Разгоняем вставку Spring + PostgreSQL

Пару слов о себе:

- Фатов Дмитрий
- Более 12 лет в ИТ
- Пишу на Kotlin
- Работаю в Газпромбанке
- Создаем и строим решения на платформе G2

О чем доклад:

Как ускорить вставку данных в PostgreSQL

- Настройки Spring (Hibernate orm)

- Создание собственной прослойки для вставки данных в БД

- Использование кастомных методов PostgreSQL

- Распараллеливание процесса вставки

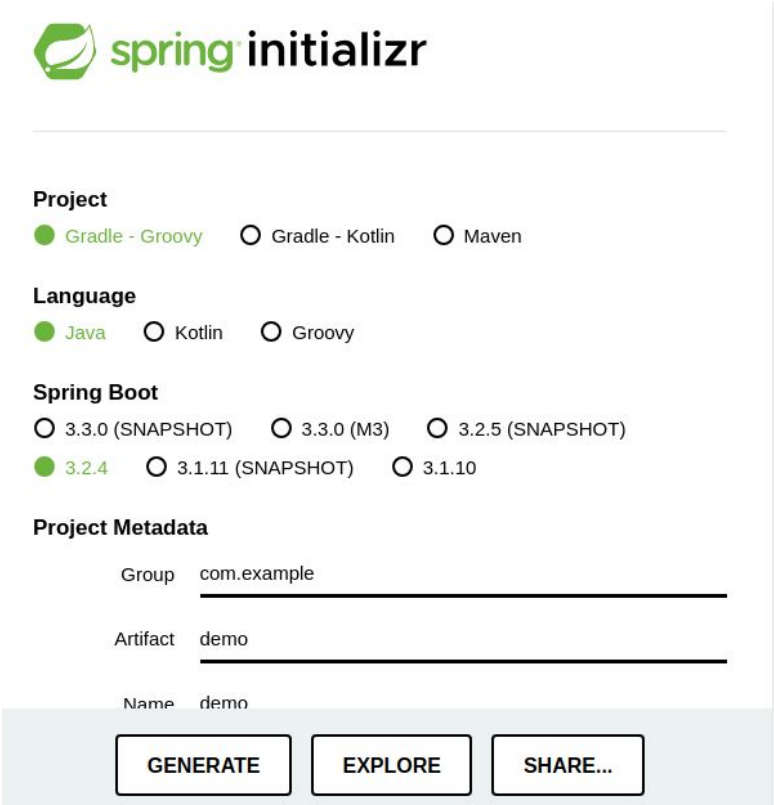
Немного предыстории:

- Разрабатываем SaaS
- Есть внешние интеграции через xml
- Было < 30 000 документов в одной выгрузке
- Стало ~ 2 000 000 документов в одной выгрузке = 4 000 000 записей в БД
- SLA < 5 минут на обмен данными со сторонними системами

Application

- Code and benchmars:
  https://github.com/FatovDI/acceleration-insertion-postgresql-pgconf2024
- Подготовленная БД, размер БД 32 Гб
- 100_000_000 строк в основной таблице с индексами
- Будем тестировать вставку на 4_000_000 записей
- Замеры: 3 итерации прогрева, 5 итераций замеров
- Окружение: java 17, PostgreSQL 14.5
- Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz, 12 ядер, 32gb ОЗУ

Spring



https://spring.io/quickstart

Spring

```kotlin
@Transactional
fun saveBySpring(count: Int) {
    val currencies = currencyRepo.findAll()
    val accounts = accountRepo.findAll()

    for (i in 0 ≤ until < count) {
        pdCustomRepository.save(
            getRandomEntity( id: null, currencies.random(), accounts.random())
        )
    }

}
```

Spring


```
"name": "Save by Spring",
"count": 4000000,
"time": "10 min, 28 sec 218 ms"
```


Spring

Hibernate caches all the newly inserted `Customer` instances in the session-level cache, so, when the transaction ends, 100 000 entities are managed by the persistence context. If the maximum memory allocated to the JVM is rather low,

Spring

```
log.info("start save $count by Spring")
for (i in 0 ≤ until < count) {
    pdCustomRepository.save(
        getRandomEntity( id: null, currencies.random(), accounts.random())
    )
}
log.info("end save $count by Spring")
```

```
14:43:03.699  INFO 637355 --- [nio-8080-exec-1] c.e.p.l.service.PaymentDocumentService   : start save 3 by Spring
insert into payment_document (account_id, amount, cur, expense, order_date, order_number, payment_purpose, prop_10,
insert into payment_document (account_id, amount, cur, expense, order_date, order_number, payment_purpose, prop_10,
insert into payment_document (account_id, amount, cur, expense, order_date, order_number, payment_purpose, prop_10,
14:43:03.738  INFO 637355 --- [nio-8080-exec-1] c.e.p.l.service.PaymentDocumentService   : end save 3 by Spring
14:43:03.745  INFO 637355 --- [nio-8080-exec-1] i.StatisticalLoggingSessionEventListener : Session Metrics {
```

Spring

```yaml
spring:
  jpa:
    properties:
      hibernate:
        generate_statistics: true
```

```
424698 nanoseconds spent acquiring 1 JDBC connections;
0 nanoseconds spent releasing 0 JDBC connections;
2621112236 nanoseconds spent preparing 4000006 JDBC statements;
514877687335 nanoseconds spent executing 4000006 JDBC statements;
0 nanoseconds spent executing 0 JDBC batches;
0 nanoseconds spent performing 0 L2C puts;
0 nanoseconds spent performing 0 L2C hits;
```

Как объединить данные в батчи?

Spring

```yaml
spring:
  jpa:
    properties:
      hibernate:
        jdbc:
          batch_size: 100000
```

```
424698 nanoseconds spent acquiring 1 JDBC connections;
0 nanoseconds spent releasing 0 JDBC connections;
2621112236 nanoseconds spent preparing 4000006 JDBC statements;
514877687335 nanoseconds spent executing 4000006 JDBC statements;
0 nanoseconds spent executing 0 JDBC batches;
0 nanoseconds spent performing 0 L2C puts;
0 nanoseconds spent performing 0 L2C hits;
```

Spring

Hibernate disables insert batching at the JDBC level transparently if you use an identity identifier generator.

```
CREATE SEQUENCE IF NOT EXISTS seq_id INCREMENT BY 1 NO MAXVALUE START WITH 1000000 CACHE 10 NO CYCLE;

ID bigint NOT NULL DEFAULT nextval('seq_id')
```

```
@Id
@GeneratedValue(strategy = GenerationType.IDENTITY)
var id: Long? = null
```

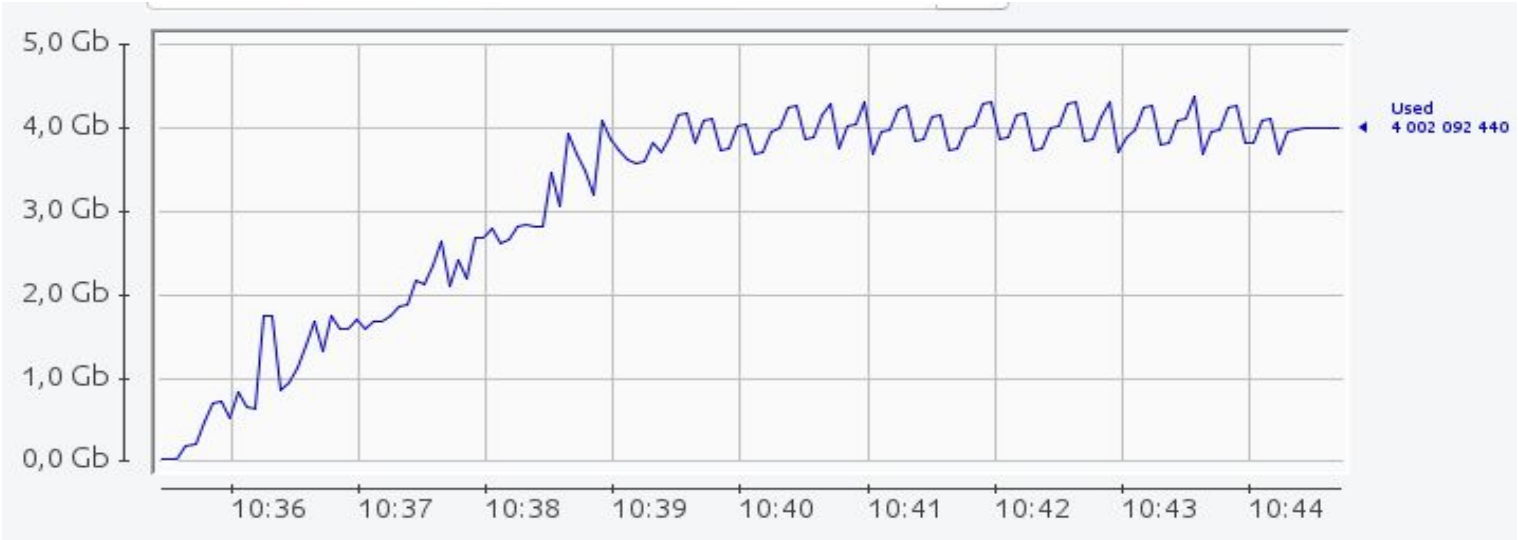


```
@Id
@SequenceGenerator(name = "seq_gen", sequenceName = "seq_id", allocationSize = 1)
@GeneratedValue(strategy = GenerationType.SEQUENCE, generator = "seq_gen")
var id: Long? = null
```

Spring with batch size 100k

```
"name": "Save by Spring",
"count": 4000000,
"time": "8 min, 4 sec 786 ms"
```

- 2 min 24 sec (23%)



Spring with batch size 100k

```
358179 nanoseconds spent acquiring 1 JDBC connections;
0 nanoseconds spent releasing 0 JDBC connections;
1465726582 nanoseconds spent preparing 4000007 JDBC statements;
129752963482 nanoseconds spent executing 4000006 JDBC statements;
295347948254 nanoseconds spent executing 40 JDBC batches;
0 nanoseconds spent performing 0 L2C puts;
0 nanoseconds spent performing 0 L2C hits;
```

```
15:36:00.014  INFO 640412 --- [nio-8080-exec-1] c.e.p.l.service.PaymentDocumentService   : start save 3 by Spring
select nextval ('seq_id')
select nextval ('seq_id')
select nextval ('seq_id')
15:36:00.042  INFO 640412 --- [nio-8080-exec-1] c.e.p.l.service.PaymentDocumentService   : end save 3 by Spring
insert into payment_document (account_id, amount, cur, expense, order_date, order_number, payment_purpose, prop_10,
insert into payment_document (account_id, amount, cur, expense, order_date, order_number, payment_purpose, prop_10,
insert into payment_document (account_id, amount, cur, expense, order_date, order_number, payment_purpose, prop_10,
15:36:00.060  INFO 640412 --- [nio-8080-exec-1] i.StatisticalLoggingSessionEventListener : Session Metrics {
```

ID caching

Как сократить запросы на получение ИД?

Caching PostgreSQL vs Application

```
CREATE SEQUENCE IF NOT EXISTS seq_id CACHE 50 NO CYCLE;
```

VS

```
ALTER SEQUENCE seq_id INCREMENT BY 50;
```

```
@Id
@SequenceGenerator(name = "seq_gen", sequenceName = "seq_id", allocationSize = 50)
```

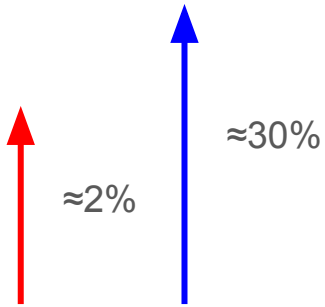
Application caching

```
919597 nanoseconds spent acquiring 1 JDBC connections;
0 nanoseconds spent releasing 0 JDBC connections;
34396639 nanoseconds spent preparing 80007 JDBC statements;
5850873179 nanoseconds spent executing 80006 JDBC statements;
246459321905 nanoseconds spent executing 40 JDBC batches;
0 nanoseconds spent performing 0 L2C puts;
0 nanoseconds spent performing 0 L2C hits;
```

```
23:08:39.918  INFO 383623 --- [nio-8080-exec-3] c.e.p.l.service.PaymentDocumentService    : start save 99 by Spring
select nextval ('seq_id')
select nextval ('seq_id')
23:08:39.947  INFO 383623 --- [nio-8080-exec-3] c.e.p.l.service.PaymentDocumentService    : end save 99 by Spring
insert into payment_document (account_id, amount, cur, expense, order_date, order_number, payment_purpose, prop_10,
insert into payment_document (account_id, amount, cur, expense, order_date, order_number, payment_purpose, prop_10,
insert into payment_document (account_id, amount, cur, expense, order_date, order_number, payment_purpose, prop_10,
```

Caching PostgreSQL vs Application

Save by Spring with app cache 50	5 min, 42 sec 565 ms
Save by Spring with pg cache 50	7 min, 56 sec 839 ms
Save by Spring without cache	8 min, 4 sec 786 ms



Caching PostgreSQL vs Application

Name: app cache 10 threads with save

Comments:

Write results to file / Read from file

Filename Browse... Log/Display

Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput
Save by spri...	30	131188	114686	141604	7092.67	0.00%	4.5/min
TOTAL	30	131188	114686	141604	7092.67	0.00%	4.5/min

Name: postgre cache 10 threads with save

Comments:

Write results to file / Read from file

Filename Browse... Log/Display

Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput
Save by spri...	30	162394	152883	168989	4216.57	0.00%	3.7/min
TOTAL	30	162394	152883	168989	4216.57	0.00%	3.7/min

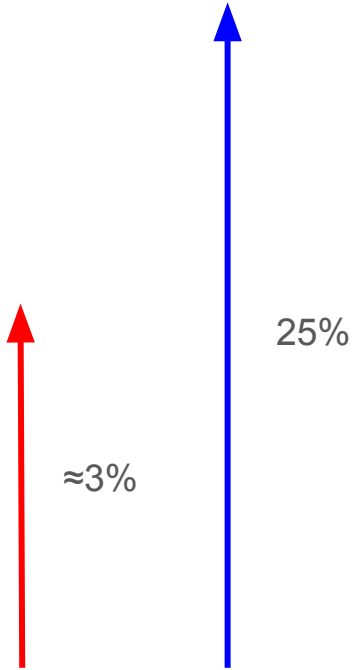
Name: without cache 10 theads with save

Comments:

Write results to file / Read from file

Filename Browse... Log/Display

Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput
Save by spri...	30	165457	143144	174207	6676.24	0.00%	3.6/min
TOTAL	30	165457	143144	174207	6676.24	0.00%	3.6/min



Id caching итого

Кеш на уровне приложения:

- Хороший прирост по производительности. До 30% при кешировании по 50 шт.

Кеш в PostgreSQL:

- Небольшой прирост по производительности. До 3% при кешировании по 50 шт.
- Сессионный. Не последовательное распределение id.

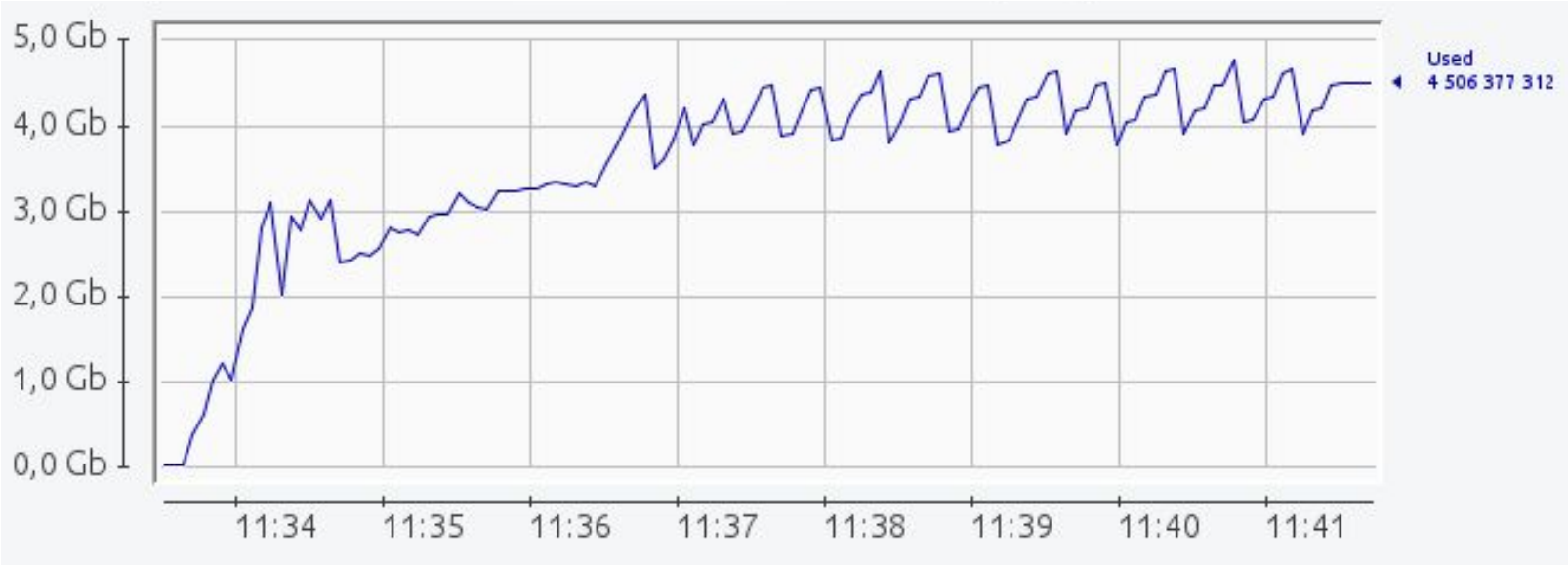
Spring with batch size 100k. Method saveAll()

```
@Transactional
fun saveBySpring(count: Int) {
    val currencies = currencyRepo.findAll()
    val accounts = accountRepo.findAll()

    (0 ≤.. ≤ count)
        .map {  getRandomEntity( id: null, currencies.random(), accounts.random()) }
        .let { it: List<PaymentDocumentEntity>
            pdCustomRepository.saveAll(it)
        }

}
```

Spring with batch size 100k. Method saveAll()

```
"name": "Save all via Spring",
"count": 4000000,
"time": "5 min, 36 sec 191 ms"
```

- 6 sec (2%)



Spring

```
Hibernate: insert into payment_document (account_id, amount, cur, expense, order_date, order_number,
  payment_purpose, prop_10, prop_15, prop_20, id) values (?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?)
Hibernate: insert into payment_document (account_id, amount, cur, expense, order_date, order_number,
  payment_purpose, prop_10, prop_15, prop_20, id) values (?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?)
```

```
2023-09-24 09:15:07.072 UTC [54] LOG:  execute S_4: insert into payment_document (account_id, amou
nt, cur, expense, order_date, order_number, payment_purpose, prop_10, prop_15, prop_20, id) values
($1, $2, $3, $4, $5, $6, $7, $8, $9, $10, $11)
2023-09-24 09:15:07.072 UTC [54] DETAIL:  parameters: $1 = '1000005', $2 = '0.8508023973840357', $
3 = 'RUB', $4 = 't', $5 = '2023-09-24', $6 = 'QJFqHvmcRb', $7 = 'MGhENeU3argzJDQHYdNAR5pZLYLyFq78K
Kt3kXaUSSeNMh3mwedQAvmemqBcBGv0I2pjMEziFjt7eRRzuLjloFnsmFVe6v2edHAJ', $8 = 'WXR4m468qQ', $9 = 'z8t
1qMct15tPuR3', $10 = 'LvM8o7ollfAQjqYv4t0q', $11 = '215382318'
```

Spring

```
INSERT INTO payment_document (account_id, amount, expense, cur, order_date, order_number, payment_purpose, prop_10,
                              prop_15, prop_20)
VALUES (1000004, '10.23', true, 'RUB', '2023-06-25', '123456', 'some purpose0', 'some 10', 'some 15', 'some 20');
INSERT INTO payment_document (account_id, amount, expense, cur, order_date, order_number, payment_purpose, prop_10,
                              prop_15, prop_20)
VALUES (1000005, '11.23', true, 'RUB', '2023-06-26', '123457', 'some purpose1', 'some 10', 'some 15', 'some 20');
INSERT INTO payment_document (account_id, amount, expense, cur, order_date, order_number, payment_purpose, prop_10,
                              prop_15, prop_20)
VALUES (1000006, '12.23', true, 'RUB', '2023-06-27', '123458', 'some purpose1', 'some 10', 'some 15', 'some 20');
```

```
INSERT INTO payment_document (account_id, amount, expense, cur, order_date, order_number, payment_purpose, prop_10,
                              prop_15, prop_20)
VALUES (1000004, '10.23', true, 'RUB', '2023-06-25', '123456', 'some purpose0', 'some 10', 'some 15', 'some 20'),
       (1000005, '11.23', true, 'RUB', '2023-06-26', '123457', 'some purpose1', 'some 10', 'some 15', 'some 20'),
       (1000006, '12.23', true, 'RUB', '2023-06-27', '123458', 'some purpose1', 'some 10', 'some 15', 'some 20');
```

Spring reWriteBatchedInserts

```
datasource:
  username: ${POSTGRES_USER_NAME}
  password: ${POSTGRES_PASSWORD}
  url: jdbc:postgresql://${POSTGRES_HOST
  hikari:
    schema: "test_insertion"
    data-source-properties:
      reWriteBatchedInserts: true
```

```
for (int i = 2; i <= batchSize; i++) {
  if (i > 2 || pos != 1) {
    // For "has binds" the first valuds
    s.append(',');
  }
  s.append(nativeSql, chunkStart[0], chunkEnd[0]);
  for (int j = 1; j < chunkStart.length; j++) {
    if (params == null) {
      NativeQuery.appendBindName(s, pos++);
    } else {
      s.append(params.toString(pos++, standardConformingStrings: true));
    }
    s.append(nativeSql, chunkStart[j], chunkEnd[j]);
  }
}
// Add trailing content: final query is like original with multi values.
// This could contain "--" comments, so it is important to add them at end.
s.append(nativeSql, start: valuesBraceClosePosition + 1, nativeSql.length());
sql = s.toString();
```

Spring reWriteBatchedInserts

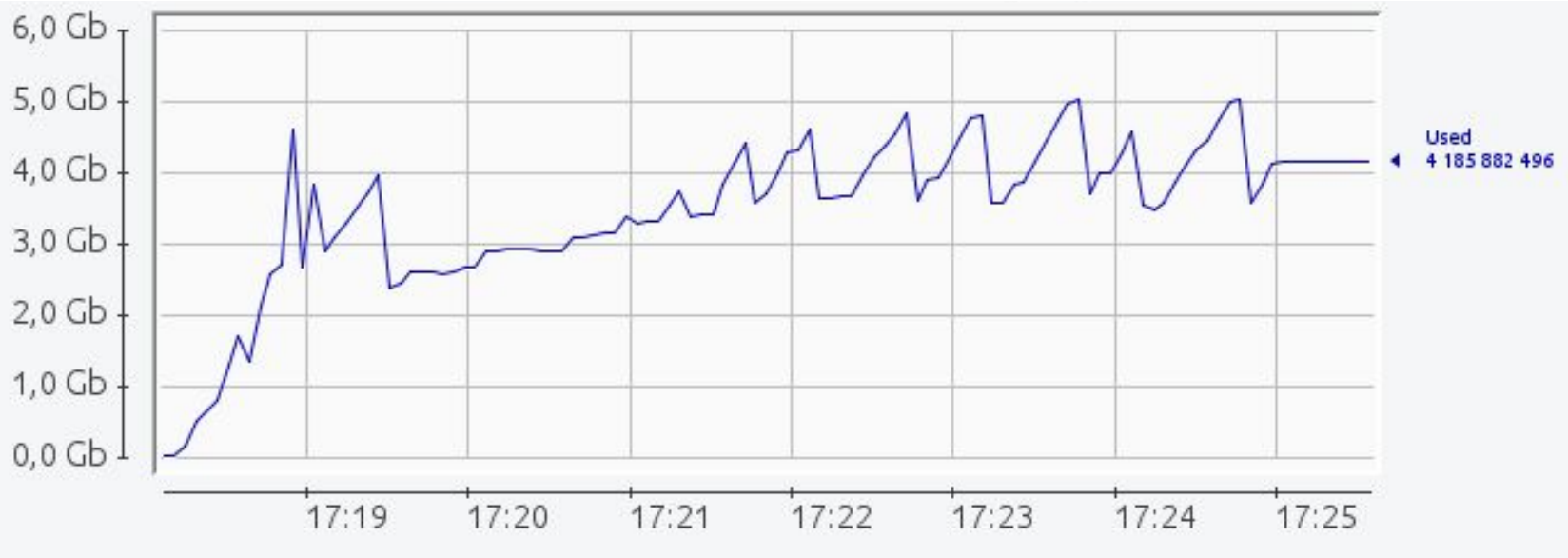
```
Hibernate: insert into payment_document (account_id, amount, cur, expense, order_date, order_number,
   payment_purpose, prop_10, prop_15, prop_20, id) values (?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?)
Hibernate: insert into payment_document (account_id, amount, cur, expense, order_date, order_number,
   payment_purpose, prop_10, prop_15, prop_20, id) values (?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?)
```

```
2023-09-24 12:00:08.120 UTC [299] LOG:  execute <unnamed>: insert into payment_document (account_id, a
mount, cur, expense, order_date, order_number, payment_purpose, prop_10, prop_15, prop_20, id) values
($1, $2, $3, $4, $5, $6, $7, $8, $9, $10, $11),($12, $13, $14, $15, $16, $17, $18, $19, $20, $21, $22)
2023-09-24 12:00:08.120 UTC [299] DETAIL:  parameters: $1 = '1000007', $2 = '0.5980502553274696', $3 =
 'USD', $4 = 'f', $5 = '2023-09-24', $6 = 'lnpXhMxqmJ', $7 = 'fY03MCMeVdovABpekvtIYIGwCxb2AcMLc7e5bgaq
lhkoalqKJdcQAGXTEt67Ldeo1ax2cpwOD7wyerMmTRsv85pxtmuJyLlIfRBw', $8 = 'WH0zrqSIMe', $9 = 'ymXzGYxukULMKT
t', $10 = 'Fla66GWWmqhRfw1gmIWS', $11 = '215382345', $12 = '1000004', $13 = '0.663112690442114', $14 =
 'USD', $15 = 'f', $16 = '2023-09-24', $17 = 'ctdFQ6lpdu', $18 = 'qbsRWtPujFF7i9TBQqknOSIeUE1plT2026db
FgCeMiIcMlVg1GopOuAcrPjCvZfdwB2w18amOdRELRlXpZucCqtCQOjzKRPwNNhc', $19 = 'IZwgH3whoM', $20 = 'AzPpm6eH
gO3neCc', $21 = '3y1l1OeoaYUXi8WSCzee', $22 = '215382346'
```

Spring reWriteBatchedInserts

```
"name": "Save by Spring",
"count": 4000000,
"time": "4 min, 37 sec 935 ms"
```

- 1 min
(17%)



Как сократить объем памяти?

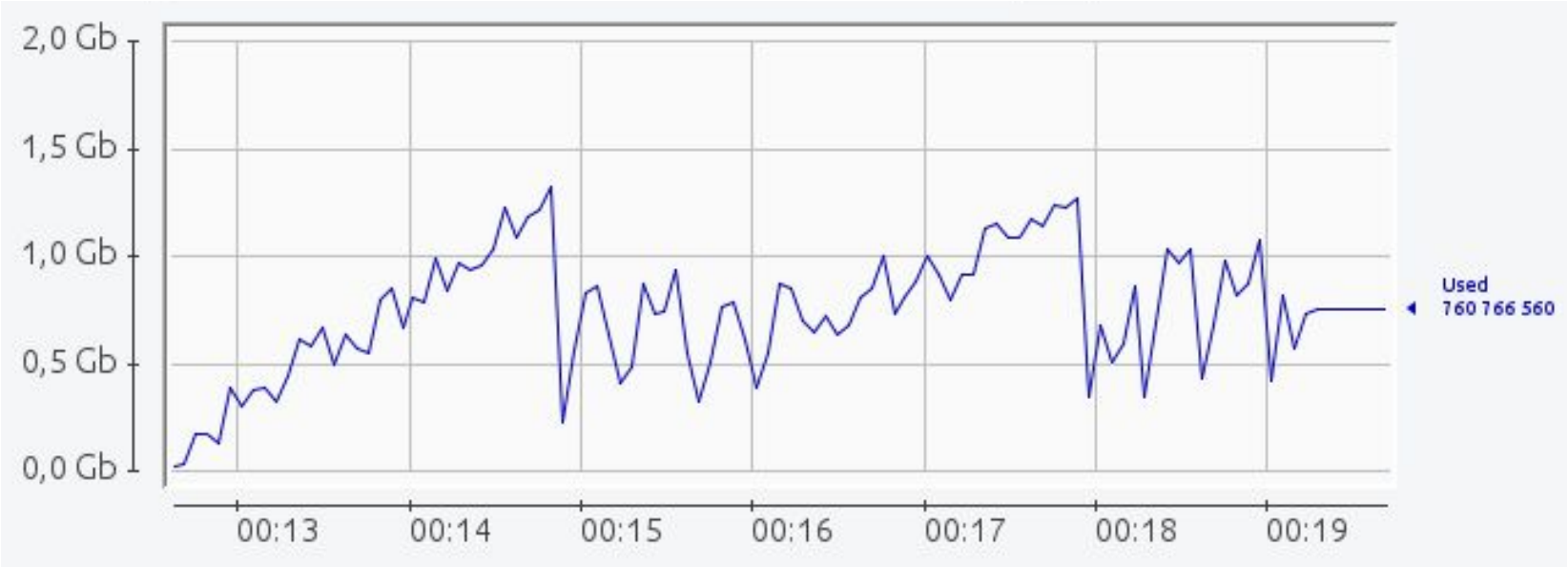
Spring with manual persisting

```
@PersistenceContext
lateinit var entityManager: EntityManager

@Transactional
fun saveBySpringWithManualBathing(count: Int) {
    val currencies = currencyRepo.findAll()
    val accounts = accountRepo.findAll()

    for (i in 0 ≤ until < count) {
        entityManager.persist(getRandomEntity( id: null, currencies.random(), accounts.random()))
        if (i != 0 && i % batchSize == 0) {
            entityManager.flush()
            entityManager.clear()
        }
    }
}
```

Spring with manual persisting and reWriteBatchedInserts

```
"name": "Save by Spring with manual batching",
"count": 4000000,
"time": "4 min, 19 sec 884 ms"
```

- 18 sec
(7%)



Spring

```yaml
spring:
  jpa:
    show-sql: false
    properties:
      hibernate:
        generate_statistics: true
        ddl-auto: validate
        jdbc:
          batch_size: ${batch_insertion.batch_size}
        order_inserts: true
```

Устанавливает порядок при сохранении нескольких типов сущностей в одной транзакции. Позволяет батчингу работать стабильно.

Spring. Итого:

Operation name	Time	Boost
Save with manual persisting	4 min, 19 sec 884 ms	≈7%
Add reWriteBatchedInserts	4 min, 37 sec 935 ms	≈17%
Save all	5 min, 36 sec 191 ms	≈2%
Add app id caching size 50	5 min, 42 sec 565 ms	≈29%
Add batching with size 100k	8 min, 4 sec 786 ms	≈23%
Save by default	10 min, 28 sec 218 ms	-

≈ 59%

Spring. Итого:

- Настройка batch_size позволяет отправлять данные батчам, не работает с GenerationType.IDENTITY
- Кеширование ID лучше делать на стороне приложения
- JDBC драйвер умеет преобразовывать обычный инсерт в пакетный
- Hibernate хранит все созданные данные в session-level cache до окончания транзакции. Можно очищать через EntityManager
- Удалось увеличить скорость вставки примерно на 60% (2,5 раза)

Может ну его, этот Hibernate?

Spring

Может ну его, этот hibernate?

```
INSERT INTO payment_document (account_id, amount, expense, cur, order_date, order_number, payment_purpose, prop_10,
                              prop_15, prop_20)
VALUES (1000004, '10.23', true, 'RUB', '2023-06-25', '123456', 'some purpose0', 'some 10', 'some 15', 'some 20'),
       (1000005, '11.23', true, 'RUB', '2023-06-26', '123457', 'some purpose1', 'some 10', 'some 15', 'some 20'),
       (1000006, '12.23', true, 'RUB', '2023-06-27', '123458', 'some purpose1', 'some 10', 'some 15', 'some 20');
```

Application

Как?

Application

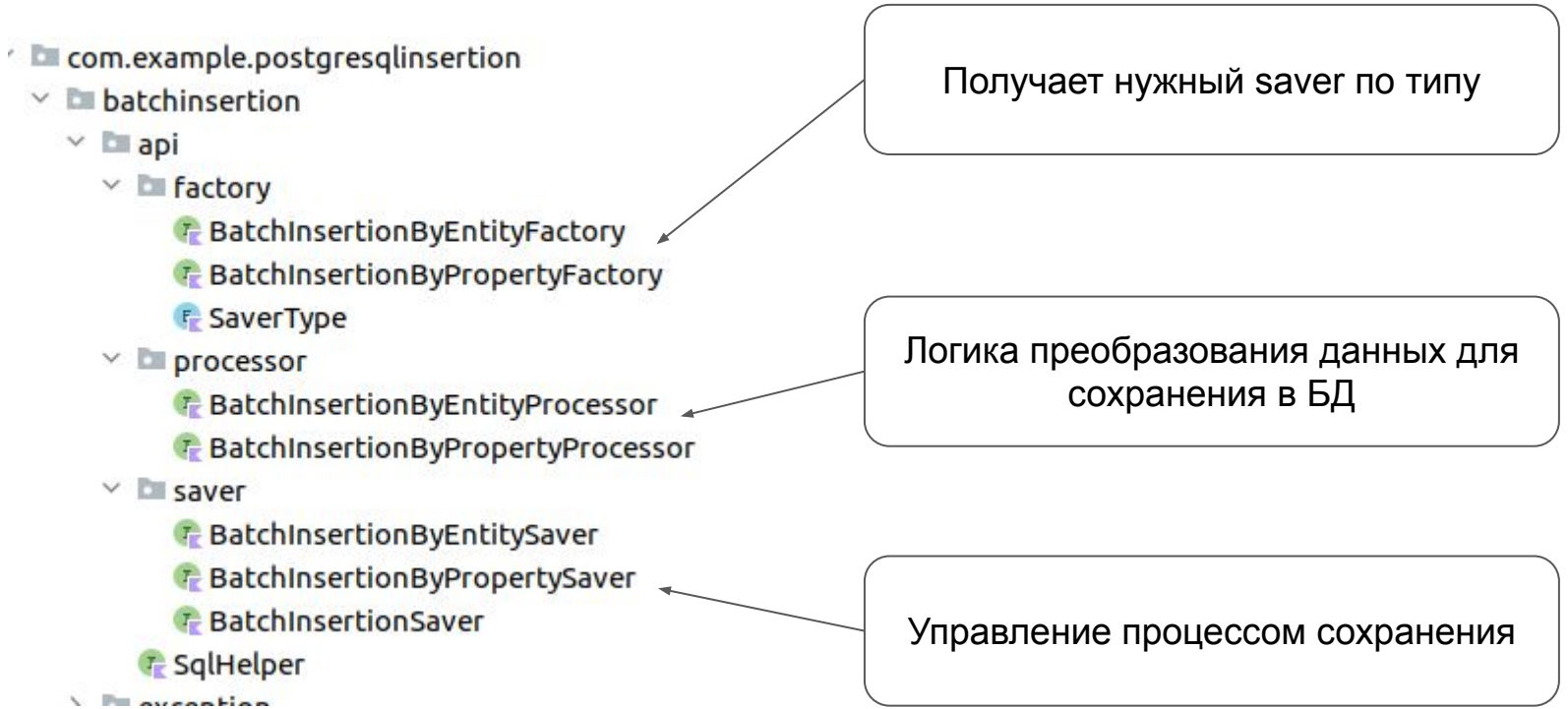
```
val data = PaymentDocumentEntity(
    account = AccountEntity().apply { id = 1 },
    expense = false,
    amount = BigDecimal( val: "10.11"),
    cur = CurrencyEntity(code = "RUB"),
    orderDate = LocalDate.parse( text: "2023-01-01"),
    orderNumber = "123",
    prop20 = "1345",
    prop15 = "END",
    paymentPurpose = "paymentPurpose",
    prop10 = "prop10",
)
```

```
fun getDataFromEntity(entity: BaseEntity) =
    entity.javaClass.declaredFields.map { field ->
        field.trySetAccessible()
        getDataFromEntityByField(entity, field)?.toString() ^map
    }

fun getDataFromEntityByField(entity: BaseEntity, field: Field) =
    when (val obj: Any? = field.get(entity)) {
        null -> null
        is BaseEntity -> {
            field.annotations Array<(out) Annotation!>!
                ?.filterIsInstance(JoinColumn::class.java) List<JoinColumn>?
                ?.firstOrNull() JoinColumn?
                ?.referencedColumnName String?
                ?.takeIf { it.isNotEmpty() }
                ?.let { obj.javaClass.getDeclaredField(it) } Field?
                ?.apply { trySetAccessible() }
                ?.get(obj)
                ?: obj.id
        }
        else -> obj
    }
```

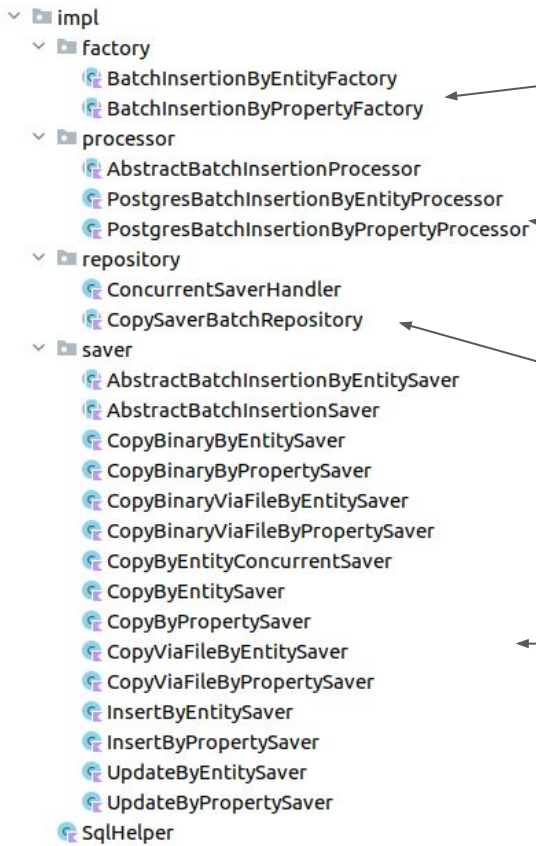
Application

Как это работает?

Application



Application



Заготовки для создания класса компонента.

Используется в saver для сохранения данных.

Репозиторий для интеграции со Spring

Реализации saver.

Application

Что внутри?

Application

```kotlin
/**
 * For save or update data
 */
interface BatchInsertionSaver: AutoCloseable {

    /**
     * commit data to DB
     */
    fun commit()

    /**
     * rollback
     */
    fun rollback()

}
```

```kotlin
abstract class AbstractBatchInsertionSaver(
    val conn: Connection
): BatchInsertionSaver {

    val log by logger()

    init {
        log.info("start save data")
        conn.autoCommit = false
    }

    override fun commit() {
        conn.commit()
    }

    override fun rollback() {
        conn.rollback()
    }

    override fun close() {
        conn.close()
        log.info("end save data")
    }
}
```

Application

```kotlin
/**
 * For save or update entity
 */
interface BatchInsertionByEntitySaver<E: BaseEntity>
    : BatchInsertionSaver {

    /**
     * add entity for save
     * @param entity - entity
     */
    fun addDataForSave(entity: E)

    /**
     * send data to DB
     */
    fun saveData()

}
```

```kotlin
abstract class AbstractBatchInsertionByEntitySaver<E : BaseEntity>(
    conn: Connection,
    private val batchSize: Int
) : AbstractBatchInsertionSaver(conn), BatchInsertionByEntitySaver<E> {

    private var counter = 0

    override fun addDataForSave(entity: E) {
        counter++
        if (counter % batchSize == 0) {
            log.info("save batch insertion $batchSize")
            saveData()
        }
    }

    override fun commit() {
        if (counter % batchSize != 0) {
            saveData()
        }
        log.info("start commit $counter data")
        counter = 0
        super.commit()
    }
}
```

Application

```
open class InsertByEntitySaver<E: BaseEntity>(
    private val processor: BatchInsertionByEntityProcessor,
    private val entityClass: KClass<E>,
    dataSource: DataSource,
    batchSize: Int
) : AbstractBatchInsertionByEntitySaver<E>(dataSource, batchSize) {

    private val dataForInsert = mutableListOf<String>()

    override fun addDataForSave(entity: E) {
        dataForInsert.add(processor.getStringForInsert(entity))
        super.addDataForSave(entity)
    }

    override fun saveData() {
        processor.insertDataToDataBase(entityClass, dataForInsert, conn)
        dataForInsert.clear()
    }
}
```

Application

```
abstract class BatchInsertionByEntityFactory<E: BaseEntity>(
    private val entityClass: KClass<E>,
) : BatchInsertionByEntityFactory<E> {

    @Value("\${batch_insertion.batch_size}")
    private var batchSize: Int = 100

    @Autowired
    override lateinit var processor: BatchInsertionByEntityProcessor

    @Autowired
    override lateinit var dataSource: DataSource

    override fun getSaver(type: SaverType): BatchInsertionByEntitySaver<E> {

        val conn = dataSource.connection

        return when (type) {
            SaverType.COPY -> CopyByEntitySaver(processor, entityClass, conn, batchSize)
            SaverType.COPY_BINARY -> CopyBinaryByEntitySaver(processor, entityClass, conn, batchSize)
            SaverType.COPY_VIA_FILE -> CopyViaFileByEntitySaver(processor, entityClass, conn, batchSize)
            SaverType.COPY_BINARY_VIA_FILE -> CopyBinaryViaFileByEntitySaver(processor, entityClass, conn, batchSize)
            SaverType.INSERT -> InsertByEntitySaver(processor, entityClass, conn, batchSize)
            SaverType.UPDATE -> UpdateByEntitySaver(processor, entityClass, conn, batchSize)
        }

    }
}
```

Application

```
@Component
class BatchInsertionPaymentDocumentByEntityFactory :
    BatchInsertionByEntityFactory<PaymentDocumentEntity>(PaymentDocumentEntity::class)
```

```
@Service
class PaymentDocumentService(
    private val pdBatchByEntitySaverFactory: BatchInsertionByEntityFactory<PaymentDocumentEntity>,
```

```
pdBatchByEntitySaverFactory.getSaver(SaverType.INSERT).use { saver ->
    for (i in 0 ≤ until < count) {
        saver.addDataForSave(getRandomEntity( id: null, currencies.random(), accounts.random()))
    }
    saver.commit()
}
```

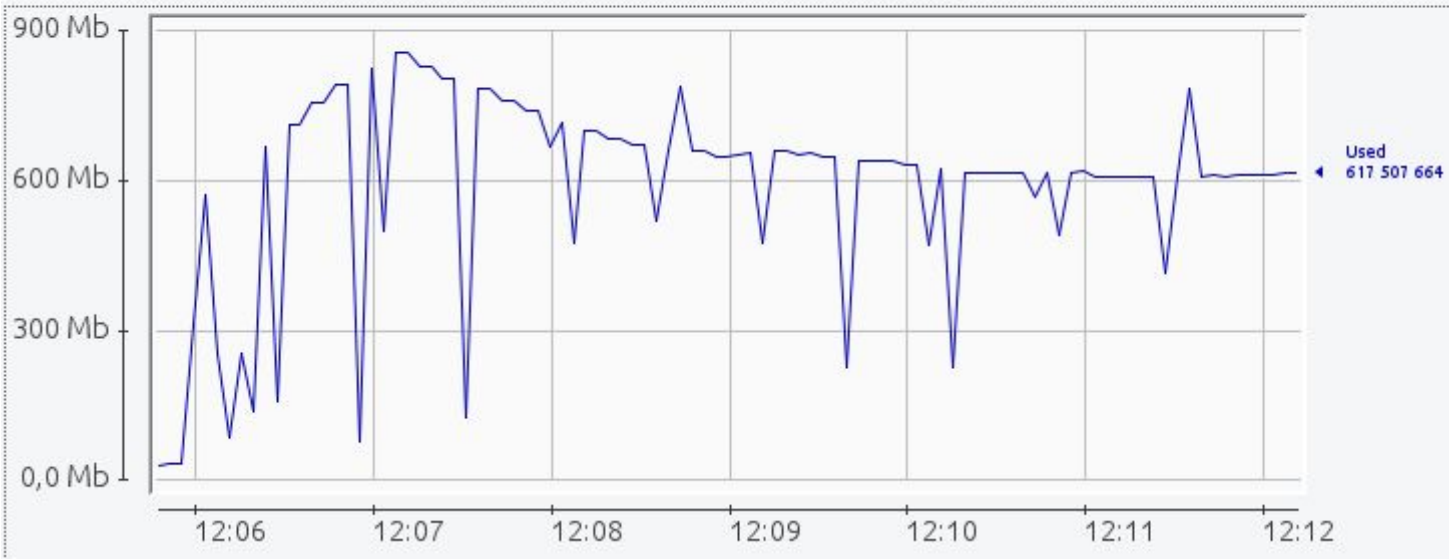
Application

Перейдем к замерам.

Insert with batch size 100k


```
"name": "Insert method",
"count": 4000000,
"time": "5 min, 5 sec 781 ms"
```


+ 46 sec (18%)



Insert with prepared statement batch size 100k

```
INSERT INTO payment_document (account_id, amount, expense, cur, order_date, order_number, payment_purpose, prop_10,
                              prop_15, prop_20)
VALUES (1000004, '10.23', true, 'RUB', '2023-06-25', '123456', 'some purpose0', 'some 10', 'some 15', 'some 20'),
       (1000005, '11.23', true, 'RUB', '2023-06-26', '123457', 'some purpose1', 'some 10', 'some 15', 'some 20'),
       (1000006, '12.23', true, 'RUB', '2023-06-27', '123458', 'some purpose1', 'some 10', 'some 15', 'some 20');
```

```
INSERT INTO payment_document (account_id, amount, expense, cur, order_date, order_number, payment_purpose, prop_10,
                              prop_15, prop_20)
VALUES (?, ?, ?, ?, ?, ?, ?, ?, ?, ?),
       (?, ?, ?, ?, ?, ?, ?, ?, ?, ?),
       (?, ?, ?, ?, ?, ?, ?, ?, ?, ?);
```

Insert with prepared statement batch size 100k

```
org.postgresql.util.PSQLException: PreparedStatement can have at most 65,535 parameters. Please consider using arrays, or splitting the query in several ones, or using COPY. Given query has 1,000,000 parameters
        at org.postgresql.jdbc.PgPreparedStatement.<init>(PgPreparedStatement.java:102) ~[postgresql-42.6.0.jar!/:42.6.0]
```

Таблица K.1. Ограничения PostgreSQL

Объект	Верхний предел	Комментарий
размер базы данных	без ограничений	
количество баз данных	4 294 950 911	
отношений в базе данных	1 431 650 303	
размер отношения	32 ТБ	со значением BLCKSZ по умолчанию, равным 8192 байта
строк в таблице	ограничивается количеством кортежей, которое может уместиться в 4 294 967 295 страниц	
столбцов в таблице	1600	дополнительно ограничивается размером кортежа, который может уместиться в одной странице; см. примечание ниже
столбцов в наборе результатов	1664	
размер поля	1 ГБ	
индексов в таблице	без ограничений	ограничивается максимальным количеством отношений в базе данных
столбцов в индексе	32	может быть увеличена при перекомпиляции PostgreSQL
ключей секционирования	32	может быть увеличена при перекомпиляции PostgreSQL
длина идентификатора	63 байта	может быть увеличена при перекомпиляции PostgreSQL
аргументы функции	100	может быть увеличена при перекомпиляции PostgreSQL
параметры запроса	65535	

https://postgrespro.ru/docs/postgresql/15/limits?ysclid=ltbda9o4r1757501391

Batch size

Подбираем размер батча.

Batch size

65535 (макс. кол-во параметров) / **11** (количество столбцов) = **5957**

Batch size	Spring	Insert	Insert PS*
100_000	4 min, 37 sec 935 ms	5 min, 5 sec 781 ms	Error
5_000	4 min, 30 sec 654 ms	4 min, 30 sec 441 ms	4 min, 2 sec 537 ms
1_000	4 min, 32 sec 727 ms	4 min, 42 sec 699 ms	4 min, 14 sec 662 ms

*PS - prepared statement

Statement vs Prepared statement

```
ALTER DATABASE postgres SET log_statement = 'all';
ALTER DATABASE postgres SET log_duration = 'on';
ALTER DATABASE postgres SET log_min_duration_statement = 0;
```

```
LOG:  duration: 40.240 ms  parse <unnamed>: INSERT INTO payme
$2, $3, $4, $5, $6, $7, $8, $9, $10),
LOG:  duration: 51.011 ms  bind <unnamed>: INSERT INTO paymer
$2, $3, $4, $5, $6, $7, $8, $9, $10),
LOG:  duration: 174.250 ms  execute <unnamed>: INSERT INTO pa
$1, $2, $3, $4, $5, $6, $7, $8, $9, $10),
```

https://docs.google.com/spreadsheets/d/1fGn9vY62akU7BhhrwAruT5vnD8eQrp1pJoZT2ZSw7Vs/edit#gid=0

Statement vs Prepared statement

Statement 4_000k by 100k		
parse	bind	execute
29630,905	29556,353	166751,025
921,587	903,203	3352,442
741,322	757,754	3290,384
743,773	779,558	3514,928
732,25	717,204	3580,637
736,112	726,01	3605,883
736,453	729,325	3644,204
729,434	741,738	4193,221
727,563	704,398	4446,76
728,658	706,667	4094,338
773,044	716,596	3997,896
771,751	710,11	4450,612
731,054	761,276	4556,644
774,627	713,053	3934,305

Statement 4_000k by 5k		
parse	bind	execute
29143,522	27075,91	146191,073
54,916	44,889	173,583
45,688	41,486	176,59
37,255	34,195	160,234
36,517	35,195	165,625
36,47	33,989	168,133
35,13	32,837	162,148
36,483	36,324	165,539
36,529	33,882	151,002
35,3	32,039	161,542
35,15	32,462	165,388
35,752	35,556	157,419
36,53	32,646	155,53
36,738	32,864	160,141

Prepared Statement 4_000k by 5k		
parse	bind	execute
161,872	5051,715	153377,617
40,24	51,011	174,25
31,804	47,879	176,805
28,44	49,988	189,109
28,238	50,269	153,466
33,15	42,182	179,462
	41,878	163,405
	40,843	160,755
	41,334	171,704
	40,795	171,097
	28,55	163,283
	5,82	158,819
	5,661	171,214
	5,763	156,854

PostgreSQL

Что может мешать вставке больших объемов данных?

- Триггеры
- Индексы

Индексы

- Можно удалить перед вставкой
- Затем вернуть

PostgreSQL

```
SELECT
    indexname,
    indexdef
FROM pg_indexes
WHERE schemaname = ? AND tablename = ? AND indexdef LIKE 'CREATE INDEX%'
```

indexname	indexdef
ix_payment_document_cur	CREATE INDEX ix_payment_document_cur ON test_insertion.payment_document USING btree (cur)
ix_payment_document_order_date	CREATE INDEX ix_payment_document_order_date ON test_insertion.payment_document USING bt…
ix_payment_document_order_number	CREATE INDEX ix_payment_document_order_number ON test_insertion.payment_document USING …

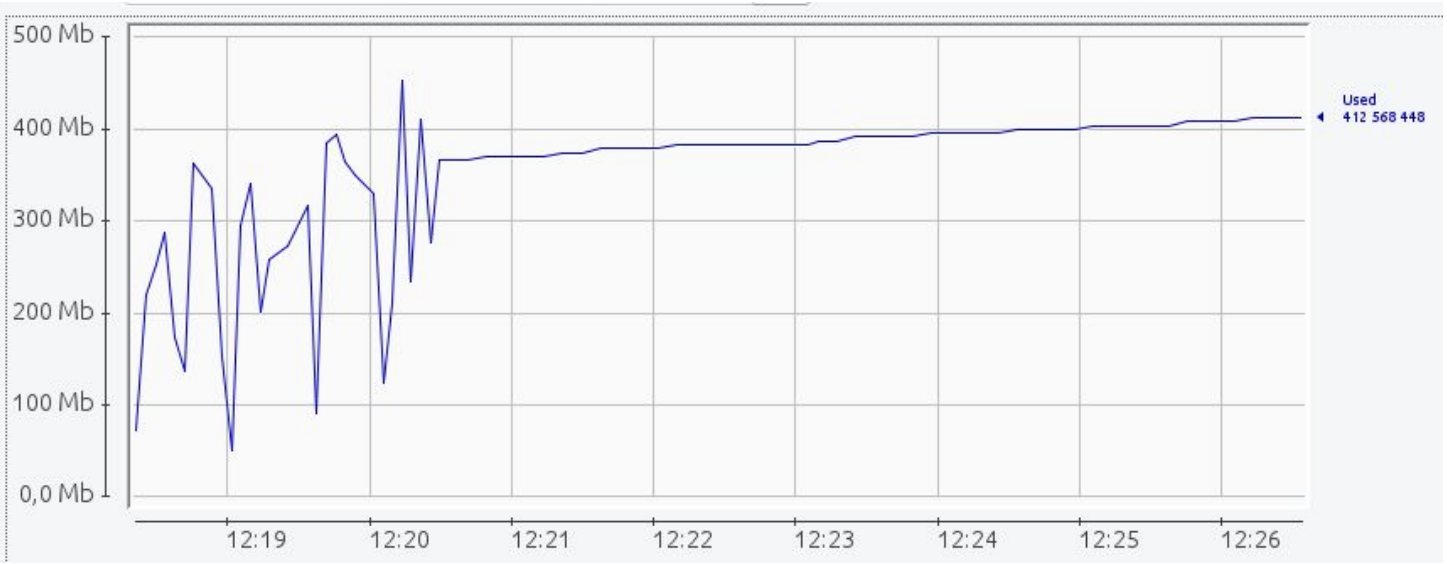
Insert with drop index

```
fun saveByInsertWithDropIndex(count: Int) {
    val currencies = currencyRepo.findAll()
    val accounts = accountRepo.findAll()

    val scriptForCreateIndexes = sqlHelper.dropIndex(PaymentDocumentEntity::class)

    pdBatchByEntitySaverFactory.getSaver(SaverType.INSERT).use { saver ->
        for (i in 0 ≤ until < count) {
            saver.addDataForSave(getRandomEntity( id: null, currencies.random(), accounts.random()))
        }
        saver.commit()
    }

    sqlHelper.executeScript(scriptForCreateIndexes)

}
```

Insert with drop index


```
"name": "Insert method with drop index",
"count": 4000000,
"time": "7 min, 19 sec 395 ms"
```

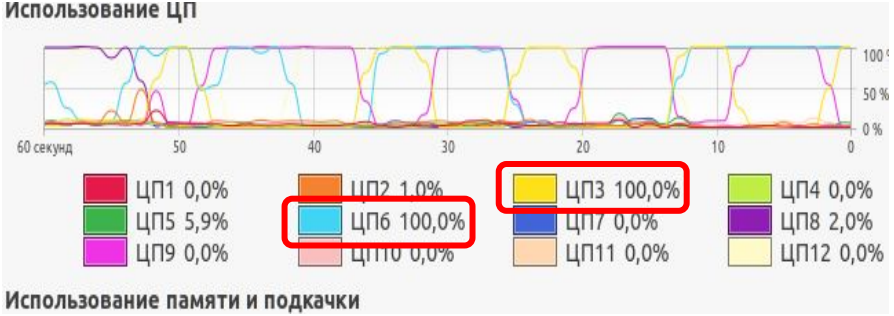

+ 3 min 17 sec (81%)



Insert with drop index

2 мин 11 сек
вставка без
индексов

5 мин 11 сек
восстановление
индексов




```
08:18:36.784  INFO 1 --- [nio-8080-exec-7] c.e.p.l.service.PaymentDocumentService   : start drop index before
08:18:37.279  INFO 1 --- [nio-8080-exec-7] i.s.InsertByEntityPreparedStatementSaver : start save data
08:18:37.350  INFO 1 --- [nio-8080-exec-7] i.s.InsertByEntityPreparedStatementSaver : save batch insertion 50
08:18:37.555  INFO 1 --- [nio-8080-exec-7] i.s.InsertByEntityPreparedStatementSaver : save batch insertion 50

08:20:45.083  INFO 1 --- [nio-8080-exec-7] i.s.InsertByEntityPreparedStatementSaver : save batch insertion
08:20:45.172  INFO 1 --- [nio-8080-exec-7] i.s.InsertByEntityPreparedStatementSaver : start commit 4000000
08:20:45.175  INFO 1 --- [nio-8080-exec-7] i.s.InsertByEntityPreparedStatementSaver : end save data
08:20:45.175  INFO 1 --- [nio-8080-exec-7] c.e.p.l.service.PaymentDocumentService   : start create index a
08:25:56.168  INFO 1 --- [nio-8080-exec-7] c.e.p.l.service.PaymentDocumentService   : stop create index af
```

Insert with drop index

Секционированные таблицы.

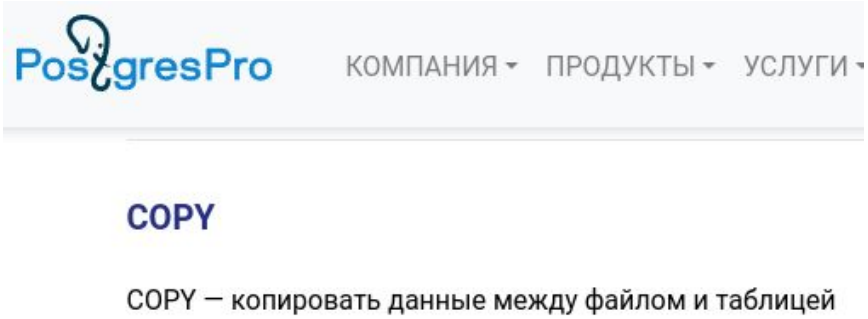
- Позволяет делать секции по диапазону, списку, хешу
- Можно добавлять секцию при массовой вставке
- В новой секции вставка будет осуществляться как в пустую таблицу
- https://postgrespro.ru/docs/postgresql/13/ddl-partitioning

Что еще ты умеешь, PostgreSQL?

PostgreSQL

Как еще PostgreSQL может вставлять данные в БД?

```
org.postgresql.util.PSQLException: PreparedStatement can have at most 65,535 parameters. Please consider using arrays, or
splitting the query in several ones, or using COPY. Given query has 1,000,000 parameters
        at org.postgresql.jdbc.PgPreparedStatement.<init>(PgPreparedStatement.java:102) ~[postgresql-42.6.0.jar!/:42.6.0]
```



https://postgrespro.ru/docs/postgrespro/16/sql-copy

Copy

```
COPY payment_document (order_date, order_number, amount, cur, expense, account_id, payment_purpose, prop_10, prop_15,
                       prop_20) FROM STDIN (DELIMITER '|', NULL 'NULL')
```

```
fun saveToDataBaseByCopyMethod(
    tableName: String,
    columns: String,
    delimiter: String,
    nullValue: String,
    from: Reader,
    conn: Connection
) {

    conn.unwrap(PGConnection::class.java) copyAPI.copyIn(
        sql: "COPY $tableName ($columns) FROM STDIN (DELIMITER '$delimiter', NULL '$nullValue')",
        from
    )
}
```

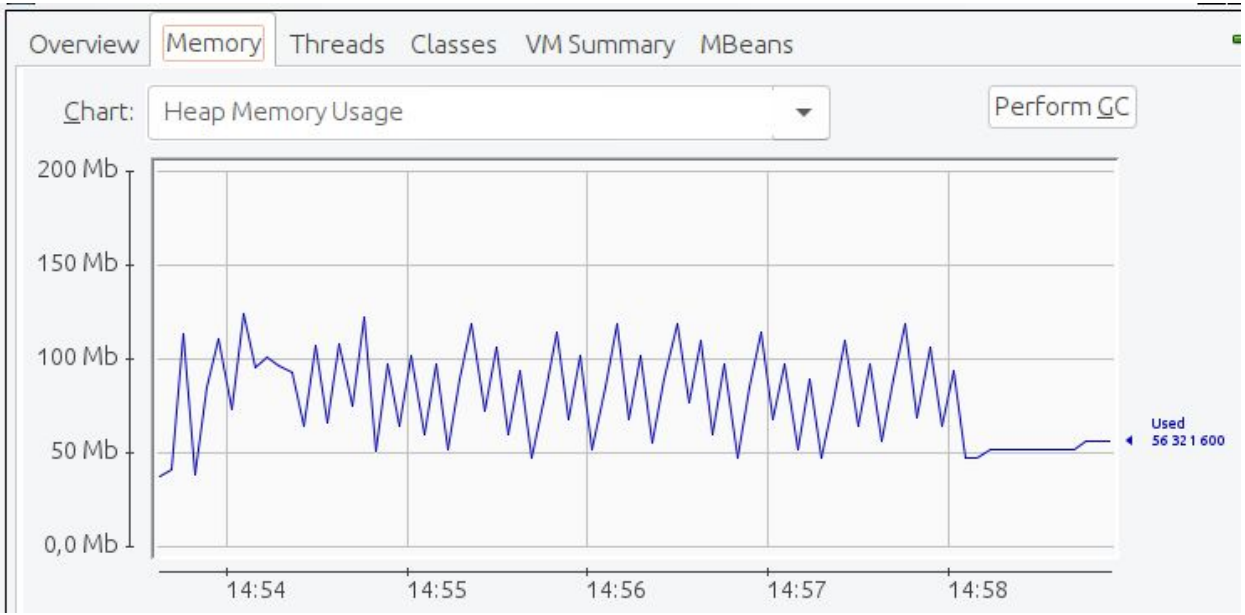
Copy

```
open class CopyViaFileByEntitySaver<E: BaseEntity>(
    private val processor: BatchInsertionByEntityProcessor,
    private val entityClass: KClass<E>,
    dataSource: DataSource,
    batchSize: Int
) : AbstractBatchInsertionByEntitySaver<E>(dataSource, batchSize) {

    private var file = File(Paths.get( first: "./${UUID.randomUUID()}.csv").toUri())
    private var writer = file.bufferedWriter()

    override fun addDataForSave(entity: E) {
        processor.addDataForCreate(entity, writer)
        super.addDataForSave(entity)
    }

    override fun saveData() {
        writer.close()
        processor.saveToDataBaseByCopyMethod(entityClass, FileReader(file), conn)
        file.delete()
        file = File(Paths.get( first: "./${UUID.randomUUID()}.csv").toUri())
        writer = file.bufferedWriter()
    }

    override fun close() {
        writer.close()
        file.delete()
        super.close()
    }
}
```

Copy via file with batch size 5k

```
"name": "Copy method via file",
"count": 4000000,
"time": "3 min, 44 sec 63 ms"
```

- 18 sec (8%)



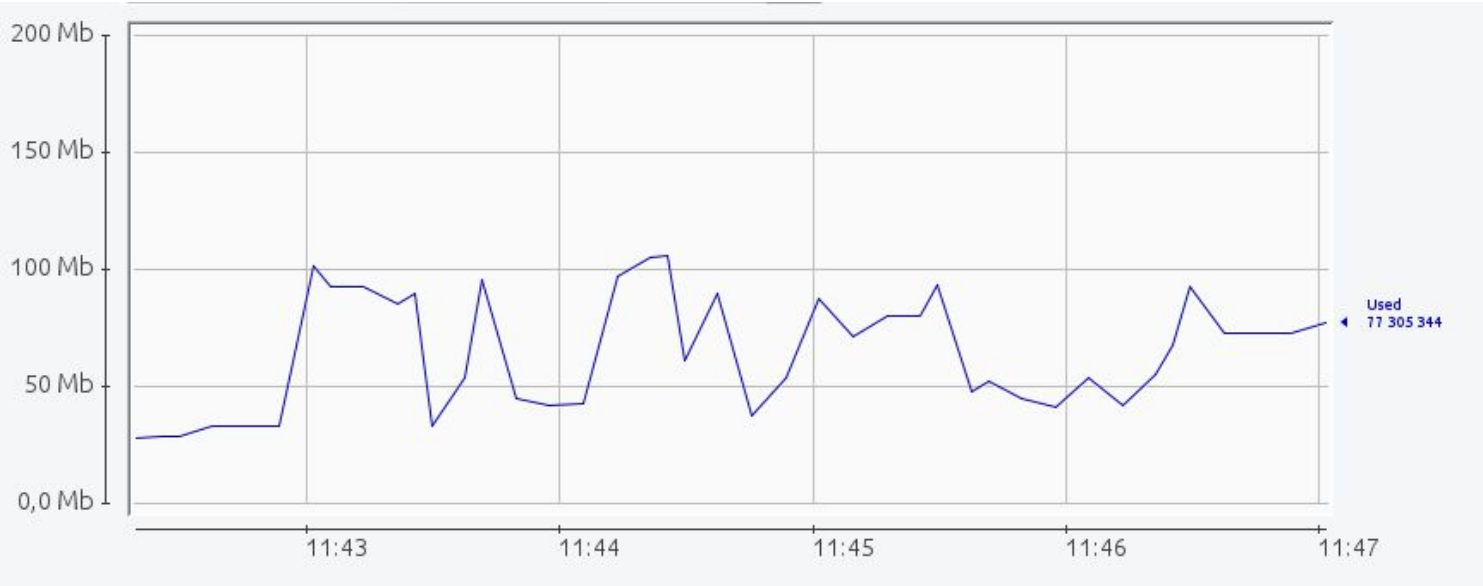
Copy

```
open class CopyByEntitySaver<E: BaseEntity>(
    private val processor: BatchInsertionByEntityProcessor,
    private val entityClass: KClass<E>,
    dataSource: DataSource,
    batchSize: Int
) : AbstractBatchInsertionByEntitySaver<E>(dataSource, batchSize) {

    private var writer = StringWriter()
    private var bufferedWriter = writer.buffered()

    override fun addDataForSave(entity: E) {
        processor.addDataForCreate(entity, bufferedWriter)
        super.addDataForSave(entity)
    }

    override fun saveData() {
        bufferedWriter.flush()
        processor.saveToDataBaseByCopyMethod(entityClass, writer.toString().reader(), conn)
        writer = StringWriter()
        bufferedWriter = writer.buffered()
    }

}
```

Copy with batch size 5k

```
"name": "Copy method",
"count": 4000000,
"time": "3 min, 39 sec 895 ms"
```

- 5 sec
(2%)



Copy

Что ещё?

Copy

Что еще?

Двоичный формат

При выборе формата `binary` все данные сохраняются/считываются в двоичном, а не текстовом виде. Иногда этот формат обрабатывается быстрее, чем текстовый и `CSV`, но он может оказаться непереносимым между разными машинными архитектурами и версиями PostgreSQL. Кроме того, двоичный формат сильно зависит от типов данных; например, он не позволяет вывести данные из столбца `smallint`, а затем прочитать их в столбец `integer`, хотя с текстовым форматом это вполне возможно.

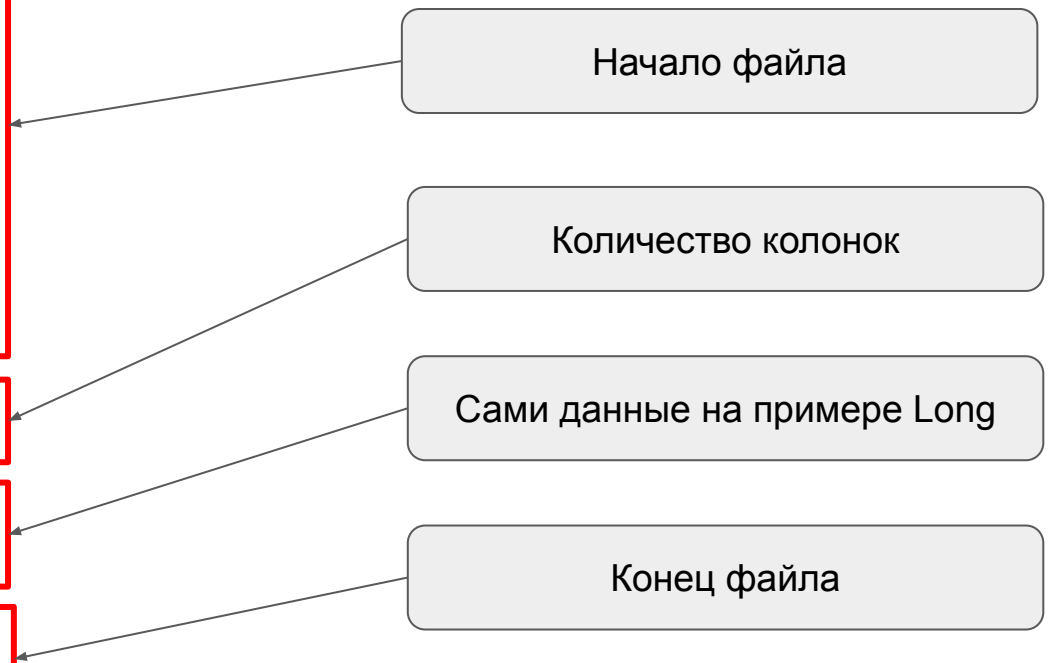
Copy binary

```
// 11 byte of start PGCOPY\n\377\r\n\0
outputStream.writeBytes( s: "PGCOPY\n")
outputStream.write( b: 0xFF)
outputStream.writeBytes( s: "\r\n")
outputStream.write(byteArrayOf(0))

// disable OID
outputStream.writeInt( v: 0)
// length of addition header
outputStream.writeInt( v: 0)
```

```
outputStream.writeShort(fields.size)
```

```
outputStream.writeInt( v: 8)
outputStream.writeLong(data)
```

```
outputStream.writeShort( v: -1)
outputStream.close()
```



Copy binary. LocalDate

```
outputStream.writeInt( v: 4)

val sqlData = Date.valueOf(data)

val buf = ByteArray( size: 4)
val tz = TimeZone.getDefault()
var millis = sqlData.time
millis += tz.getOffset(millis).toLong()
val secs = toPgSecs( seconds: millis / 1000)
ByteConverter.int4(buf,  idx: 0, (secs / 86400).toInt())

outputStream.write(buf)
```

Преобразование LocalDate в binary

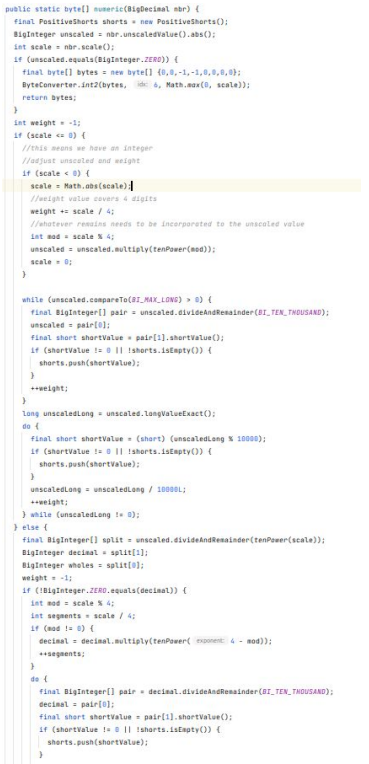
```
private fun toPgSecs(seconds: Long): Long {
    var secs = seconds
    // java epoc to postgres epoc
    secs -= 946684800L

    // Julian/Gregorian calendar cutoff point
    if (secs < -13165977600L) { // October 15, 1582 -> October 4, 1582
        secs -= 86400 * 10
        if (secs < -15773356800L) { // 1500-03-01 -> 1500-02-28
            var years = ((secs + 15773356800L) / -3155823050L).toInt()
            years++
            years -= years / 4
            secs += years * 86400.toLong()
        }
    }
    return secs
}
```

Взято из драйвера PostgreSQL

Copy binary. BigDecimal

```
val bytes = ByteConverter.numeric(data)

outputStream.writeInt(bytes.size)
outputStream.write(bytes)
```

110 строк кода



Benchmark. Reflection vs jpa-modelgen vs KProperty vs Binary file

Benchmark	Mode	Cnt	Score	Error	Units
ProcessorBenchmark.saveDataByJpamodelgen_4_000_000	avgt	10	2,111	± 0,021	s/op
ProcessorBenchmark.saveDataByKotlinProperty_4_000_000	avgt	10	2,794	± 0,040	s/op
ProcessorBenchmark.saveDataWithReflectionAndBinary_4_000_000	avgt	10	5,608	± 0,071	s/op
ProcessorBenchmark.saveDataWithReflection_4_000_000	avgt	10	5,284	± 0,032	s/op

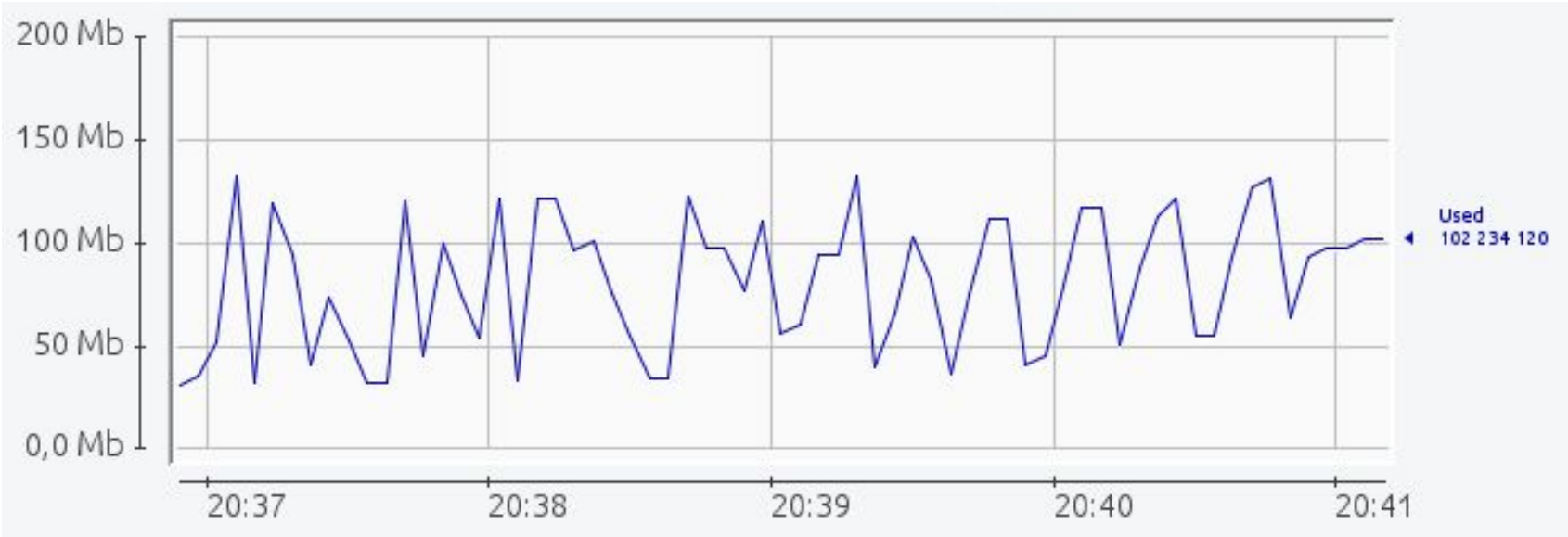
Copy binary

Перейдем к замерам.

Copy binary via file with batch size 5k

```
"name": "Copy method via binary file",
"count": 4000000,
"time": "3 min, 46 sec 131 ms"
```

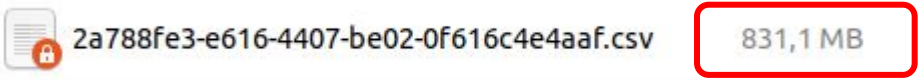
+ 2 sec (1%)



Copy. csv vs binary

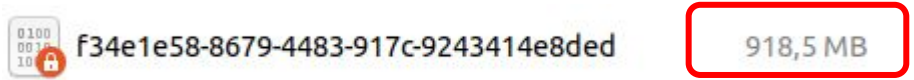
CSV. Размер файла: 831 мб. Создание файла: 56 сек, вставка в БД: 3 мин 3 сек.

```
15:09:47.419  INFO 1 --- [nio-8080-exec-9] c.e.p.b.i.s.CopyViaFileByEntitySaver     : start save data
15:10:43.086  INFO 1 --- [nio-8080-exec-9] c.e.p.b.i.s.CopyViaFileByEntitySaver     : save batch insertion 4000000
15:13:46.740  INFO 1 --- [nio-8080-exec-9] c.e.p.b.i.s.CopyViaFileByEntitySaver     : start commit 4000000 data
15:13:46.751  INFO 1 --- [nio-8080-exec-9] c.e.p.b.i.s.CopyViaFileByEntitySaver     : end save data
```



Binary. Размер файла: 918 мб. Создание файла: 56 сек, вставка в БД: 3 мин 8 сек.

```
15:26:57.318  INFO 1 --- [nio-8080-exec-1] e.p.b.i.s.CopyBinaryViaFileByEntitySaver : start save data
15:27:53.865  INFO 1 --- [nio-8080-exec-1] e.p.b.i.s.CopyBinaryViaFileByEntitySaver : save batch insertion 4000000
15:31:01.342  INFO 1 --- [nio-8080-exec-1] e.p.b.i.s.CopyBinaryViaFileByEntitySaver : start commit 4000000 data
15:31:01.354  INFO 1 --- [nio-8080-exec-1] e.p.b.i.s.CopyBinaryViaFileByEntitySaver : end save data
```



Copy binary with batch size 5k


```
"name": "Copy method by binary",
"count": 4000000,
"time": "3 min, 43 sec 823 ms"
```


+ 4 sec (2%)

Copy

Как прикрутить это к транзакциям Spring?

Copy

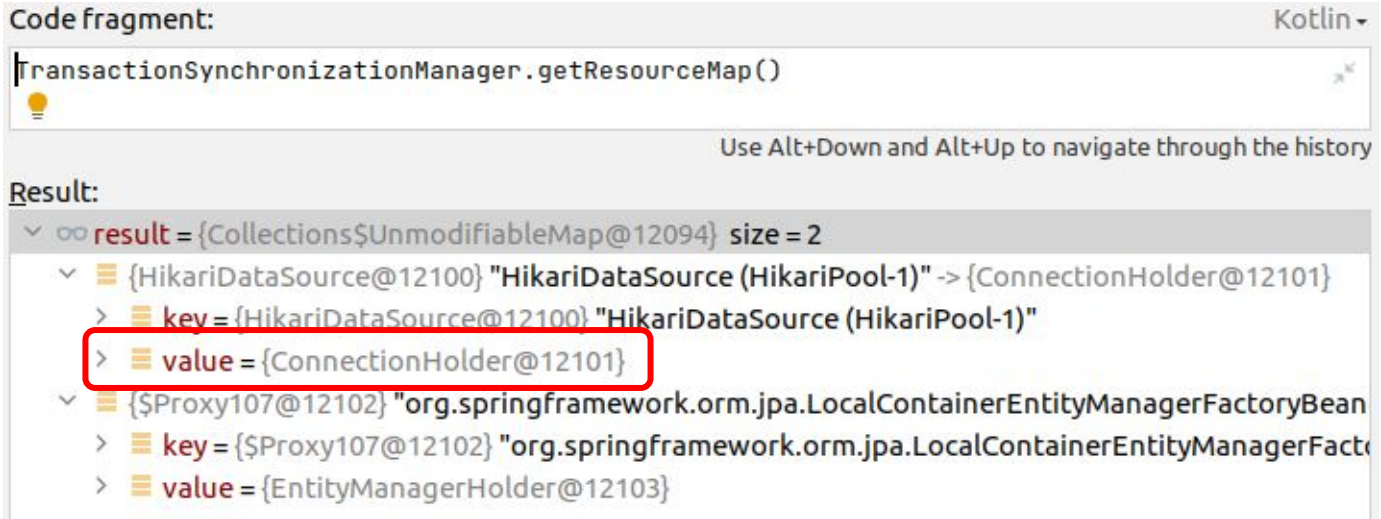
Как прикр м Spring?

Copy

```
@Transactional
fun saveByCopyViaSpring(count: Int) {
    val currencies = currencyRepo.findAll()
    val accounts = accountRepo.findAll()

    for (i in 0 ≤ until < count) {
        pdCustomRepository.saveByCopy(
            getRandomEntity( id: null, currencies.random(), accounts.random())
        )
    }

}
```

Transaction synchronization manager

```
public abstract class TransactionSynchronizationManager {

    7 usages
    private static final ThreadLocal<Map<Object, Object>> resources =
            new NamedThreadLocal<>("Transactional resources");
```



Transaction synchronization manager

```
val conn = (TransactionSynchronizationManager.getResource(dataSource) as ConnectionHolder).connection
val saver = CopyByEntitySaver(processor, entityClass, conn, batchSize)
```

```
TransactionSynchronizationManager.bindResource(copySaverResourceName, saver)
```

```
TransactionSynchronizationManager.getResource(copySaverResourceName)
```

```
TransactionSynchronizationManager.registerSynchronization(
    object : TransactionSynchronization {
        override fun beforeCommit(readOnly: Boolean) {
            super.beforeCommit(readOnly)
            saver.saveData()
        }
    }
)
```

JPA repository with copy saver

```
abstract class CopySaverBatchRepository<E : BaseEntity>(
    val entityClass: KClass<E>
) {

    @Value("\${batch_insertion.batch_size}")
    private var batchSize: Int = 100

    @Autowired
    private lateinit var processor: BatchInsertionByEntityProcessor

    @Autowired
    private lateinit var dataSource: DataSource

    private val copySaverResourceName = "BatchInsertionCopySaver"

    fun saveByCopy(entity: E) {
        getCopySaver().addDataForSave(entity)
    }

    @Suppress( ...names: "UNCHECKED_CAST")
    private fun getCopySaver(): BatchInsertionByEntitySaver<E> {...}
}
```

JPA repository with copy saver

```
@Component
class PaymentDocumentCustomRepository(
    val repo: PaymentDocumentRepository,
) : PaymentDocumentRepository by repo,
    CopySaverBatchRepository<PaymentDocumentEntity>(PaymentDocumentEntity::class)
```

Save by custom repository with copy saver

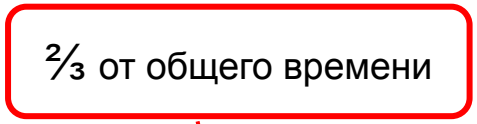
```
"name": "Save by Spring with copy method",
"count": 4000000,
"time": "3 min, 39 sec 984 ms"
```

Copy

Как распараллелить вставку данных?

Copy

Где время?




```
21:52:49.124  INFO 1 --- [nio-8080-exec-1] c.e.p.b.impl.saver.CopyByEntitySaver     : start save batch insertion 100000
21:52:53.725  INFO 1 --- [nio-8080-exec-1] c.e.p.b.impl.saver.CopyByEntitySaver     : end save batch insertion 100000
21:52:55.396  INFO 1 --- [nio-8080-exec-1] c.e.p.b.impl.saver.CopyByEntitySaver     : start save batch insertion 100000
21:52:59.824  INFO 1 --- [nio-8080-exec-1] c.e.p.b.impl.saver.CopyByEntitySaver     : end save batch insertion 100000
21:52:59.828  INFO 1 --- [nio-8080-exec-1] c.e.p.b.impl.saver.CopyByEntitySaver     : save time 2 min, 53 sec 167 ms data
21:52:59.828  INFO 1 --- [nio-8080-exec-1] c.e.p.b.impl.saver.CopyByEntitySaver     : start commit 4000000 data
21:52:59.833  INFO 1 --- [nio-8080-exec-1] c.e.p.b.impl.saver.CopyByEntitySaver     : end save data
```

Copy

Где время?


```
21:52:49.124  INFO 1 --- [nio-8                start save batch insertion 100000
21:52:53.725  INFO 1 --- [nio-8                end save batch insertion 100000
21:52:55.396  INFO 1 --- [nio-8                start save batch insertion 100000
21:52:59.824  INFO 1 --- [nio-8                end save batch insertion 100000
21:52:59.828  INFO 1 --- [nio-8                save time 2 min, 53 sec 167 ms data
21:52:59.828  INFO 1 --- [nio-8                start commit 4000000 data
21:52:59.833  INFO 1 --- [nio-8                end save data
```

Copy with concurrent saver

Что для это сделаем:

- Отдельный ThreadPoolExecutor для управления задачами
- ConcurrentSaverHandler который будет распределять нагрузку по нескольким Saver
- Расширим функциональность CopyByEntitySaver для неблокирующей отправки данных в БД

Copy with concurrent saver

Какие минусы у этого подхода:

- Неконтролируемое потребление коннектов при больших нагрузках
- Транзакция для параллельных saver перестанет быть атомарной

Concurrent saver

```
class CopyByEntityConcurrentSaver<E : BaseEntity>(
    processor: BatchInsertionByEntityProcessor,
    entityClass: KClass<E>,
    conn: Connection,
    batchSize: Int,
    private val executorService: ExecutorService
) : CopyByEntitySaver<E>(processor, entityClass, conn, batchSize) {

    private var saveDataJob: Future<*>? = null
```

Concurrent saver

```
override fun addDataForSave(entity: E) {
    checkSaveDataJob()
    super.addDataForSave(entity)
}

override fun saveData() {
    checkSaveDataJob()
    saveDataJob = executorService.submit { super.saveData() }
}

override fun commit() {
    checkSaveDataJob()
    super.saveData()
    conn.commit()
}

private fun checkSaveDataJob() {
    try {
        saveDataJob?.get()
    } catch (e: Exception) {
        throw BatchInsertionException("Can not execute send data to DB", e)
    }
}
```

Concurrent saver handler

```
class ConcurrentSaverHandler<E : BaseEntity>(
    private val processor: BatchInsertionByEntityProcessor,
    private val entityClass: KClass<E>,
    private val dataSource: DataSource,
    private val batchSize: Int,
    private val numberOfSavers: Int = 4,
    executorService: ExecutorService
) {
    private var counterEntity = 0
    private var counterSaver = 0
    private val savers = (1 ≤ .. ≤ numberOfSavers)
        .map { CopyByEntityConcurrentSaver(processor, entityClass, dataSource.connection, batchSize, executorService) }
```

Concurrent saver handler

```
fun addDataForSave(entity: E) {

    val currSaver = savers[counterSaver % numberOfSavers]

    currSaver.addDataForSave(entity)

    counterEntity++
    counterEntity.takeIf { it % batchSize == 0 }?.let { counterSaver++ }
}

fun commit() {
    savers.forEach { it: CopyByEntityConcurrentSaver<E>
        it.commit()
        it.close()
    }
}

fun rollback() {
    savers.forEach { it: CopyByEntityConcurrentSaver<E>
        it.rollback()
        it.close()
    }
}
```

Concurrent saver handler

```
fun addDataForSave(entity: E) {

    val currSaver = savers[counterS

    currSaver.addDataForSave(entity

    counterEntity++
    counterEntity.takeIf { it % bat
}

fun commit() {
    savers.forEach { it: CopyByEntityCon
        it.commit()
        it.close()
    }
}

fun rollback() {
    savers.forEach { it: CopyByEntityCon
        it.rollback()
        it.close()
    }
}
```

Save by copy method with concurrent

```
fun saveByCopyConcurrent(entity: E) {

    checkTransactionIsOpen()

    val handler = TransactionSynchronizationManager.getResource(concurrentSaverHandlerName)
        ?.let { it as ConcurrentSaverHandler<E> }
        ?: let { it: CopySaverBatchRepository<E>
            val handler = ConcurrentSaverHandler(
                processor = processor,
                entityClass = entityClass,
                dataSource = dataSource,
                batchSize = batchSize,
                numberOfSavers = concurrentSavers,
                executorService = executorService
            )
```

Save by copy method with concurrent

```
TransactionSynchronizationManager.registerSynchronization(
    object : TransactionSynchronization {
        override fun beforeCommit(readOnly: Boolean) {
            super.beforeCommit(readOnly)
            handler.commit()
        }
        override fun afterCompletion(status: Int) {
            if (status != 0) {
                handler.rollback()
            }
            TransactionSynchronizationManager.unbindResource(concurrentSaverHandlerName)
        }
    }
)
```

Save by copy method with concurrent

```
@Transactional
fun saveByCopyConcurrentViaSpring(count: Int) {
    val currencies = currencyRepo.findAll()
    val accounts = accountRepo.findAll()

    for (i in 0 ≤ until < count) {
        pdCustomRepository.saveByCopyConcurrent(
            getRandomEntity( id: null, currencies.random(), accounts.random())
        )
    }

}
```

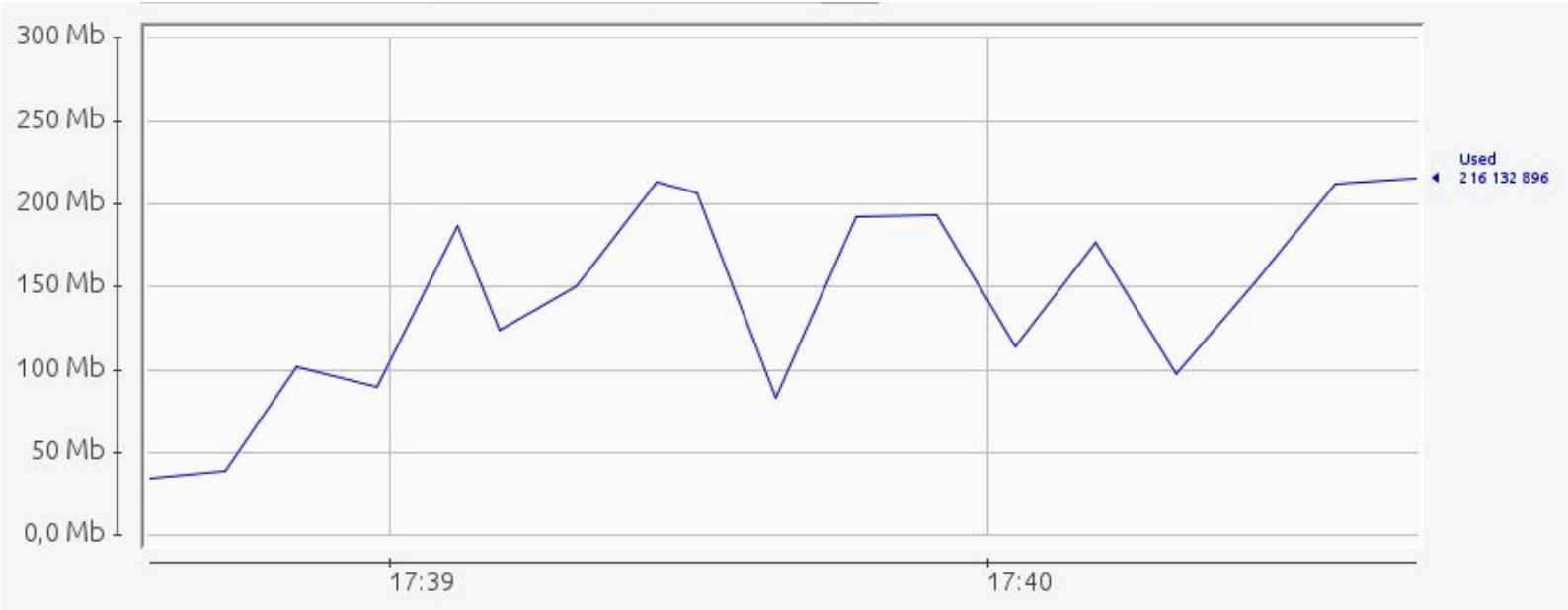
Save by copy method with concurrent

Перейдем к замерам.

Save by copy method with concurrent

```
"name": "Save by Spring with copy concurrent method",
"count": 4000000,
"time": "1 min, 46 sec 64 ms"
```

- 2 min 53 sec (52%)



Итого:

Operation name	Time	Boost
Concurrent copy	1 min, 46 sec 64 ms	≈ 52%
Copy binary	3 min, 43 sec 823 ms	≈ -2%
Copy	3 min, 39 sec 895 ms	≈ 10%
Insert with drop index	7 min, 19 sec 395 ms	≈ -81%
Insert prepared statement	4 min, 2 sec 537 ms	≈ 11%
Insert	4 min, 30 sec 441 ms	-

≈ 61%

Заключение:

- Spring и Hibernate делает свой overhead, можно увеличить скорость вставки данных ≈ 60%
- Своя реализация прослойки. Быстрее, можно подружить со Spring, распараллелить процесс вставки, плюшки спринга не работают.
- Copy метод быстрее insert ≈ 10%. Работает только с PostgreSQL
- Copy binary vs csv. Сомнительный профит по скорости, возможны проблемы с переходом на новые версии
- Удалось ускорить процесс вставки данных в 6 раз.

Телеграм: @FatovDI

Спасибо за внимание!

Репозиторий:
https://github.com/FatovDI/acceleration-insertion-postgresql-pgconf2024