

Sushi: An R/Bioconductor package for visualizing genomic data

Douglas H. Phanstiel*, Alan P. Boyle, Carlos L. Araya, and Mike Snyder

October 14, 2015

Contents

1	Introduction	2
2	Data	2
2.1	Data types	2
2.2	Example datasets	2
3	Functions	3
3.1	Functions overview	3
3.2	Non-Sushi Functions	4
3.3	plotBedgraph	4
3.4	plotHic	10
3.5	plotBedpe	12
3.6	plotBed	14
3.7	plotManhattan	18
3.8	plotGenes	19
3.9	Zoom functions	22
3.10	Color functions	25
3.10.1	SushiColors	25
3.10.2	opaque	26
3.10.3	maptocolors	27
3.11	labeling functions	28
3.11.1	labelgenome	28
3.11.2	labelplot	30
4	Tips	31
5	Appendix	32
6	Bibliography	43

*Corresponding contact: doug.phanstiel@gmail.com

1 Introduction

Sushi is an R package for plotting genomic data stored in multiple common genomic formats including bed, bedpe, bedgraph format. The package was designed to be very flexible to allow for combinations of plots into multipanel figures that can include plots made by Sushi, R basecode, or other R packages. Sushi allows for simple flexible plotting of gene structures, transcript structures, sequencing tracks, ChIP-seq peaks, chromatin interactions, GWAS results and other common genomic data types. This vignette shows some examples of the functions included in Sushi to get you started with plotting these diverse data types.

2 Data

2.1 Data types

Sushi accepts 4 types of genomic data as input. These include:

- bed format: 3-6 columns (chromosome, start, stop, name, score, strand)
- bedpe format: 6-10 columns (chromosome1, start1, stop1, chromosome2, start2, stop2, name, score, strand1, strand2)
- bedgraph format: 4 columns (chromosome, start, stop, score)
- interaction matrix: This is matrix in which row and column names are genomic coordinates and matrix values are some type of interaction score.

** strands can be represented as 1 or -1 or "+" and "-".

** Some functions may require additional information depending on the plot and features desired.

2.2 Example datasets

To illustrate how Sushi works, we have included several publically available data sets in the package Sushi. The data types include RNA-seq, ChIP-seq, ChIA-PET, and HiC data:

Sushi_5C.bedpe	Sanyal et al. [7]
Sushi_ChIAPET_pol2.bedpe	Li et al. [4]
Sushi_ChIPExo_CTCF.bedgraph	Rhee and Pugh [6]
Sushi_ChIPSeq_CTCF.bedgraph	The ENCODE Project Consortium [8]
Sushi_ChIPSeq_pol2.bed	The ENCODE Project Consortium [8]
Sushi_ChIPSeq_pol2.bedgraph	The ENCODE Project Consortium [8]
Sushi_ChIPSeq_severalfactors.bed	The ENCODE Project Consortium [8]
Sushi_DNaseI.bedgraph	Neph et al. [5]
Sushi_GWAS.bed	International Consortium for Blood Pressure [3]
Sushi_HiC.matrix	Dixon et al. [2]
Sushi_RNASeq_K562.bedgraph	The ENCODE Project Consortium [8]
Sushi_genes.bed	Biomart [1]
Sushi_hg18_genome	Biomart [1]
Sushi_transcripts.bed	The ENCODE Project Consortium [8]

These data sets can be loaded using the following commands:

```
> library('Sushi')
> Sushi_data = data(package = 'Sushi')
> data(list = Sushi_data$results[,3])
```

To see which data sets are loaded

```
> Sushi_data$results[,3]

[1] "Sushi_5C.bedpe" "Sushi_ChIAPET_pol2.bedpe"
[3] "Sushi_ChIPExo_CTCF.bedgraph" "Sushi_ChIPSeq_CTCF.bedgraph"
[5] "Sushi_ChIPSeq_pol2.bed" "Sushi_ChIPSeq_pol2.bedgraph"
[7] "Sushi_ChIPSeq_severalfactors.bed" "Sushi_DNaseI.bedgraph"
[9] "Sushi_GWAS.bed" "Sushi_HiC.matrix"
[11] "Sushi_RNASeq_K562.bedgraph" "Sushi_genes.bed"
[13] "Sushi_hg18_genome" "Sushi_transcripts.bed"
```

3 Functions

3.1 Functions overview

Sushi functions can be broken down into 3 categories: plotting, annotating, zooming, and coloring. Plotting functions generate a basic plot object using the data. Annotating functions add information to the plots such as an x-axis labeling the genomic region or a legend describing the values represented by different colors. Zooming functions allow for highlighting and zooming of genomic regions, which are of particular use for multipanel plots generated with base R functions `mfrow()` or `layout()`. The coloring functions provide simple tools for generating R colors and palettes.

- Plotting functions: `plotBed()`, `plotBedgraph()`, `plotBedpe()`, `plotGenes()`, `plotHiC()`, and `plotManhattan()`
- Annotating functions: `labelgenome()` and `addlegend()`
- Zooming functions: `zoomsregion()` and `zoombox()`
- Coloring functions: `maptocolors()`, `SushiColors()`, and `opaque()`

3.2 Non-Sushi Functions

An important characteristic of Sushi plots is their compatibility with all base R functions and their ability to be combined into complex multipanel figures. Two of the most useful base R functions for creating multipanel figures are `layout()` and `mfrow()`. Basic R plotting functions such as `axis()`, `mtext()`, and `legend()` are also particularly well suited to combine with Sushi plots. A familiarity with these functions will greatly improve your ability to create Sushi plots.

3.3 plotBedgraph

Signal tracks can be plotted using `plotBedgraph()`. The input requires data in bedgraph format. We will demonstrate this using bedgraph data representing a DNaseI hypersensitivity experiment in K562 cells.

```
> head(Sushi_DNaseI.bedgraph)
```

	chrom	start	end	value
1	chr11	1640504	1640664	1
2	chr11	1640904	1641004	1
3	chr11	1641004	1641064	2
4	chr11	1641064	1641164	1
5	chr11	1645224	1645384	1
6	chr11	1645504	1645664	1

The `plotBedgraph()` function is used to plot the data. As with most Sushi functions the basic required arguments include the data to be plotted, the chromosome, and a start and stop position.

```
> chrom          = "chr11"
> chromstart     = 1650000
> chromend       = 2350000
> plotBedgraph(Sushi_DNaseI.bedgraph, chrom, chromstart, chromend, colorbycol= SushiColors(5))
```



To annotate the genome position we use the `labelgenome()` function. We use `n = 4` to specify the desired number of tickmarks. The scale is set to `Mb` (other options are `Kb` or `bp`).

```
> labelgenome(chrom,chromstart,chromend,n=4,scale="Mb")
```



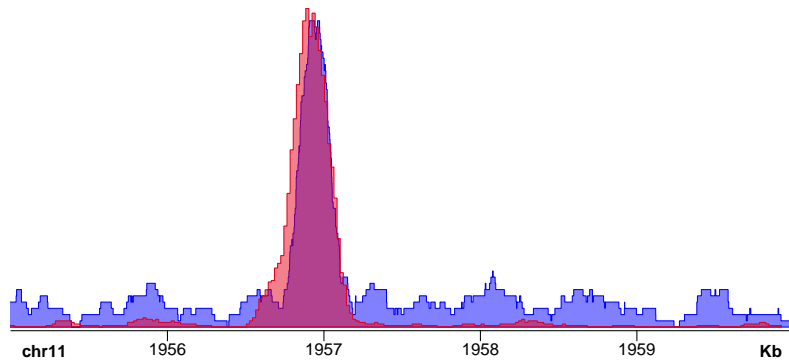
The y-axis can be added using basic R functions `mtext()` and `axis()`.

```
> mtext("Read Depth",side=2,line=1.75,cex=1,font=2)
> axis(side=2,las=2,tcl=.2)
```



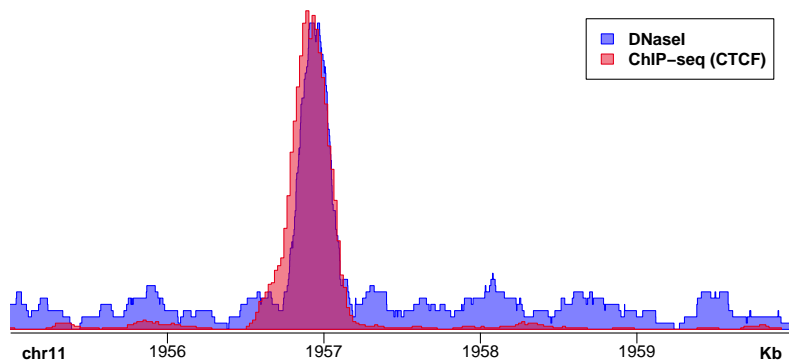
Multiple bedgraph tracks can be plotted on the same plot by setting `overlay=TRUE`. Transparencies can be added for easier viewing by adjusting the transparency value. The second plot can be rescaled to the maximum of the first plot by setting `rescaleoverlay=TRUE`.

```
> chrom          = "chr11"
> chromstart     = 1955000
> chromend       = 1960000
> plotBedgraph(Sushi_ChIPSeq_CTCF.bedgraph,chrom,chromstart,chromend,
               transparency=.50,color=SushiColors(2)(2)[1])
> plotBedgraph(Sushi_DNaseI.bedgraph,chrom,chromstart,chromend,
               transparency=.50,color=SushiColors(2)(2)[2],overlay=TRUE,
               rescaleoverlay=TRUE)
> labelgenome(chrom,chromstart,chromend,n=3,scale="Kb")
```



Then we can use the base R function `legend()` to add a legend to the plot. First we need to use the `rgb` function to add transparency to the colors in order to match our plot.

```
> legend("topright",inset=0.025,legend=c("DNaseI", "ChIP-seq (CTCF)"),
      fill=opaque(SushiColors(2)(2)),border=SushiColors(2)(2),text.font=2,
      cex=1.0)
```



Setting `flip=TRUE` is another method that can be used to compare tracks. First, we will use `mflow` to divide the plotting device into two vertically stacked regions.

```
> par(mfrow=c(2,1),mar=c(1,4,1,1))
```


Next, we plot the first plot. We set the transparency of the plot to 0.5. We will also add the legend.

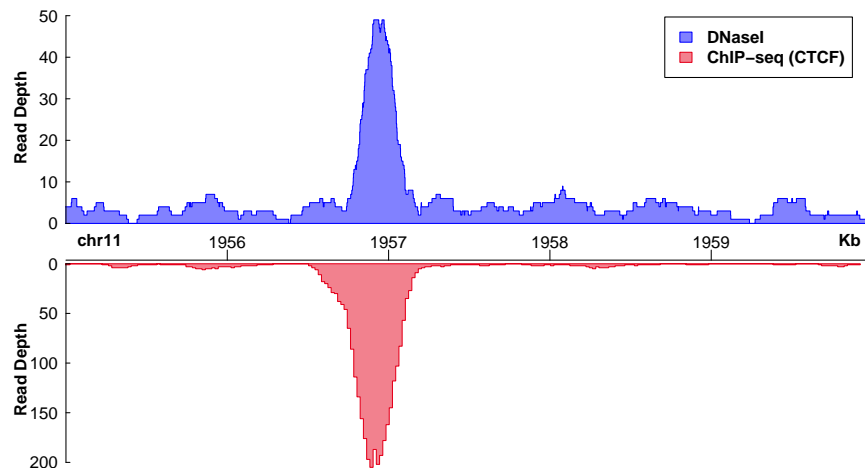
```
> plotBedgraph(Sushi_ChIPSeq_CTCF.bedgraph,chrom,chromstart,chromend,transparency=.50,
               color=SushiColors(2)(2)[1])
> axis(side=2,las=2,tcl=.2)
> mtext("Read Depth",side=2,line=1.75,cex=1,font=2)
> legend("topright",inset=0.025,legend=c("DNaseI","ChIP-seq (CTCF)"),
        fill=opaque(SushiColors(2)(2)),border=SushiColors(2)(2),text.font=2,
        cex=1.0)
```



Finally, we add the second plot with `flip=TRUE`. We will also label the x-axis using `labelgenome()` and label the y-axis using `mtext()` and `axis()`.

```
> plotBedgraph(Sushi_DNaseI.bedgraph, chrom, chromstart, chromend,
               transparency=.50, flip=TRUE, color=SushiColors(2)(2)[2])
> labelgenome(chrom,chromstart,chromend,side=3,n=3,scale="Kb")
```

```
> axis(side=2,las=2,tcl=.2,at=pretty(par("yaxp")[c(1,2)]),
      labels=-1*pretty(par("yaxp")[c(1,2)]))
> mtext("Read Depth",side=2,line=1.75,cex=1,font=2)
```



3.4 plotHic

HiC interaction plots can be plotted given an interaction matrix in which row and column names are genomic coordinates and matrix values are some tye of interaction score.

```
> Sushi_HiC.matrix[100:105,100:105]

      4460000  4500000  4540000  4580000  4620000  4660000
4460000 60.758775 18.84723 33.31506 22.56641  7.926361 10.69235
4500000 18.847231 32.56282 36.31212 29.04343 13.375643 12.67360
4540000 33.315060 36.31212 17.97024 43.43753 20.411952 16.98875
4580000 22.566409 29.04343 43.43753 38.93754 25.206417 23.87764
4620000  7.926361 13.37564 20.41195 25.20642  9.201501 38.33665
4660000 10.692351 12.67360 16.98875 23.87764 38.336646 22.55054
```

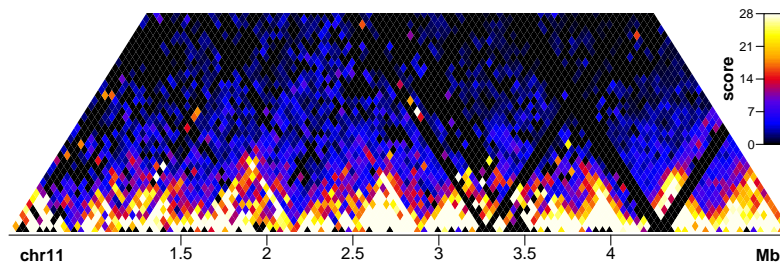
The `plotHic()` function is used to plot the data while the `labelgenome()` function is used to add the genome labels to the x-axis. `plotHic()` returns an object indicating the color palette and data range that can be fed into `addlegend()` to create a legend.

```
> chrom          = "chr11"
> chromstart     = 500000
> chromend       = 5050000
> phic = plotHic(Sushi_HiC.matrix, chrom,chromstart, chromend, max_y = 20,
                zrange=c(0,28), palette=SushiColors(7))
```

```

> addlegend(phic[[1]], palette=phic[[2]], title="score", side="right",
            bottominset=0.4, topinset=0, xoffset=-.035, labelside="left",
            width=0.025, title.offset=0.035)
> labelgenome(chrom, chromstart, chromend, n=4, scale="Mb",
              edgeblankfraction=0.20)

```



plotHic() has a number of customizable options. The plot can be flipped over the x-axis by setting `flip = TRUE`. The color palette can be changed by the `palette` argument.

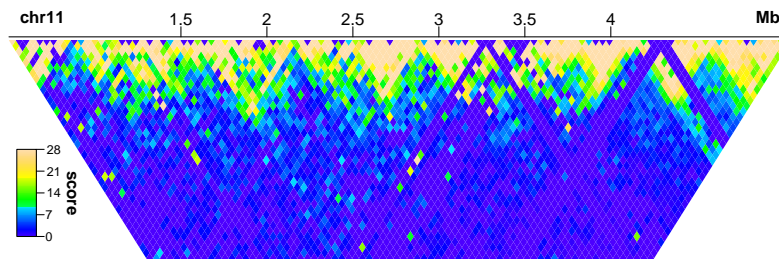
addlegend() also has customizable features. The legend can be moved to the left side of the plot by setting `side = "left"` and the labeling can be moved to the right side of the legend by setting `labelside = "right"`. The vertical position of the legend can be adjusted by changing the `topinset` and `bottominset`.

Finally, the x-axis label can be moved to the top of the plot by setting `side = 3` in the `labelgenome()` function.

```

> chrom          = "chr11"
> chromstart     = 500000
> chromend       = 5050000
> phic = plotHic(Sushi_HiC.matrix, chrom, chromstart, chromend, max_y = 20,
                xrange=c(0,28), flip=TRUE, palette=topo.colors)
> addlegend(phic[[1]], palette=phic[[2]], title="score", side="left", bottominset=0.1,
            topinset=0.5, xoffset=-.035, labelside="right", width=0.025, title.offset=0.035)
> labelgenome(chrom, chromstart, chromend, side=3, n=4, scale="Mb", edgeblankfraction=0.20)

```



3.5 plotBedpe

`plotBedpe()` allows for data in bedpe format to be plotted in multiple fashions. To illustrate this we will use 5C data formatted in the following way.

```
> head(Sushi_5C.bedpe)
```

	chrom1	start1	end1	chrom2	start2	end2	name	score	strand1
1	chr2	234208447	234223064	chr2	234156762	234159135	NA	44.39862	.
2	chr15	41711734	41718116	chr15	41802421	41808201	NA	20.62534	.
3	chr11	64172456	64183193	chr11	64068878	64079209	NA	16.91630	.
4	chr2	234208447	234223064	chr2	234163674	234170252	NA	12.34501	.
5	chr6	41755186	41769245	chr6	41435903	41452283	NA	11.63480	.
6	chr11	64159283	64172456	chr11	64068878	64079209	NA	11.13098	.

	strand2	samplenum
1	.	1
2	.	1
3	.	1
4	.	1
5	.	1
6	.	1

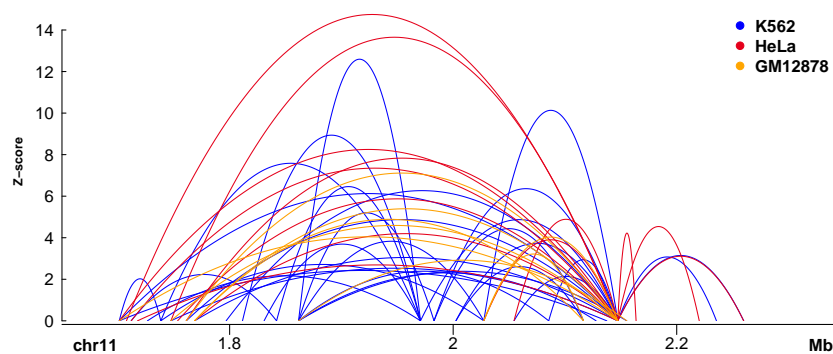
`plotBedpe()` can plot bedpe as arches. The height, linewidth, and color of each arch can be scaled to represent different aspects of the data. Here the height of the arches represents the Z-score of the 5C interaction, the color represents the cell line each interaction was detected in, and the line widths are kept constant (default `lwd = 1`).

```
> chrom = "chr11"
> chromstart = 1650000
> chromend = 2350000
> pbpe = plotBedpe(Sushi_5C.bedpe, chrom, chromstart, chromend,
  heights = Sushi_5C.bedpe$score, plotype="loops",
```

```

        colorby=Sushi_5C.bedpe$samplenumbers,
        colorbycol=SushiColors(3))
> labelgenome(chrom, chromstart,chromend,n=3,scale="Mb")
> legend("topright",inset =0.01,legend=c("K562","HeLa","GM12878"),
        col=SushiColors(3)(3),pch=19,bty='n',text.font=2)
> axis(side=2,las=2,tcl=.2)
> mtext("Z-score",side=2,line=1.75,cex=.75,font=2)

```



The plot can be flipped over the x-axis by setting `flip = TRUE`, Bedpe elements can be represented by boxes and straight lines by setting `plottype = "lines"`. And colors can be used to represent Z-scores by setting `colorby = "Sushi_5C.bedpe$score"`.

```

> chrom          = "chr11"
> chromstart     = 1650000
> chromend       = 2350000
> pbpe = plotBedpe(Sushi_5C.bedpe,chrom,chromstart,chromend,flip=TRUE,
                  plottype="lines",colorby=Sushi_5C.bedpe$score,
                  colorbycol=SushiColors(5))
> labelgenome(chrom, chromstart,chromend,side=3,n=3,scale="Mb")
> addlegend(pbpe[[1]],palette=pbpe[[2]],title="Z-score",side="right",bottominset=0.05,
            topinset=0.05,xoffset=-.035,labelside="right",width=0.025,title.offset=0.045)

```



3.6 plotBed

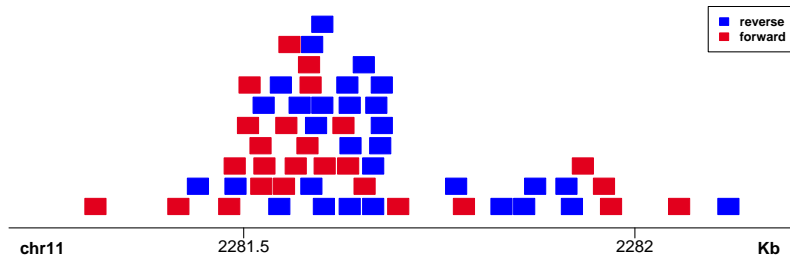
plotBed provides multiple different ways to represent genomic data stored in bed format. Below are the first six lines of a bed file detailing reads from Pol2 ChIP-Seq analysis of K562 cells.

```
> head(Sushi_ChIPSeq_pol2.bed)
```

	chrom	start	end	name	score	strand
1	chr11	2280543	2280570	GGGCTCTCTCCGGCTTCCCTGTCCCGT	63	-1
2	chr11	2288946	2288973	CCTTCCCATCCGCAGGGGCACCATG	1000	-1
3	chr11	2272471	2272498	TGGGCATCAGTCAGGCTCCTTCCCCAG	1000	-1
4	chr11	2288939	2288966	ATCCGCAGGGGCACCATGAGTCACC	1000	-1
5	chr11	2281534	2281561	TGTCCTAGTGACAAGTGGCCGACTTG	250	-1
6	chr11	2286805	2286832	GGTGAGGGCCAGCAGCTCCCTGGGGG	250	1

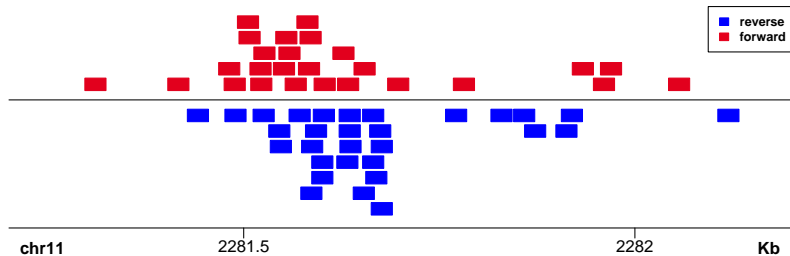
Leaving row set to auto provides a pile-sup style plot. Here the colorby argument is used to color the bed elements by the strand.

```
> chrom = "chr11"
> chromstart = 2281200
> chromend = 2282200
> plotBed(beddata = Sushi_ChIPSeq_pol2.bed, chrom = chrom, chromstart = chromstart,
          chromend = chromend, colorby = Sushi_ChIPSeq_pol2.bed$strand,
          colorbycol = SushiColors(2), row = "auto", wiggle=0.001)
> labelgenome(chrom, chromstart, chromend, n=2, scale="Kb")
> legend("topright", inset=0, legend=c("reverse", "forward"), fill=SushiColors(2)(2),
          border=SushiColors(2)(2), text.font=2, cex=0.75)
```



Setting `splitstrand = TRUE` plots reads from different strands in two separate vertical regions.

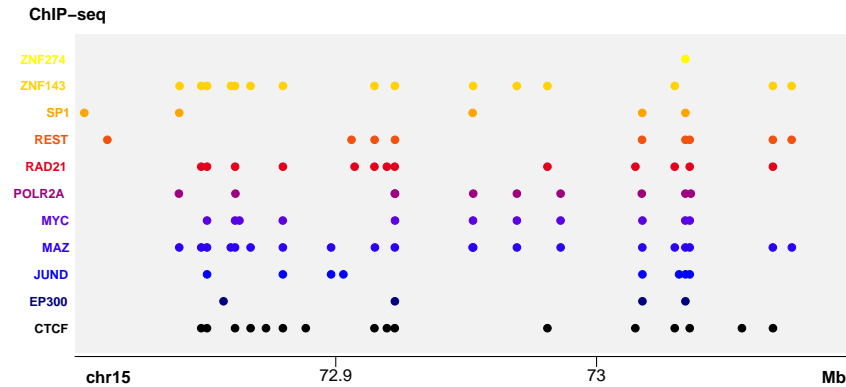
```
> chrom = "chr11"
> chromstart = 2281200
> chromend = 2282200
> plotBed(beddata = Sushi_ChIPSeq_pol2.bed, chrom = chrom, chromstart = chromstart,
  chromend = chromend, colorby = Sushi_ChIPSeq_pol2.bed$strand,
  colorbycol = SushiColors(2), row = "auto", wiggle=0.001, splitstrand=TRUE)
> labelgenome(chrom, chromstart, chromend, n=2, scale="Kb")
> legend("topright", inset=0, legend=c("reverse", "forward"), fill=SushiColors(2)(2),
  border=SushiColors(2)(2), text.font=2, cex=0.75)
```



`plotBed` can also plot bed elements on different rows as specified by the user. First, we will use the Sushi function `maptocolors()` to assign a different color to each row.

```
> Sushi_ChIPSeq_severalfactors.bed$color =
  maptocolors(Sushi_ChIPSeq_severalfactors.bed$row,
    col=SushiColors(6))
```

By providing row and color information `plotBed()` can be used to compare bed elements from different samples by plotting them on different rows.



```
> chrom          = "chr15"
> chromstart     = 72800000
> chromend       = 73100000
> plotBed(beddata = Sushi_ChIPSeq_severalfactors.bed, chrom = chrom,
          chromstart = chromstart, chromend = chromend,
          rownumber = Sushi_ChIPSeq_severalfactors.bed$row, type = "circles",
          color=Sushi_ChIPSeq_severalfactors.bed$color, row="given",
          plotbg="grey95", rowlabels=unique(Sushi_ChIPSeq_severalfactors.bed$name),
          rowlabelcol=unique(Sushi_ChIPSeq_severalfactors.bed$color), rowlabelcex=0.75)
> labelgenome(chrom, chromstart, chromend, n=3, scale="Mb")
> mtext("ChIP-seq", side=3, adj=-0.065, line=0.5, font=2)
```

That same data can be represented by rectangles that depict the actual width of each bed element.

```
> plotBed(beddata = Sushi_ChIPSeq_severalfactors.bed, chrom = chrom,
          chromstart = chromstart, chromend = chromend,
          rownumber = Sushi_ChIPSeq_severalfactors.bed$row, type = "region",
          color=Sushi_ChIPSeq_severalfactors.bed$color, row="given",
          plotbg="grey95", rowlabels=unique(Sushi_ChIPSeq_severalfactors.bed$name),
          rowlabelcol=unique(Sushi_ChIPSeq_severalfactors.bed$color), rowlabelcex=0.75)
> labelgenome(chrom, chromstart, chromend, n=3, scale="Mb")
> mtext("ChIP-seq", side=3, adj=-0.065, line=0.5, font=2)
```




plotBed() can also be used to plot heatmaps representing the density of bed elements. First, we will use the biomaRt function getBM() to get the gene information we require.

```
> chrom = "chr15"
> chromstart = 60000000
> chromend = 80000000
> chrom_biomart = gsub("chr", "", chrom)
> mart=useMart(host='may2009.archive.ensembl.org', biomart='ENSEMBL_MART_ENSEMBL',
  dataset='hsapiens_gene_ensembl')
> geneinfobed = getBM(attributes = c("chromosome_name", "start_position", "end_position"),
  filters= c("chromosome_name", "start", "end"),
  values=list(chrom_biomart, chromstart, chromend), mart=mart)
> geneinfobed[,1] = paste("chr", geneinfobed[,1], sep="")
```

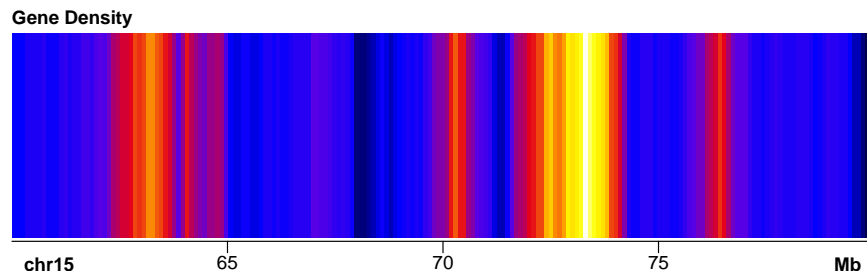
The data is in simple bed format with just three columns representing chromosome, start, and stop.

```
> head (geneinfobed)

  chromosome_name start_position end_position
1          chr15      73372069      73372334
2          chr15      64580642      64580710
3          chr15      63375442      63375557
4          chr15      72570353      72570422
5          chr15      60903209      60903293
6          chr15      70130646      70130724
```

Now we can make a gene density plot using the plotBed function.

```
> plotBed(beddata = geneinfobed[!duplicated(geneinfobed),],chrom = chrom,
          chromstart = chromstart,chromend =chromend,row='supplied',
          palettes = list(SushiColors(7)), type = "density")
> labelgenome(chrom, chromstart, chromend, n=4,scale="Mb",edgeblankfraction=0.10)
> mtext("Gene Density",side=3, adj=0,line=0.20,font=2)
```



3.7 plotManhattan

`plotManhattan()` differs from most other Sushi functions in that it can plot multiple chromosomes in a single plot. Because of this `plotManhattan` requires some additional inputs. It requires an object in bed format describing the location of data points as well as vector of p-values (typically one of the columns of the bed file). But it also requires an genome object that describes which chromosomes to plot and their sizes (in bp). The genome object is very similar to the genome files used for `bedtools`.

The bed data should look something like this:

```
> head(Sushi_GWAS.bed)

chr.hg18 pos.hg18 pos.hg18.1      rsid pval.GC.DBP V6
1   chr1  1695996   1695996   rs6603811    0.003110 .
2   chr1  1696020   1696020   rs7531583    0.000824 .
3   chr1  1698661   1698661   rs12044597    0.001280 .
4   chr1  1711339   1711339   rs2272908    0.001510 .
5   chr1  1712792   1712792   rs3737628    0.001490 .
6   chr1  1736016   1736016   rs12408690    0.004000 .
```

And the genome file should look like this:

```
> head(Sushi_hg18_genome)

      V1      V2
1 chr1 247249719
2 chr10 135374737
```

```

3 chr11 134452384
4 chr12 132349534
5 chr13 114142980
6 chr14 106368585

```

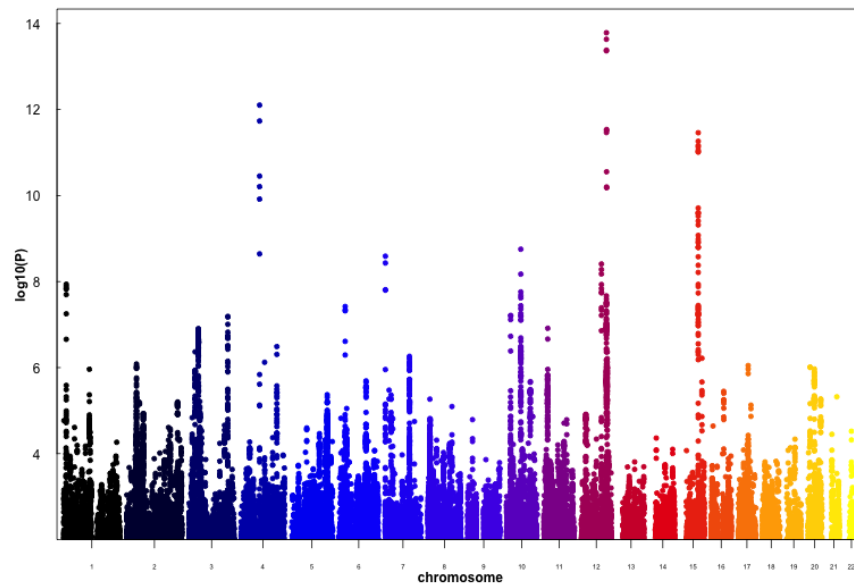
The `plotManhattan()` function is used to plot the data while the `labelgenome()` function is used to add the genome labels to the x-axis. The `labelgenome()` function also requires a genome object.

```

> plotManhattan(bedfile=Sushi_GWAS.bed,pvalues=Sushi_GWAS.bed[,5],
               col=SushiColors(6),genome=Sushi_hg18_genome,cex=0.75)
> labelgenome(genome=Sushi_hg18_genome,n=4,scale="Mb",
             edgeblankfraction=0.20,cex.axis=.5)
> axis(side=2,las=2,tcl=.2)
> mtext("log10(P)",side=2,line=1.75,cex=1,font=2)
> mtext("chromosome",side=1,line=1.75,cex=1,font=2)

```

pdf
2



3.8 plotGenes

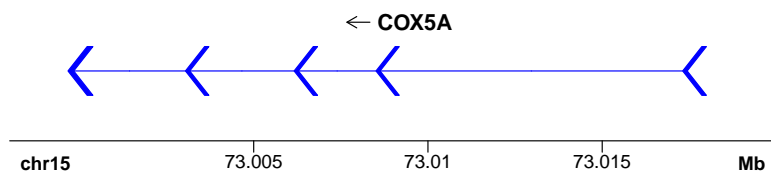
`plotGenes()` can be used to plot gene structures that are stored in bed format. If no `geneinfo` object is provided genes are looked up in the region using biomart with `biomart='ensembl'` and `dataset='hsapiens_gene_ensembl'`.

```
> head(Sushi_genes.bed)
```

	chrom	start	stop	gene	score	strand
1	chr15	73017309	73017438	COX5A	.	-1
2	chr15	72999672	72999836	COX5A	.	-1
3	chr15	73003042	73003164	COX5A	.	-1
4	chr15	73006160	73006281	COX5A	.	-1
5	chr15	73008510	73008626	COX5A	.	-1

Using `plotGenes()` with arguments `bentline=FALSE` and `plotgenetype="arrow"` produces arrow and line gene structures.

```
> chrom          = "chr15"
> chromstart      = 72998000
> chromend        = 73020000
> pg = plotGenes(Sushi_genes.bed, chrom, chromstart, chromend ,
                 types=Sushi_genes.bed$type, maxrows=1, bheight=0.2,
                 plotgenetype="arrow", bentline=FALSE,
                 labeloffset=.4, fontsize=1.2, arrowlength = 0.025,
                 labeltext=TRUE)
> labelgenome( chrom, chromstart, chromend, n=3, scale="Mb")
```



This function can also be used to plot transcript structures. The first 20 lines of a data frame describing RNA seq data are shown below.

```
> Sushi_transcripts.bed[1:20,]
```

	chrom	start	stop	gene	score	strand	type
1	chr15	73062668	73062770	ENST000000362710	0.000000	-1	exon
2	chr15	73097788	73097929	ENST000000361900	0.000000	1	exon
3	chr15	73097264	73097365	ENST000000361900	0.000000	1	exon
4	chr15	73095987	73096143	ENST000000361900	0.000000	1	exon
5	chr15	73092071	73092199	ENST000000361900	0.000000	1	exon
6	chr15	73091234	73091240	ENST000000361900	0.000000	1	exon
7	chr15	73017309	73017408	ENST000000322347	31.488695	-1	exon
8	chr15	73006160	73006281	ENST000000322347	31.488695	-1	exon

9	chr15	73008510	73008626	ENST00000322347	31.488695	-1	exon
10	chr15	72984058	72984106	ENST00000357635	7.473977	-1	exon
11	chr15	72984548	72984625	ENST00000357635	7.473977	-1	exon
12	chr15	72985672	72985759	ENST00000357635	7.473977	-1	exon
13	chr15	72985981	72986194	ENST00000357635	7.473977	-1	exon
14	chr15	72975546	72975719	ENST00000379693	2.422616	1	exon
15	chr15	72972532	72972714	ENST00000379693	2.422616	1	exon
16	chr15	72972055	72972196	ENST00000379693	2.422616	1	exon
17	chr15	72970773	72970973	ENST00000379693	2.422616	1	exon
18	chr15	72969965	72970048	ENST00000379693	2.422616	1	exon
19	chr15	72972532	72972714	ENST00000352410	0.917141	1	exon
20	chr15	72972055	72972196	ENST00000352410	0.917141	1	exon

A vector type can be used to specify if each region is an 'exon' or 'utr' while `plotgenetype="box"` plots regions as a boxes rather than arrows. The data can be plotted using `plotGenes()`. The `colorby` argument is used to color the transcripts by $\log_{10}(\text{FPKM})$. UTR regions are drawn as shorter boxes than exons.

```
> chrom = "chr15"
> chromstart = 72965000
> chromend = 72990000
> pg = plotGenes(Sushi_transcripts.bed, chrom, chromstart, chromend ,
  types = Sushi_transcripts.bed$type,
  colorby=log10(Sushi_transcripts.bed$score+0.001),
  colorbycol= SushiColors(5), colorbyrange=c(0,1.0),
  labeltext=TRUE, maxrows=50, height=0.4, plotgenetype="box")
> labelgenome( chrom, chromstart, chromend, n=3, scale="Mb")
> addlegend(pg[[1]], palette=pg[[2]], title="log10(FPKM)", side="right",
  bottominset=0.4, topinset=0, xoffset=-.035, labelside="left",
  width=0.025, title.offset=0.055)
```



3.9 Zoom functions

A critical characteristic of the Sushi package is its ability to create highly customizable, publication-ready, multi-panel figures. Here, we will create a basic three panel figure and demonstrate how the zoom functions work (`zoomsregion` and `zoombox`). To illustrate these feature we will use the `plotBedgraph()` function to plot bedgraph data representing a DNaseI hypersensitivity experiment in K562 cells.

In order to make a multipanel figure we will use the R function `layout`. `Layout` divides the device into rows and columns according to a matrix you provide. The matrix also tells it which plots will appear on which parts of the plotting device. Below we make a 2 by 2 matrix. The entire top row will be used to plot the first plot while the bottom row will contain two plots. For more info on `layout` try `?layout`.

```
> layout(matrix(c(1,1,2,3),2, 2, byrow = TRUE))
> par(mar=c(3,4,1,1))
```

Next we will add the first plot

```
> chrom          = "chr11"
> chromstart     = 1900000
> chromend       = 2350000
```

```

> plotBedgraph(Sushi_DNaseI.bedgraph,chrom,chromstart=chromstart,
               chromend=chromend,colorbycol= SushiColors(5))
> labelgenome(chrom,chromstart=chromstart,chromend=chromend,n=4,
               scale="Mb")
> mtext("Read Depth",side=2,line=1.75,cex=1,font=2)
> axis(side=2,las=2,tcl=.2)

```



Next we will add the zoom regions using the function `zoomsregion()`. The argument `offsets` is used to precisely position the left and right edges of the widest part of the zoom.

```

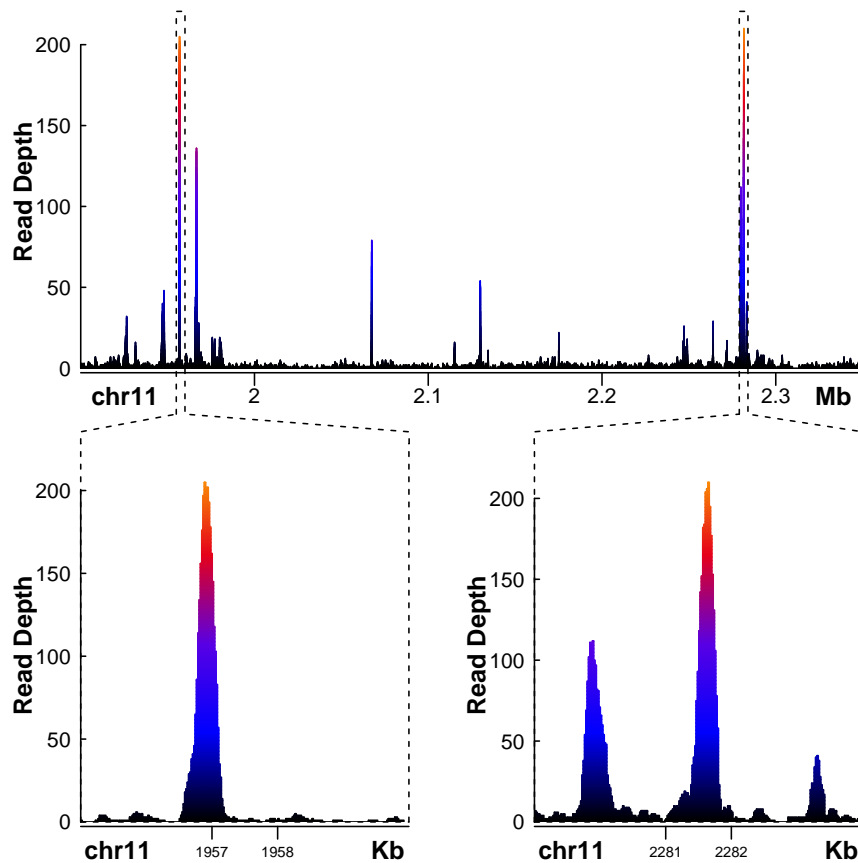
> zoomregion1      = c(1955000,1960000)
> zoomregion2      = c(2279000,2284000)
> zoomsregion(zoomregion1,extend=c(0.01,0.13),wideextend=0.05,
               offsets=c(0,0.580))
> zoomsregion(zoomregion2,extend=c(0.01,0.13),wideextend=0.05,
               offsets=c(0.580,0))

```



Then we can add each of the zoomed inset regions. For, each region we need execute the `zoombox` function in order to draw the lines around the new plots.

```
> plotBedgraph(Sushi_DNaseI.bedgraph,chrom,chromstart=zoomregion1[1],
  chromend=zoomregion1[2],colorbycol= SushiColors(5))
> labelgenome(chrom,chromstart=zoomregion1[1],chromend=zoomregion1[2],
  n=4,scale="Kb",edgeblankfraction=0.2,cex.axis=.75)
> zoombox()
> mtext("Read Depth",side=2,line=1.75,cex=1,font=2)
> axis(side=2,las=2,tcl=.2)
> plotBedgraph(Sushi_DNaseI.bedgraph,chrom,chromstart=zoomregion2[1],
  chromend=zoomregion2[2],colorbycol= SushiColors(5))
> labelgenome(chrom,chromstart=zoomregion2[1],chromend=zoomregion2[2],
  n=4,scale="Kb",edgeblankfraction=0.2,cex.axis=.75)
> zoombox()
> mtext("Read Depth",side=2,line=1.75,cex=1,font=2)
> axis(side=2,las=2,tcl=.2)
```

3.10 Color functions

Sushi includes three functions to assist in the generating of R colors and color palettes: `SushiColors()`, `maptocolors()`, `opaque()`.

3.10.1 SushiColors

`SushiColors()` provides default color palettes for the Sushi package.

To see a list of available color palettes:

```
> SushiColors(palette='list')
```

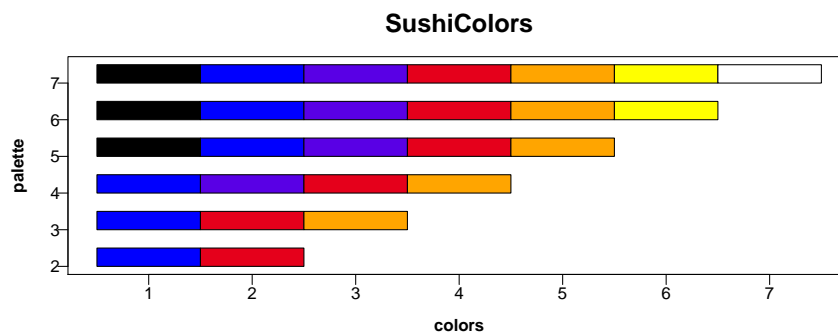
```
[1] 2 3 4 5 6 7
```

To view the color palettes:

```

> plot(1,xlab='',xaxt='n',ylab='',yaxt='n',xlim=c(0.5,7.5),
      ylim=c(2,7.5),type='n')
> for (i in (2:7))
{
  for (j in (1:i))
  {
    rect(j-.5,i,j+.5,i+.5,col=SushiColors(i)(i)[j])
  }
}
> axis(side=2,at=(2:7),labels=(2:7),las=2)
> axis(side=1,at=(1:7),labels=(1:7))
> mtext("SushiColors",side=3,font=2, line=1, cex=1.5)
> mtext("colors",side=1,font=2, line=2)
> mtext("palette",side=2,font=2, line=2)

```



3.10.2 opaque

`opaque()` takes any color or vector of colors and makes them opaque. The degree of transparency is determined by the argument `transparency` which is a value between 0 and 1.

```

> plot(1,xlab='',xaxt='n',ylab='',yaxt='n',bty='n',type='n',
      xlim=c(-.15,1.05),ylim=c(-1,2))
> for (i in seq(0,1,by=0.1))
{
  rect(i-.05,-1,i+.05,1,col=opaque("red",transparency=i))
  rect(i-.05,0,i+.05,2,col=opaque("blue",transparency=1-i))
}
> axis(side=1,at=seq(0,1,by=0.1),labels=seq(0,1,by=0.1))
> mtext("red transparency",side=1,font=2, line=2)
> axis(side=3,at=seq(0,1,by=0.1),labels=seq(1,0,by=-0.1))
> mtext("blue transparency",side=3,font=2, line=2)
> text(-0.075,1.5,labels="blue",font=2,adj=1)

```

```
> text(-0.075,0.5,labels="overlap",font=2,adj=1)
> text(-0.075,-.5,labels="red",font=2,adj=1)
```



3.10.3 maptocolors

`maptocolors()` takes a vector of values and maps them to a color palette which can be used for plotting.

```
> set.seed(3)
> values = rnorm((1:10))
> colorpalette = SushiColors(5)
> plot(x=(1:10),y=values,col=maptocolors(values,colorpalette),
      pch=19,cex=4,xlab="data points",yaxt='n',ylim=range(values)*1.2)
> addlegend(range(values),title="key",palette=colorpalette,
      side='left',xoffset = -0.125,width=0.03,bottominset = 0.5, topinset = 0.025)
> axis(side=2,las=2)
```



3.11 labeling functions

3.11.1 labelgenome

`labelgenome()` Add genome coordinates to the x-axis of a plot. The `line` argument can be used to offset the axis and `n` can be used to determine the desired number of tick marks.

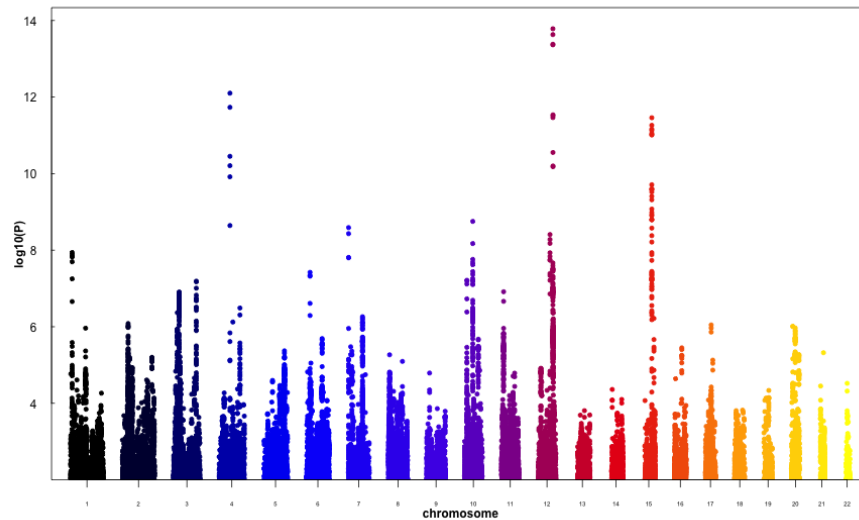
```
> par(mar=c(8,3,3,1),mgp=c(3, .3, 0))
> plotBedgraph(Sushi_DNaseI.bedgraph,chrom="chr11",chromstart=1650000,
               chromend=2350000,colorbycol=SushiColors(7))
> labelgenome(chrom="chr11",chromstart=1650000,chromend=2350000,
               side=1,n=4,scale="Mb",line=.25)
> labelgenome(chrom="chr11",chromstart=1650000,chromend=2350000,
               side=1,n=3,scale="Kb",line=2)
> labelgenome(chrom="chr11",chromstart=1650000,chromend=2350000,
               side=1,n=1,scale="bp",line=4)
```



Manhattan plots include multiple genomes and labeling the axes of Manhattan plots requires the same `genome` object and value of `space` that were used to in `plotManhattan()`

```
> plotManhattan(bedfile=Sushi_GWAS.bed,pvalues=Sushi_GWAS.bed[,5],
                 col=SushiColors(6),genome=Sushi_hg18_genome,
                 cex=0.75,space=0.05)
> labelgenome(genome=Sushi_hg18_genome,n=4,scale="Mb",
               edgeblankfraction=0.20,cex.axis=.5,space=0.05)
> axis(side=2,las=2,tcl=.2)
> mtext("log10(P)",side=2,line=1.75,cex=1,font=2)
> mtext("chromosome",side=1,line=1.75,cex=1,font=2)
```

pdf
2



3.11.2 labelplot

Plot labels and titles can be added with the `labelplot()` function.

```
> labelplot("A ", "Manhattan Plot")

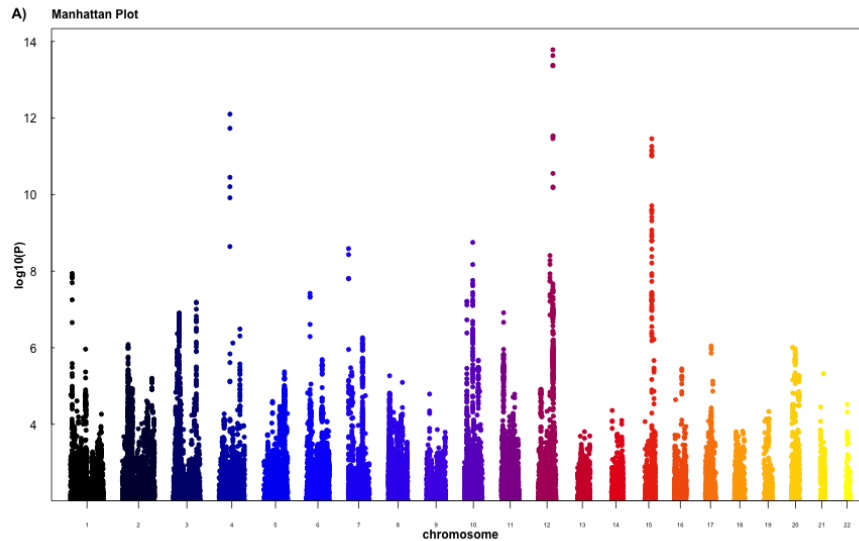
> plotManhattan(bedfile=Sushi_GWAS.bed, pvalues=Sushi_GWAS.bed[,5],
               col=SushiColors(6), genome=Sushi_hg18_genome,
               cex=0.75, space=0.05)

> labelgenome(genome=Sushi_hg18_genome, n=4, scale="Mb"
             , edgeblankfraction=0.20, cex.axis=.5, space=0.05)

> axis(side=2, las=2, tcl=.2)
> mtext("log10(P)", side=2, line=1.75, cex=1, font=2)
> mtext("chromosome", side=1, line=1.75, cex=1, font=2)
> labelplot("A ", "Manhattan Plot")
```

pdf

2



```
[1] TRUE
```

4 Tips

Other popular file formats such as BAM and GFF are not explicitly supported by Sushi. However, data stored in these formats can be easily converted to BED format using common command line tools such as the `bedtools` software suite available at <https://github.com/arq5x/bedtools2>. Some examples taken from the `bedtools` are shown below.

Convert BAM alignments to BED format.

```
bamToBed -i reads.bam > reads.bed
```

Convert BAM alignments to BED format using edit distance (NM) as the BED score.

```
bamToBed -i reads.bam -ed > reads.bed
```

Convert BAM alignments to BEDPE format.

```
bamToBed -i reads.bam -bedpe > reads.bedpe
```

These BED files can easily be read into R for use with Sushi using the following R command:

```
> read.table(file="reads.bed", sep="\t")
```

5 Appendix

For illustrative purposes we include a complex figure as published in the accompanying manuscript (Phanstiel, et al.).

```
1 library( 'Sushi' )
2 pdfname = "vignettes/Figure_1.pdf"
3 Sushi_data = data(package = 'Sushi')
4 data(list = Sushi_data$results[,3])
5 makepdf = TRUE
6
7 ###
8 ### CODE
9 ###
10
11 if (makepdf == TRUE)
12 {
13   pdf(pdfname, height=10, width=12)
14 }
15
16 # make a layout for all of the plots
17 layout(matrix(c(1,1,1,1,
18                 1,1,1,1,
19                 2,2,8,8,
20                 2,2,9,9,
21                 3,3,10,10,
22                 3,3,10,10,
23                 4,4,11,11,
24                 4,4,11,11,
25                 5,5,12,12,
26                 5,5,12,12,
27                 6,7,13,13,
28                 6,7,14,14
29 ), 12, 4, byrow=TRUE))
30 par(mgp=c(3,.3,0))
31
32
33 ###
34 ### (A) manhattan plot
35 ###
36
37 # set the margins
38 par(mar=c(3,4,3,2))
39
40 # set the genomic regions
41 chrom1 = "chr11"
42 chromstart1 = 500000
43 chromend1 = 5050000
44
45 chrom2 = "chr15"
```



```

46 chromstart2      = 73000000
47 chromend2        = 89500000
48
49 # make the manhattan plot
50 plotManhattan( bedfile=Sushi_GWAS.bed, pvalues=Sushi_GWAS.bed
51                [,5], genome=Sushi_hg18_genome, cex=0.75)
52
53 # add zoom 1
54 zoomsregion(region=c(chromstart1,chromend1), chrom=chrom1,
55                genome=Sushi_hg18_genome, extend=c(0.07,0.2), wideextend
56                =0.2, offsets=c(0,.535))
57
58 # add zoom 2
59 zoomsregion(region=c(chromstart2,chromend2), chrom=chrom2,
60                genome=Sushi_hg18_genome, extend=c(0.07,0.2), wideextend
61                =0.2, offsets=c(.535,0))
62
63 # add labels
64 labelgenome(genome=Sushi_hg18_genome, n=4, scale="Mb",
65             edgeblankfraction=0.20)
66
67 # add y-axis
68 axis(side=2, las=2, tcl=.2)
69 mtext("log10(P)", side=2, line=1.75, cex=.75, font=2)
70
71 # Add plot label
72 labelplot("A)", "_GWAS", letteradj=-.025)
73
74 ####
75 #### (B) Hi-C
76 ####
77
78 # set the margins
79 par(mar=c(3,4,2,2))
80
81 # set the genomic regions
82 chrom          = "chr11"
83 chromstart     = 500000
84 chromend       = 5050000
85 zoomregion     = c(1700000,2350000)
86
87 # plot the HiC data
88 phic = plotHic(Sushi_HiC.matrix, chrom, chromstart, chromend,
89               max_y = 20, zrange=c(0,28))
90
91 # add labels
92 labelgenome(chrom, chromstart, chromend, n=4, scale="Mb",
93             edgeblankfraction=0.20)
94
95

```

```

88 # add the legend
89 addlegend(phic[[1]], palette=phic[[2]], title="score", side="
    right", bottominset=0.4, topinset=0, xoffset=-.035,
    labelside="left", width=0.025, title.offset=0.035)
90
91 # add zoom
92 zoomsregion(region=zoomregion, extend=c(0.05,0.25))
93
94 # add zoombox
95 zoombox(zoomregion=zoomregion)
96
97 # Add plot label
98 labelplot("B", "_HiC")
99
100
101 ###
102 ### (C) 5C
103 ###
104
105 # set the margins
106 par(mar=c(3,4,2,2))
107
108 # set the genomic regions
109 chrom          = "chr11"
110 chromstart     = 1650000
111 chromend       = 2350000
112
113 # plot the loops
114 pbpe = plotBedpe(Sushi_5C.bedpe, chrom, chromstart, chromend,
    heights=Sushi_5C.bedpe$score, offset=0, flip=FALSE, bty='n',
    lwd=1, plotype="loops", colorby=Sushi_5C.bedpe$
    samplenummer, colorbycol=SushiColors(3))
115
116 # add zoombox
117 zoombox(passthrough=TRUE)
118
119 # add the genome labels
120 labelgenome(chrom, chromstart, chromend, n=3, scale="Mb")
121
122 # add the legend
123 legend("topright", inset=0.01, legend=c("K562", "HeLa", "GM12878
    "), col=SushiColors(3)(3), pch=19, bty='n', text.font=2)
124
125 # add y-axis
126 axis(side=2, las=2, tcl=.2)
127 mtext("Z-score", side=2, line=1.75, cex=.75, font=2)
128
129 # Add plot label
130 labelplot("C", "_5C")
131

```

```

132
133 ###
134 ### (D) ChIA PET (PolII)
135 ###
136
137 # set the margins
138 par(mar=c(3,4,2,2))
139
140 # set the genomic regions
141 chrom = "chr11"
142 chromstart = 1650000
143 chromend = 2350000
144
145 # plot the loops
146 pbpe = plotBedpe(Sushi_ChIAPET_pol2.bedpe, chrom, chromstart,
147                 chromend, flip=TRUE, bty='n', lwd=1, plotype="lines",
148                 colorby=abs(Sushi_ChIAPET_pol2.bedpe$start1-Sushi_ChIAPET_
149                             pol2.bedpe$start2), colorbycol=SushiColors(5))
150
151 # add the genome labels
152 labelgenome(chrom, chromstart, chromend, n=4, scale="Mb")
153
154 # add the legend
155 addlegend(pbpe[[1]], palette=pbpe[[2]], title="distance_(bp)",
156           side="right", bottominset=0.05, topinset=0.35, xoffset
157           =-.035, labelside="left", width=0.025, title.offset=0.08,
158           labels.digits=0)
159
160 # add zoombox
161 zoombox(passthrough=TRUE)
162
163 # Add plot label
164 labelplot("D)", "_ChIA-PET_(Pol2)")
165
166 ###
167 ### (E) DNaseI
168 ###
169
170 # set the margins
171 par(mar=c(3,4,2,2))
172
173 # set the genomic regions
174 chrom = "chr11"
175 chromstart = 1650000
176 chromend = 2350000
177 zoomregion1 = c(1860000,1861000)
178 zoomregion2 = c(2281000,2282400)
179
180 # overlapping, transparent, and rescaled

```

```

176 plotBedgraph(Sushi_DNaseI.bedgraph, chrom, chromstart,
               chromend, colorbycol=SushiColors(5))
177
178 # add zoom 1
179 zoomsregion(zoomregion1, extend=c(-0.8,0.18), wideextend=0.10,
              offsets=c(0,.577))
180
181 # add the genome labels
182 labelgenome(chrom, chromstart, chromend, n=4, scale="Mb")
183
184 # add zoombox
185 zoombox(zoomregion=zoomregion)
186
187 # add zoom 2
188 zoomsregion(zoomregion2, extend=c(0.01,0.18), wideextend=0.10,
              offsets=c(.577,0))
189
190 # add y-axis
191 axis(side=2, las=2, tcl=.2)
192 mtext("Read_Depth", side=2, line=1.75, cex=.75, font=2)
193
194 # Add plot label
195 labelplot("E", "_DNaseI")
196
197
198 ###
199 ### (F) ChIP-Seq ChIP Exo
200 ###
201
202 # set the genomic regions
203 chrom          = "chr11"
204 chromstart     = 1650000
205 chromend       = 2350000
206 zoomregion1    = c(1860000,1861000)
207 zoomregion2    = c(2281000,2282400)
208
209 # plot chip-seq data
210 plotBedgraph(Sushi_ChIPSeq-CTCF.bedgraph, chrom, zoomregion1
              [1], zoomregion1[2], transparency=.50, color=SushiColors
              (2)(2)[1])
211
212 # plot chip-seq data
213 plotBedgraph(Sushi_ChIPExo-CTCF.bedgraph, chrom, zoomregion1
              [1], zoomregion1[2], transparency=.50, color=SushiColors
              (2)(2)[2], overlay=TRUE, rescaleoverlay=TRUE)
214
215 # Add plot label
216 labelplot("F", "_ChIP-Seq/_ChIP-Exo", letteradj=-.125)
217
218 # add the genome labels

```

```

219 labelgenome(chrom, zoomregion1[1], zoomregion1[2], n=3, line
      =.5, scale="Mb", edgeblankfraction=0.2)
220
221 # add zoombox
222 zoombox()
223
224 # add legend
225 legend("topright", inset=0.025, legend=c("ChIP-seq_(CTCF)",
      ChIP-exo_(CTCF)", fill=opaque(SushiColors(2)(2),0.5),
      border=SushiColors(2)(2), text.font=2, cex=0.75)
226
227
228 ###
229 #### (G) Bed Pile up
230 ###
231
232 # set the genomic regions
233 chrom          = "chr11"
234 chromstart     = 1650000
235 chromend       = 2350000
236 zoomregion1    = c(1955000,1965000)
237 zoomregion2    = c(2281000,2282400)
238
239 # plt the chip-seq data as a pile-up
240 plotBed(beddata=Sushi_ChIPSeq_pol2.bed, chrom=chrom,
      chromstart=zoomregion2[1], chromend=zoomregion2[2],
      colorby=Sushi_ChIPSeq_pol2.bed$strand, colorbycol=
      SushiColors(2), wiggle=0.001, height=0.25)
241
242 # add the genome labels
243 labelgenome(chrom, zoomregion2[1], zoomregion2[2], n=2, scale=
      "Mb")
244
245 # add zoombox
246 zoombox()
247
248 # add legend
249 legend("topright", inset=0.025, legend=c("reverse","forward"),
      fill=SushiColors(2)(2), border=SushiColors(2)(2), text.
      font=2, cex=0.75)
250
251 # Add plot label
252 labelplot("G", "_ChIP-Seq", letteradj=-.125)
253
254
255 ###
256 #### (H) manhattan plot zoomed
257 ###
258
259 # set the margins

```

```

260 par(mar=c(0.1,4,2,2))
261
262 # set the genomic regions
263 chrom          = "chr15"
264 chromstart     = 60000000
265 chromend       = 80000000
266 chromstart2    = 72000000
267 chromend2      = 74000000
268
269 # make the manhattan plot
270 plotManhattan(bedfile=Sushi_GWAS.bed, chrom=chrom2, chromstart
               =chromstart, chromend=chromend, pvalues=Sushi_GWAS.bed$
               pval.GC.DBP, col=SushiColors(6)(nrow(Sushi_hg18_genome))
               [15], cex=0.75)
271
272 # add zoom in
273 zoomsregion(region=c(chromstart2,chromend2), chrom=chrom2,
               genome=NULL, extend=c(0.075,1), offsets=c(0.0,0))
274
275 # add zoom box
276 zoombox(passthrough=TRUE, toextend=5)
277
278 # add y-axis
279 axis(side=2, las=2, tcl=.2)
280 mtext("Z-score", side=2, line=1.75, cex=.75, font=2)
281
282 # Add plot label
283 labelplot("H", "_GWAS")
284
285
286 ###
287 ### (I) Gene density
288 ###
289
290 # set the margins
291 par(mar=c(3,4,1.8,2))
292
293 # set the genomic regions
294 chrom          = "chr15"
295 chromstart     = 60000000
296 chromend       = 80000000
297 chrom_biomart  = gsub("chr","",chrom)
298
299 # set the mart (since we want hg18 coordinates)
300 mart=useMart(host='may2009.archive.ensembl.org', biomart='
               ENSEMBL_MART_ENSEMBL', dataset='hsapiens_gene_ensembl')
301
302 # get just gene info
303 geneinfobed = getBM(attributes=c("chromosome_name","start_
               position","end_position"), filters=c("chromosome_name",

```

```

        start", "end"), values=list(chrom_biomart, chromstart,
        chromend), mart=mart)
304
305 # add "chr" to the chrom column
306 geneinfobed[,1] = paste("chr", geneinfobed[,1], sep="")
307
308 # plot gene density
309 plotBed(beddata=geneinfobed[!duplicated(geneinfobed),], chrom=
        chrom, chromstart=chromstart, row='supplied', chromend=
        chromend, palettes=list(SushiColors(7)), type="density")
310
311 #label genome
312 labelgenome(chrom=chrom, chromstart, chromend, n=4, scale="Mb"
        , edgeblankfraction=0.10)
313
314 # add zoom in
315 zoomsregion(region=c(chromstart2, chromend2), chrom=chrom2,
        genome=NULL, extend=c(2,1.0), wideextend=.75, offsets=c
        (0.0,0))
316
317 # add zoombox
318 zoombox(zoomregion=c(chromstart2, chromend2), topextend=5)
319
320 # Add plot label
321 labelplot("I", "_Gene_Density")
322
323
324 ###
325 ### (J) RNA seq
326 ###
327
328 # set the margins
329 par(mar=c(3,4,2,2))
330
331 # set the genomic regions
332 chrom2 = "chr15"
333 chromstart2 = 72800000
334 chromend2 = 73100000
335 zoomregion = c(72998000,73020000)
336 chrom2_biomart = 15
337
338 # plot transcripts
339 pg = plotGenes(Sushi_transcripts.bed, chrom2, chromstart2,
        chromend2, types=Sushi_transcripts.bed$type, colorby=log10
        (Sushi_transcripts.bed$score+0.001), colorbycol=
        SushiColors(5), labeltext=FALSE, maxrows=50, height=0.4,
        plotgenetype="box")
340
341 # label genome
342 labelgenome(chrom2, chromstart2, chromend2, n=3, scale="Mb")

```

```

343
344 # add the legend
345 addlegend(pg[[1]], palette=pg[[2]], title="log10(FPKM)", side=
      "right", bottominset=0.4, topinset=0, xoffset=-.035,
      labelside="left", width=0.025, title.offset=0.055)
346
347 # add zoombox
348 zoombox(passthrough=TRUE)
349
350 # add zoom
351 zoomsregion(region=zoomregion, extend=c(-.025,1))
352
353 # Add plot label
354 labelplot("J)", "_RNA-seq")
355
356
357 ###
358 #### (K) ChIP Seq peaks
359 ####
360
361 # set the margins
362 par(mar=c(3,4,2,2))
363
364 # set the genomic regions
365 chrom = "chr15"
366 chromstart = 72800000
367 chromend = 73100000
368 zoomregion = c(72998000,73020000)
369
370 Sushi_ChIPSeq_severalfactors.bed$color = maptoColors(Sushi_
      ChIPSeq_severalfactors.bed$row, col=SushiColors(6))
371
372 # plot it
373 plotBed(beddata=Sushi_ChIPSeq_severalfactors.bed, chrom=chrom,
      chromstart=chromstart, chromend=chromend, rownumber=Sushi_
      ChIPSeq_severalfactors.bed$row, type="circles", color=
      Sushi_ChIPSeq_severalfactors.bed$color, row="given",
      plotbg="grey95", rowlabels=unique(Sushi_ChIPSeq_
      severalfactors.bed$name), rowlabelcol=unique(Sushi_ChIPSeq_
      severalfactors.bed$color), rowlabelcex=0.75)
374
375 # label genome
376 labelgenome(chrom, chromstart, chromend, n=3, scale="Mb")
377
378 # add zoom
379 zoombox(zoomregion = zoomregion)
380
381 # add zoom in
382 zoomsregion(region=zoomregion, chrom=chrom, extend=c(0.5,.22),
      wideextend=0.15, offsets=c(0.0,0))

```



```

383
384 # Add plot label
385 labelplot("K", "_ChIP-seq")
386
387
388 ###
389 ### (L) Pol2 bedgraph
390 ###
391
392 # set the margins
393 par(mar=c(3,4,2,2))
394
395 # set the genomic regions
396 chrom          = "chr15"
397 chromstart     = 72998000
398 chromend       = 73020000
399
400 # plot the Pol2 bedgraph data
401 plotBedgraph(Sushi_ChIPSeq_pol2.bedgraph, chrom, chromstart,
              chromend, colorbycol=SushiColors(5))
402
403 # label genome
404 labelgenome(chrom, chromstart, chromend, n=3, scale="Mb")
405
406 # add zoombox
407 zoombox(passthrough=TRUE)
408
409 # add y-axis
410 axis(side=2, las=2, tcl=.2)
411 mtext("Read_Depth", side=2, line=1.75, cex=.75, font=2)
412
413 # Add plot label
414 labelplot("L", "_Chip-Seq_(Pol2)")
415
416
417 ###
418 ### (M) RNA-seq bedgraph
419 ###
420
421 # set the margins
422 par(mar=c(2,4,.5,2))
423
424 # set the genomic regions
425 chrom          = "chr15"
426 chromstart     = 72998000
427 chromend       = 73020000
428
429 # plot the K562 RNAseq bedgraph data
430 plotBedgraph(Sushi_RNASeq_K562.bedgraph, chrom, chromstart,
              chromend, colorbycol=SushiColors(5))

```

```

431
432 # label genome
433 labelgenome(chrom, chromstart, chromend, n=3, scale="Mb")
434
435 # add zoombox
436 zoombox(passthrough=TRUE)
437
438 # Add plot label
439 labelplot("M", "_RNA-seq")
440
441
442 ###
443 ### (N) Gene Structures
444 ###
445
446 # set the margins
447 par(mar=c(3,4,.5,2))
448
449 # set the genomic region
450 chrom          = "chr15"
451 chromstart     = 72998000
452 chromend       = 73020000
453
454 # plot gene structures
455 plotGenes(Sushi_genes.bed, chrom, chromstart, chromend,
            maxrows=1, bheight=0.15, plotgenetype="arrow", bentline=
            FALSE, labeloffset=1, fontsize=1.2, arrowlength = 0.01)
456
457 # label genome
458 labelgenome(chrom, chromstart, chromend, n=3, scale="Mb")
459
460 # add zoombox
461 zoombox()
462
463 # Add plot label
464 labelplot("N", "_Gene_Structures", letterline=-0.4, titleline
            =-0.4)
465
466 if (makepdf == TRUE)
467 {
468     dev.off()
469 }

```



6 Bibliography

- [1] Biomart. URL <http://www.biomart.org/>.
- [2] JR Dixon, S Selvaraj, F Yue, A Kim, Y Li, Y Shen, M Hu, JS Liu, and B Ren. Topological domains in mammalian genomes identified by analysis of chromatin interactions. *Nature*, 485, September 2012. doi: 10.1038/nature11082. PMID: 22495300.
- [3] International Consortium for Blood Pressure. Genetic variants in novel pathways influence blood pressure and cardiovascular disease risk. *Nature*, 478, September 2011. doi: 10.1038/nature10405. PMID: 21909115.
- [4] G Li, X Ruan, RK Auerbach, KS Sandhu, M Zheng, P Wang, HM Poh, Y Goh, J Lim, J Zhang, HS Sim, SQ Peh, FH Mulawadi, CT Ong, YL Orlov, S Hong, Z Zhang, S Landt, D Raha, G Euskirchen, CL Wei, W Ge, H Wang, C Davis, KI Fisher-Aylor, A Mortazavi, M Gerstein, T Gingeras, B Wold, Y Sun, MJ Fullwood, E Cheung, E Liu, WK Sung, M Snyder, and Y Ruan. Extensive promoter-centered chromatin interactions provide a topological basis for transcription regulation. *Cell*, 148:84–98, January 2012. doi: 10.1016/j.cell.2011.12.014. PMID: 22265404.

- [5] S Neph, J Vierstra, AB Stergachis, AP Reynolds, E Haugen, B Vernot, RE Thurman, S John, R Sandstrom, AK Johnson, MT Maurano, R Humbert, E Rynes, H Wang, S Vong, K Lee, D Bates, M Diegel, V Roach, D Dunn, J Neri, A Schafer, RS Hansen, T Kutyaivin, E Giste, M Weaver, T Canfield, P Sabo, M Zhang, G Balasundaram, R Byron, MJ MacCoss, JM Akey, MA Bender, M Groudine, R Kaul, and JA Stamatoyannopoulos. An expansive human regulatory lexicon encoded in transcription factor footprints. *Nature*, 489:83–90, September 2012. doi: 10.1038/nature11212. PMID: 22955618.
- [6] HS Rhee and BF Pugh. Comprehensive genome-wide protein-dna interactions detected at single-nucleotide resolution. *Cell*, 147, December 2011. doi: 10.1016/j.cell.2011.11.013. PMID: 22153082.
- [7] A Sanyal, BR Lajoie, G Jain, and J Dekker. The long-range interaction landscape of gene promoters. *Nature*, 489(7414):109–113, September 2012. doi: 10.1038/nature11279. PMID: 22955621.
- [8] The ENCODE Project Consortium. An integrated encyclopedia of DNA elements in the human genome. *Nature*, 489(7414):57–74, September 2012. ISSN 1476-4687. doi: 10.1038/nature11247. URL <http://www.ncbi.nlm.nih.gov/pubmed/22955616>. PMID: 22955616.