
3/10/23 12:11:43 Out[20]=

```
{vidFrameRate, kernelFrameRate, luminance, adaptationLevel, contrast,
 energy, risk, correlationEnergy, energies, responses, energyKernel,
 mitigationStrength, contrastKernels, normalizedCorrelations}
```

3/10/23 12:11:50 In[21]:=

```
ListStepPlot[vfmtest["luminance"], PlotRange → {0, All},
 Frame → True, FrameLabel → {"Time (frames)", "Nits"}]
```

3/10/23 12:11:50 Out[21]=



3/10/23 12:12:30 In[24]:=

```
ListStepPlot[vfmtest["adaptationLevel"], PlotRange → {0, All},
 Frame → True, FrameLabel → {"Time (frames)", "Nits"}]
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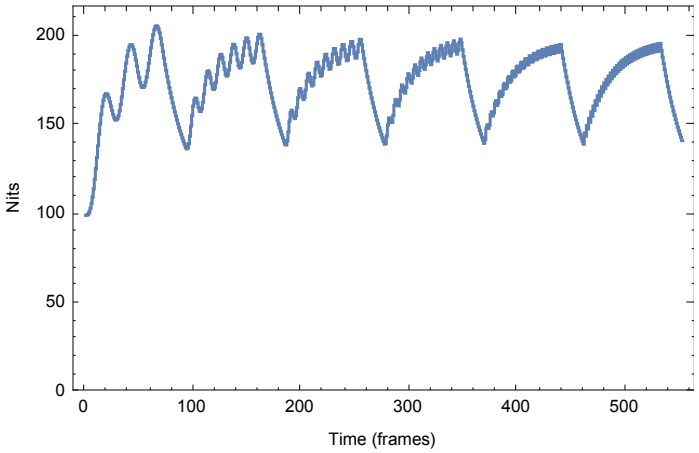
3/10/23 12:12:30 Out[24]=



3/10/23 12:11:58 In[22]:=

```
ListStepPlot[vfmtest["risk"], PlotRange → {0, 100},
 Frame → True, FrameLabel → {"Time (frames)", "Strength"}]
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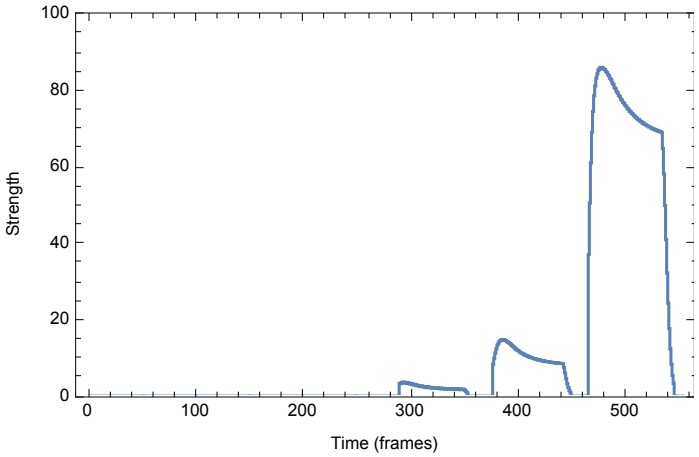
3/10/23 12:11:58 Out[22]=



3/10/23 12:12:03 In[23]:=

```
ListStepPlot[vfmtest["mitigationStrength"], PlotRange → {0, 1},
 Frame → True, FrameLabel → {"Time (frames)", "Strength"}]
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3/10/23 12:12:03 Out[23]=